PROVENANCE AND DEPOSITIONAL ENVIRONMENT OF SOME LOWER MISSISSIPPIAN SEDIMENTS, CAPE GEORGE, NOVA SCOTIA

BY

ANDREW W. HUBLEY

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE

DALHOUSIE UNIVERSITY
HALIFAX, NOVA SCOTIA

Distribution License

DalSpace requires agreement to this non-exclusive distribution license before your item can appear on DalSpace.

NON-EXCLUSIVE DISTRIBUTION LICENSE

You (the author(s) or copyright owner) grant to Dalhousie University the non-exclusive right to reproduce and distribute your submission worldwide in any medium.

You agree that Dalhousie University may, without changing the content, reformat the submission for the purpose of preservation.

You also agree that Dalhousie University may keep more than one copy of this submission for purposes of security, back-up and preservation.

You agree that the submission is your original work, and that you have the right to grant the rights contained in this license. You also agree that your submission does not, to the best of your knowledge, infringe upon anyone's copyright.

If the submission contains material for which you do not hold copyright, you agree that you have obtained the unrestricted permission of the copyright owner to grant Dalhousie University the rights required by this license, and that such third-party owned material is clearly identified and acknowledged within the text or content of the submission.

If the submission is based upon work that has been sponsored or supported by an agency or organization other than Dalhousie University, you assert that you have fulfilled any right of review or other obligations required by such contract or agreement.

Dalhousie University will clearly identify your name(s) as the author(s) or owner(s) of the submission, and will not make any alteration to the content of the files that you have submitted.

If you have questions regarding this license please contact the repository manager at dalspace@dal.ca.

Grant the distribution license by signing and dating below.

______________________________ ______________________________

Name of signatory Date

ABSTRACT

The conglomerates of northern Cape George represent a tectonic block, thrusted from the north during the Carboniferous. Previous provenance studies of the Cape George alluvial fan sediments have not been done in great detail so that a probable source of the sediments had not been determined. During a provenance study of the Cape George sediments the following questions were asked, concerning the reliability of the southeasterly paleocurrent direction:

(1) Has the Cape George thrust block received any rotation?

(2) Are the strata of Cape George representative of only a part of an alluvial fan or is the entire fan contained in Cape George?

(3) Have enough paleocurrent vectors been measured so that a reliable average paleocurrent direction can be determined?

During the Middle to Late Devonian, uplift in northern Nova Scotia and Cape Breton Island resulted in extensive unroofing and weathering of deeply buried metaquartzites and granites. During the Early Carboniferous extensive block faulting resulted in the formation of deep intermontane basins in which thick accumulations of sediment occurred. The coarse-grained, poorly sorted orthoconglomerates of northern Cape George were deposited by alluvial fans during the Early Carboniferous and accumulated to a thickness of greater than 1 km. Southward thrusting of the Cape George conglomerates, with minor amounts of rotation, occurred during the Carboniferous.

An analysis of structural and sedimentological data, together with a study of the clast lithologies in the conglomerates, suggests that the

Cape George sediments were probably derived from a northerly source and that since the Early Carboniferous most of the original rocks in the source area have been eroded or buried.

Acknowledgements

I wish to give special thanks to my supervisor, Dr. P. E. Schenk, and to Dr. David Piper for their constructive criticism and encouragement in the preparation of this report. I also wish to extend my gratitude to Dr. Damian Nance for suggesting the thesis topic and to Philip Fralick and Marie-Claude Blanchard for their time spent in discussing several of the topics in this report.

TABLE OF CONTENTS

FIGURES

Page

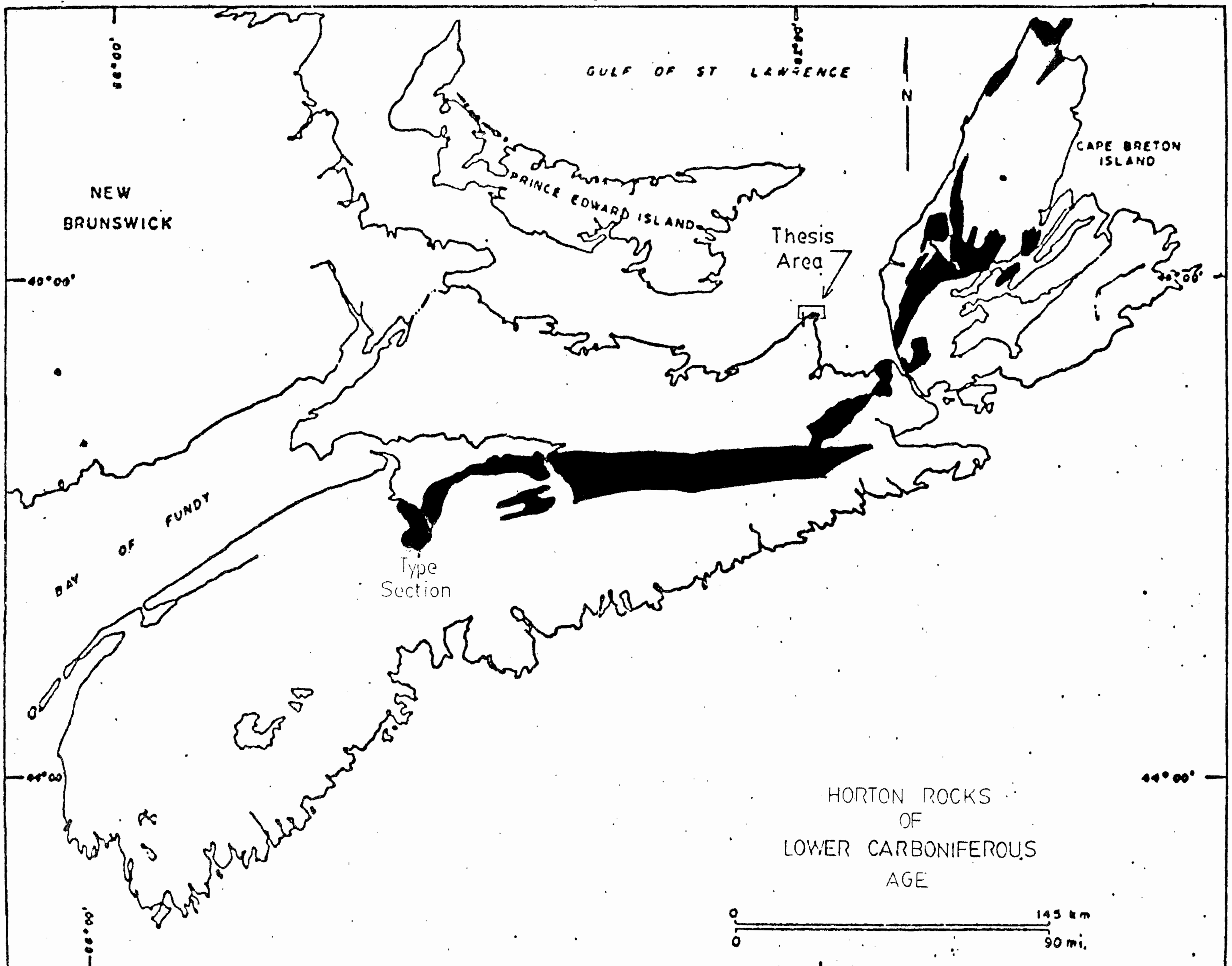
TABLES

INTRODUCTION

Objective of Thesis

Lower Mississippian conglomerates of the Horton Group (Kaminsky, 1953) are well exposed in the area of northern Cape George (Figures 1 and 2). Minor amounts of detailed sedimentological studies have been done on the sediments and very little is known about their depositional environment and source area. Extensive faulting, which has taken place near Cape George since the Early Devonian (Williams, 1914), suggests that the area has had an involved tectonic history. This can create problems which must be carefully considered in a provenance study of the sediments. The objective of this thesis is to reconstruct the composition of the source area and to determine a probable area of derivation for the sediments. The sedimentology of the sediments will be examined and an interpretation of the depositional environment will be presented.

Figure 1


GULF OF ST LAWRENCE
N
CAPE BRETON ISLAND
NEW BRUNSWICK
PRINCE EDWARD ISLAND
Thesis Area
40°00'
BAY OF FUNDY
Type Section
44°00'
HORTON ROCKS OF LOWER CARBONIFEROUS AGE
0 145 km
0 90 mi.

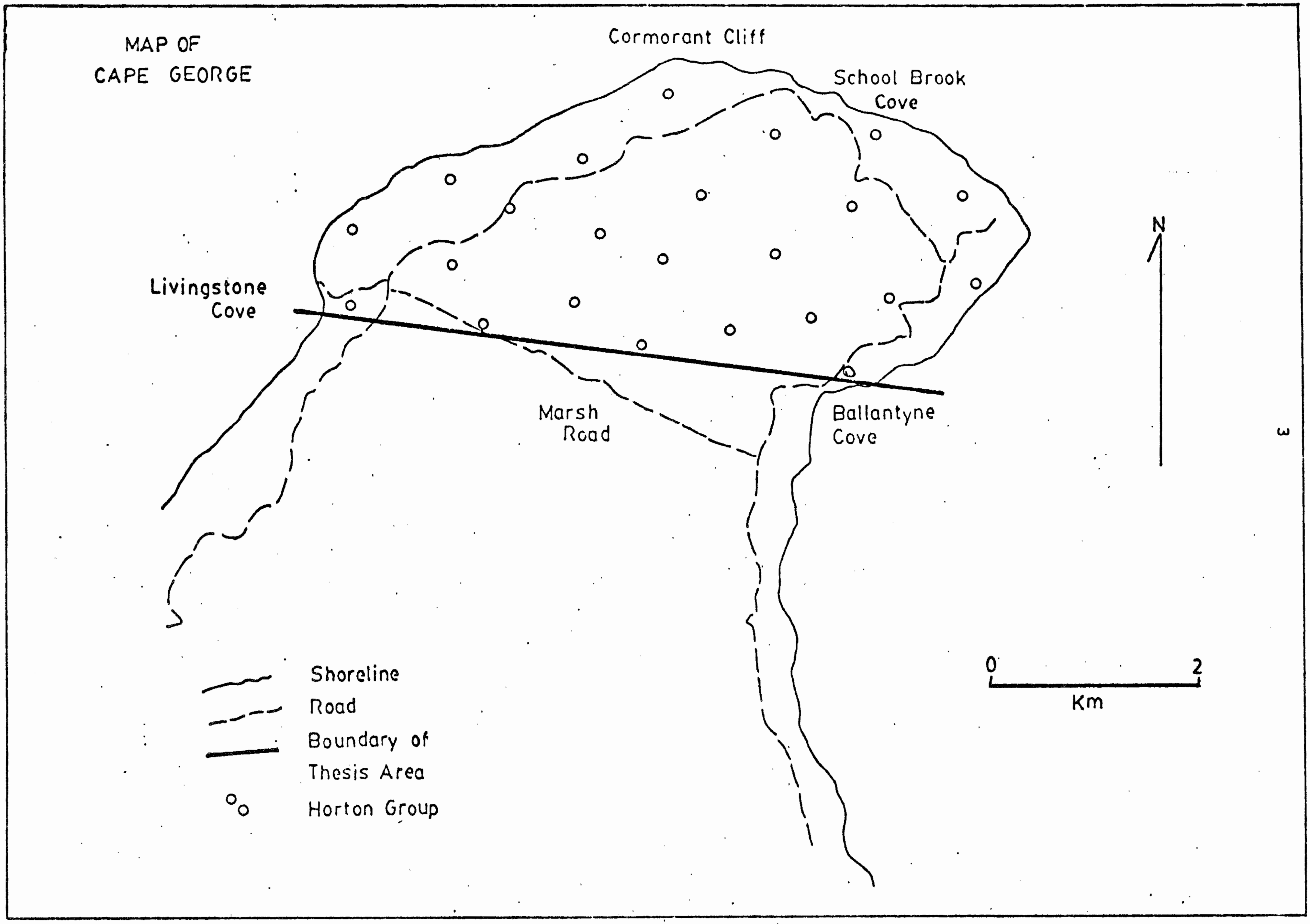

MAP OF
CAPE GEORGE
Cormorant Cliff
School Brook
Cove
Livingstone
Cove
Marsh
Road
Ballantyne
Cove
N
0
2
Km
Shoreline
Road
Boundary of
Thesis Area
Horton Group

Figure 2

Study Area and Access to Area

The rocks studied for this thesis cover approximately 15 km^2 of land in northern Cape George, Nova Scotia (Figure 2). The thesis area is bounded on the east by St. George Bay and on the north and west by the Northumberland Strait. The northwest-southeast trending Marsh Road marks the approximate southern boundary of the thesis area and extends from Ballantyne Cove in the east to Livingstone Cove in the west.

The thesis area (referred to subsequently as northern Cape George) was studied while camping at one of the private campgrounds in the town of Antigonish. By way of highway 337 excellent access is provided to and from northern Cape George and once within the region, graded and ungraded roads provide access to many of the outcrops. Numerous trails and cart tracks within the mapping area provide ways to much of the shoreline area. Beach traverses can normally be conducted during low tide along accessable parts of the shoreline. Stream channels can normally be entered from either the beaches or from highway 337 and once on them they are generally wide and shallow enough so as not to be a hinderance to walking.

Previous Work

The first extensive field work in the Cape George area was done in 1886 by Fletcher. Fletcher described the rocks and fossils at the tip of Cape George as being Silurian in age (refer to Map 3 in the folder). He referred to the conglomerate on Cape George as "Carboniferous conglomerate".

Little geologic study was done in the area during the early to middle parts of the twentieth century. In 1949 Decker studied the Horton sediments of Cape George. He referred to the Carboniferous conglomerates as "basal Horton sediments".

Since the middle part of the twentieth century most of the geologic studies done in the Cape George area was by theses done in conjunction with the program of the Nova Scotia Centre for Geological Science at Crystal Cliffs. In 1952 Kaminsky studied the geology of Cape George and concluded that in the vicinity of Ballantyne Cove, Early Carboniferous conglomerate of the Horton Group was thrust upon Devonian rocks of the McAras Brook Formation. North of Ballantyne Cove, Kaminsky estimated that the Horton conglomerates reached a maximum thickness of 1219 m.

At about the time of Kaminsky's studies Huppi, Kramer, and Phinney were also studying the geology of the region. Their ideas and conclusions about the geology of Cape George are similar to Kaminsky's.

In the early 1970's the geologic studies done around the Cape George region were of a general geologic nature and not specifically centered on northern Cape George. In 1974 Ziegler and also Boucot et. al. worked on the geology of the Arisaig area of Antigonish County. In his reports, Boucot refers to the Early Carboniferous conglomerates of Cape George as basal Horton sediments.

In 1976 Fralick did a study of some Devonian sediments in the area of Antigonish County. His studies were centered on a depositional history and provenance study of the McAras Brook Formation.

In 1978 Keppie, Giles and Boehner of the Nova Scotia Department of Mines studied the Middle Devonian to Lower Carboniferous rocks of Cape George. They refer to the conglomerates of northern Cape George as Middle to Late Devonian undifferentiated sediments.

Unpublished work by Nance has been centered on the structural aspects of the northern Cape George region. He suggests that the Ballantyne - Livingstone Fault is a thrust fault that has subsequently carried the Cape George sediments from the north.

Methods of Study

The field and laboratory work for this thesis were done by the writer during the school session of 1980-81. The field work on this subject was conducted during the later part of the summer of 1980; the laboratory and literature research during the school session from September 1980 to March 1981.

During the period of September 3 to September 8, approximately 10 hours a day were spent in the field mapping various sections of conglomerates of northern Cape George. The field work involved detailed mapping of structural (attitudes of bedding, faults, folds) and sedimentological features (paleocurrent measurements, bedding features, pebble counting). Measurements of paleocurrents involved field corrections for the tilt of the strata. Such corrections were made by using a clip board to represent the strata and rotating the clip board along the strike until it became horizontal. The imaginary paleocurrent vectors on the clip board were then measured. This technique is suggested in Potter and Pettyjohn (1963).

An important part of the field study involved the collection of pebble - count data. The stations for pebble - counting were chosen at random, but in such a way as to cover the entire region of northern Cape George. These stations were planned such that four groups of 50 clasts constituted each station. The individual groups of 50 were counted at stratigraphic intervals of 3 m and on an outcrop area of 1 m^2. The first clast to be counted in this area was chosen at random and successive clasts were selected at 3 cm intervals in random directions. The majority of the clasts in the conglomerates were clean and easily identified. Those coated with a mud or a chemical stain were removed from the rock and shattered to expose a fresh surface. Several of the clean clasts were selected as representative samples and brought back to the University for laboratory studies.

In the laboratory the samples were prepared by cutting slabs from each and subsequently wetting each slab with water and oil to more clearly see the features of the rocks. These slabs were then examined under the binocular microscope to determine composition and texture so that general depositional environment and source area could be determined for each sample. Figure 3 (from Williams, Turner, and Gilbert, 1954) is the sandstone classification tetrahedra that was used to classify the sandstone pebbles. The acidic volcanic clasts were classified according to the Streckeisen triangle for volcanic rocks (Figure 4).

The data obtained from the pebble - counts was analyzed statistically to determine any geologic trends. Factor analysis was applied to obtain the relationships between various clast lithologies. Subsequent to factor analysis, analysis of variance was applied at a 95 percent confidence interval to test for variation in the relative abundance of clast lithologies between stations.

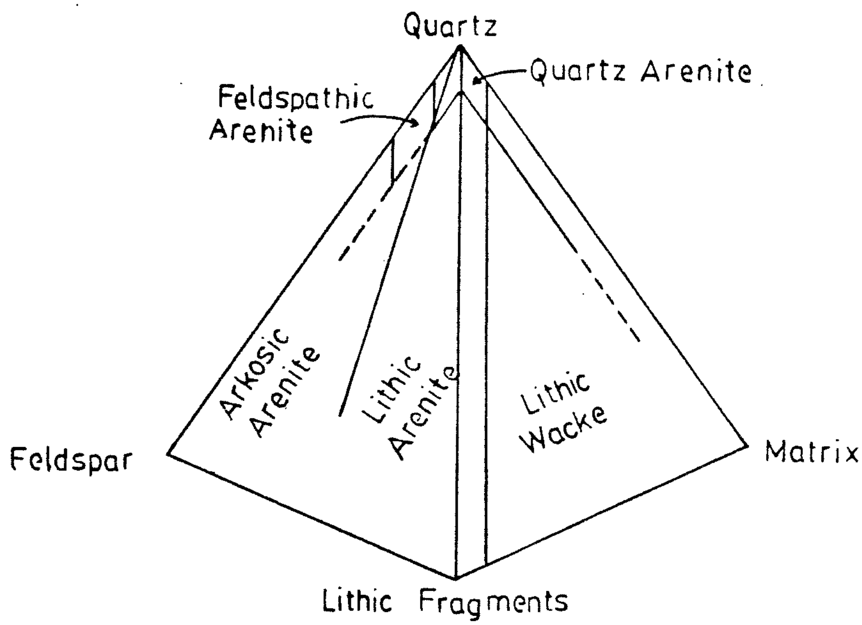


Figure 3

Sandstone classification tetrahedra. (adapted from Williams, Turner, and Gilbert, 1954).

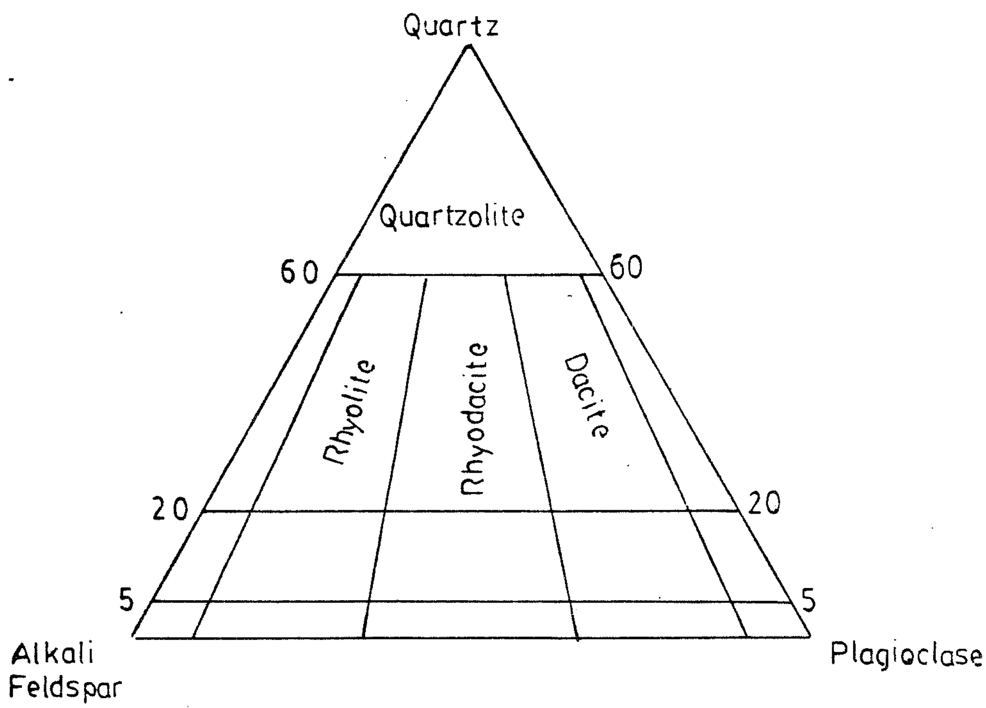


Figure 4

General classification of volcanic rocks (after Hyndman, 1972).

GENERAL GEOLOGY

General Statement

Nova Scotia is part of the Appalachian orogen that extends from southeastern United States through Newfoundland. Although much of the area of northern Nova Scotia and Cape Breton Island is underlain by rocks of Helikian to Devonian age the most aerially extensive rocks of the region belong to the Carboniferous System. These rocks underlie approximately 2788 km^2 of land area of Cape Breton Island (Kelley, 1951) and a comparable area of northern Nova Scotia.

Much of the Carboniferous rock of Nova Scotia belongs to the Early Carboniferous Horton Group (Figure 1). In Cape Breton Island the Horton Group is restricted to the northwestern half of the Island. In mainland Nova Scotia these rocks predominate south of the Cobequid Fault along a region averaging 15 km in width and 105 km in length. Other occurrences of the Horton Group are near the southern shore of the Minas Basin and in the vicinity of Cape George in Antigonish County.

The type section for the Horton Group occurs in the Windsor - Horton district near the estuaries of the Avon River (refer to Figure 1) (Bell, 1960). There the Horton Group consists of an upper Cheverie Formation and a lower Horton Bluff Formation. The rocks of the type section consist of sandstone, shale and conglomerate with a general arkosic to feldspathic composition.

Structural Geology

The southern limit of the Mississippian section of northern Cape George occurs at the Ballantyne - Livingstone Fault where the Horton has been thrust southward over the McAras Brook Formation (refer to map 1 in the folder). Northward this fault, the Horton strata strike in a general east-west direction and have a northerly dip averaging 35°. With the exception of the northernmost regions of the Cape the strata are relatively undeformed and display the results of only minor faulting.

The faults of northern Cape George are the major structural features present in the area. The overturned folds occurring in the northern and southeastern regions of the area are localized features and may be the result of the extensive faulting (Kaminsky, 1953; Huppi, 1953). Several major faults occur in the northern Cape George section and one major fault occurs west of the area (refer to map 1 in the folder).

The Hollow Fault which extends northeast-southwest is a major structural feature that may be responsible for the straight shoreline south of Livingstone Cove (Huppi, 1953). This fault is observed on aerial photographs as a prominent lineation extending in a northeast direction about 1067 m from the western shoreline of Cape George. This feature is described by Williams (1914) as a post-Early Devonian to pre-Mississippian normal fault that dips at a relatively steep angle. The Hollow Fault extends southwest from Malignant Cove where, further inland, it forms a steep scarp on the side of a U-shaped valley. The northwestern extension of the Hollow Fault disappears under the waters of the Northumberland Strait (Huppi, 1953).

With the aid of aerial photographs and topographic maps another major lineation can be traced across Cape George from Ballantyne Cove to Livingstone Cove where it appears to interfer with the Hollow Fault. This lineation, called the Ballantyne - Livingstone Fault is a steep, northward dipping thrust (Kaminsky, 1953) with an estimated maximum throw of 1560 m (Huppi, 1953). In the eastern section of Cape George this fault can be located along several sections of Cove Brook and subsequently traced further east to the shoreline where it can be observed in the conglomerates several hundred metres north of Ballantyne Cove. There the fault consists of three surfaces striking from N85E to N85W and dipping approximately 70° to the north (Kaminsky, 1953). A mylonite zone 1 m in thickness is present in the rocks north of Ballantyne Cove and again in an outcrop on the north side of the road at Ballantyne Cove. The fault surfaces and the mylonite zone cannot be observed at Livingstone Cove. The only evidence for faulting there is the deformational appearance of the Horton conglomerate. The clasts are notably stretched and display a thick hematite coating. The only evidence for southward thrusting along the Ballantyne - Livingstone Fault occurs in the conglomerates north of the mylonite zone.

Evidence for southward thrusting along the Ballantyne - Livingstone Fault is evident in the conglomerates for several hundred metres north of the mylonite zone. In that area the strata are overturned and dip northward, as if dragged by the thrusting of the Horton Group over the McAras Brook Formation (refer to map 2 in the folder). Kaminsky (1953) noted the presence of recumbent anticlines in an exposure of Horton sediment near Ballantyne Cove and suggested that they be indicative of thrusting and subsequent dragging of the overlying Horton strata. The writer has noted that the overturned strata strike nearly parallel with the trend of the Ballantyne - Livingstone Fault and suggests that such a structural relationship is indicative of a lack of rotation during southward thrusting of the Horton strata.

The writer has estimated that at least some movement along the Ballantyne - Livingstone Fault post-dates the Hollow Fault. Evidence comes from the geomorphology near Livingstone Cove (refer to map 1 in the folder). There the shoreline is not parallel to the northeast trend of the Hollow Fault as it is further to the south. The writer suggests that this relationship is the result of later movement along the Ballantyne - Livingstone Fault.

Other major fault zones occur far north from the Ballantyne - Livingstone Fault. Near the northernmost tip of Cape George, in the vicinities of Cormorant Cliff Cove, School Brook Cove and approximately 1.5 km southwest along the shoreline from Cormorant Cliff (refer to map 1 in the folder) there are major east-west trending faults that represent a part of a much larger fault complex (Boucot et. al., 1974). The complex can be thought of as consisting of a northern zone and a southern zone (Boucot et. al., 1974).

The northern zone of the complex is best observed near Cormorant Cliff Cove (Boucot et. al., 1974). There are major east-west trending faults there that can be traced for over 180 m (Boucot et. al., 1974). Boucot et. al. (1974) suggests that these vertical faults are responsible for the straight shoreline near Cormorant Cliff Cove.

The southern zone of the complex is well exposed near School Brook Cove and approximately 1.5 km southwest along the shoreline from Cormorant Cliff Cove. Kaminsky (1953) and Huppi (1953) noted that a major east-west trending thrust fault, passing through School Brook Cove, consisted of at least two minor faults. The rock occurring near these faults consists of mixed, angular blocks of Siluro - Ordovician volcanics and metasediments (Boucot et. al., 1974; Kaminsky, 1953) and is referred to as a megabreccia (Kaminsky, 1953; Huppi, 1953; Boucot, et. al., 1974). The writer did not observe Siluro-Ordovician rocks where the southern zone outcrops on the western shoreline of Cape George. A megabreccia of coarse-grained, greenish conglomerate was the only rock type noted. The greenish conglomerate was also noted to be present at School Brook Cove. Kaminsky (1953) attributed the darkened greenish colour of the conglomerate to the faulting. The writer suggests that perhaps the faulting assisted in the chemical reduction of the iron in the matrix.

The Horton strata occurring between the two zones is not as extensively faulted as the zones themselves. More characteristic of the interzone region is the large overturned fold (refer to map 1 in the folder). The strata dip north and strike relatively parallel to the trend of the fault complex. Kaminsky (1953) suggests that the overturning of the beds is the result of dragging during the thrusting of the northernmost section of Cape George over the southern section. The writer agrees with Kaminsky (1953) and also suggests that because of the structural relationship between the strike of the strata and the trend of the thrust fault, the northernmost thrust block of Cape George probably received minor amounts of rotation during southward thrusting.

In addition to the folding and faulting within the complex Kaminsky (1953) noted that an unconformity was also present. He observed that in the vicinity of School Brook Cove an unconformity occurs between the Siluro-Devonian quartzite and metasediments and the Carboniferous conglomerates. He also noted the presence of a one metre boulder of Siluro-Devonian quartzite embedded in the overlying conglomerates. The writer suggests that since stratified metasediments predominate below the erosional structure then perhaps the feature described by Kaminsky (1953) is an angular unconformity.

Pre - Carboniferous Rocks of Northern Cape George

Paleozoic rocks are of minor abundances in the northern Cape George region. These rocks are confined to areas of School Brook Cove and Cormorant Cliff Cove where diorite, quartzite, sandstone, siltstone and shale are known to occur (Boucot, et. al., 1974). Immediately south of the Ballantyne - Livingstone Fault are exposed Devonian sandstones, conglomerates and basalts of the McAras Brook Formation (refer to map 3 in the folder).

The Paleozoic rocks of northern Cape George have been described in great detail by Boucot et. al. (1974). The rocks occurring at School Brook Cove have been described as Devonian red siltstone, Silurian quartzite, Silurian cross-bedded sandstone and Ordovician hornblende diorite (Boucot, et. al., 1974). North of School Brook Cove, in the vicinity of Cormorant Cliff Cove, the Paleozoic rocks are predominantly red, green and gray-blue siltstones. Silurian fauna taken from the quartzites at School Brook Cove and fish fragments from the sandstones at both Coves provide absolute ages for many of the rocks in these areas.

The region immediately south of the Ballantyne - Livingstone Fault consists of Devonian rocks belonging to the McAras Brook Formation. These rocks consist predominantly of basalt, siltstone, sandstone, and conglomerate (Boucot et. al., 1974) (refer to map 3 in the folder). The sandstones and conglomerates possess a deep red colour due to the iron oxide in the matrix. In the vicinities of Ballantyne and Livingstone Coves, clasts of the conglomerates consist mainly of green quartzite and red sandstone which have subsequently been coated with a thick layer of blackish-red hematite. The absence of granitic clasts in the McAras Brook conglomerate aid in distinquishing it from the Carboniferous conglomerates to the north. In the vicinity of Ballantyne Cove a grey shale sample yielded polynomorphs of Devonian age (Keppie et. al., 1978).

Carboniferous Rocks of Northern Cape George

General Statement

The Carboniferous sediments of northern Cape George cover an area of approximately 15 km^2. The sediments are mainly coarse conglomerates with minor amounts of interbedded coarse to fine-grained sandstone (refer to fig. 2). An average thickness of these sediments is estimated to be 1219 m (Kaminsky, 1953).

Lithology

The Carboniferous rocks of northern Cape George are mainly orthoconglomerates with minor amounts of interbedded coarse to fine-grained arkosic to feldspathic arenite. The sandstones are quartz-rich and range from lithic to arkosic in composition (refer to Appendix 3).

The sediments possess an overall reddish colour with a subtle purple tint that subsequently distinguishes them from the deep, rusty red colour of the McAras Brook sediments. In the vicinity of the Ballantyne - Livingstone Fault the conglomerate clasts display a thick, black hematite coating. This coating on the clasts is less noticeable in the sediments further northward from the fault. This feature was also noted by Kaminsky (1953) and has since been interpreted as being the result of precipitation of iron from solutions that subsequently permeated through the fault zone.

The clast lithologies of the conglomerates are predominately coarse-grained granite, mottled gray-red limestone, purple-brown rhyolite, mafic volcanic rocks, green metaquartzite, red sandstone, quartz arenite, and fossiliferous carbonate.

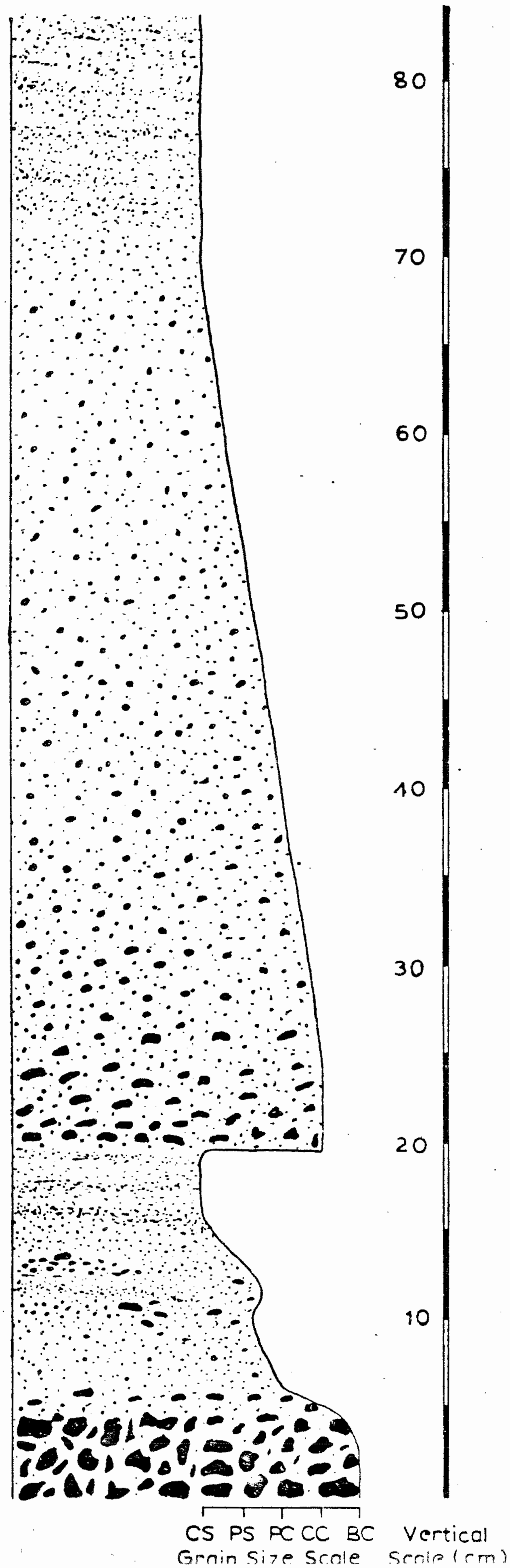
CARBONIFEROUS SEDIMENTOLOGY OF NORTHERN CAPE GEORGE

Sedimentary Structures

The texture of the conglomerates is much the same throughout the northern Cape George region. Strata units are seldom extensive laterally and generally display erosive bases with sharp to gradational upper contacts. Extensive cross stratification and a preferred clast orientation are common features of the entire Mississippian section of northern Cape George. Much of the strata display an initial lag gravel that grades upwards into a coarse to medium grained sandstone. Other units consist of lenses of interbedded gravel and sandstone. There are minor amounts of cross stratification present and there is little to no correlation between bedding thickness and clast size (Figure 5a).

Various types of sedimentary structures commonly occur in the Mississippian section of Cape George. The most common are the pebble imbrications, sand laminations, cross stratification, channel structures and scours (Figures 5b, c, d,). Less commonly observed are the primary current lineations that develop in the finer-grained sandy units.

Channel sections are the most common sedimentary feature present in the conglomerates. These structures can be typically described as consisting of boulder conglomerate and having distinct erosional bases with a subtle fining upward sequence. They are not continuous laterally. Clasts generally display some degree of imbrication. The channels are commonly observed throughout the entire thesis section.



Gradational Contact

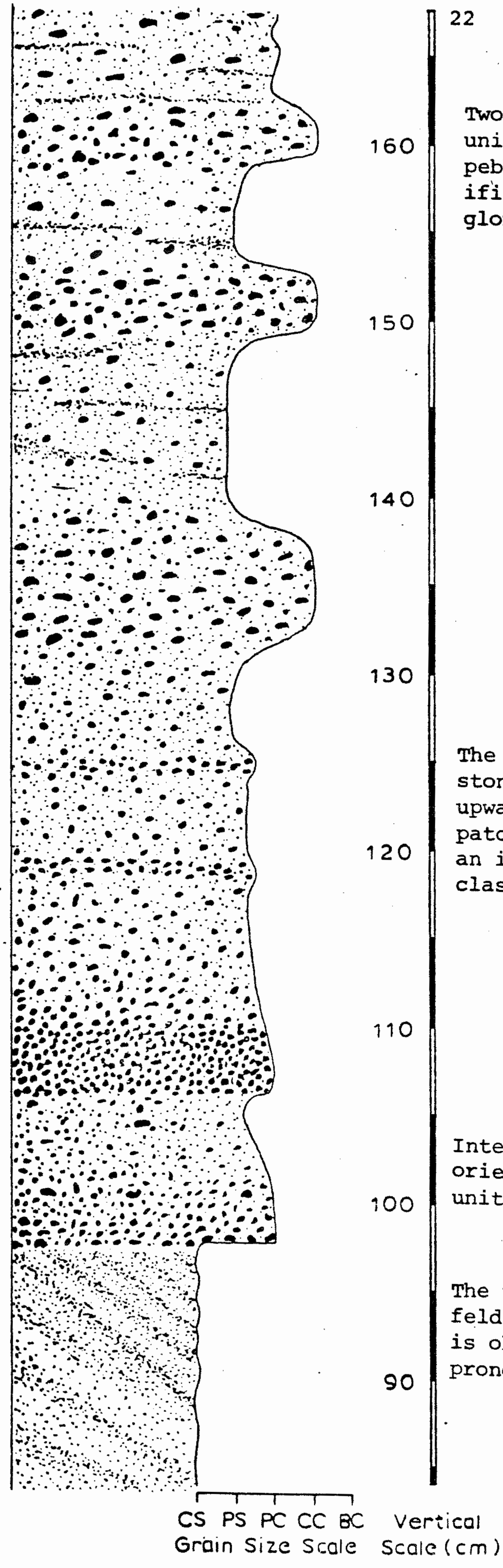
A fining upward texture is prominent; a preferred grain orientation is common, but internal stratification is lacking.

Erosional Contact

Rock type ranges from a feldspathic lithic arenite to an arkosic arenite; stratification is most obvious in the upper parts of the unit where the average grain size is smallest; lensoid patches of pebbly sandstone are common in the middle part of the unit.

Semi Abrupt Contact

Channel section displaying minor imbrication of subangular to subrounded clasts.



Two types of stratification are common in this unit: (A) stratification within the coarse to pebbly sandstone (140 - 150 cm); (B) stratification between (A) and the cobble conglomerate (130 - 150 cm).

Gradational Contact

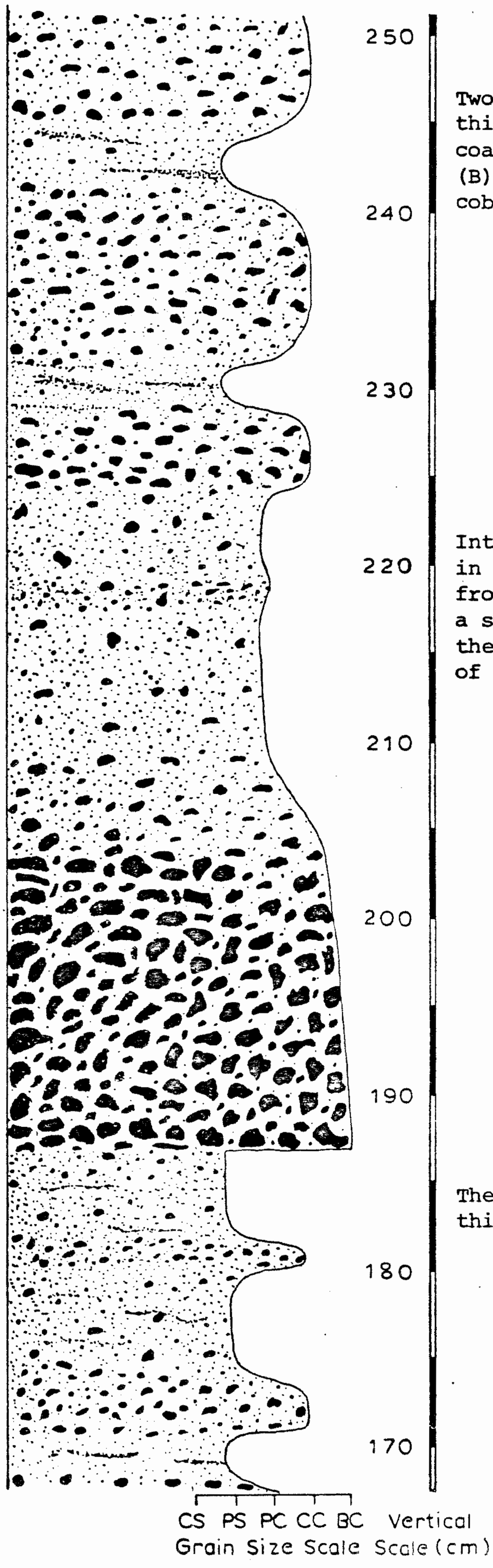
The relative percent of coarse-grained sandstone (feldspathic lithic arenite) increases upward in the unit. Local , linear-shaped patches of larger clasts provides the unit with an internal stratification. Many of the tabular clasts show a preferred orientation.

Semi Abrupt Contact

Internal stratification and preferred grain orientation are common to this poorly sorted unit (refer to Figure 5d).

Abrupt Contact

The unit consists of stratified, coarse-grained feldspathic lithic arenite. Cross stratification is obvious near the upper contact, but is less pronounced below 85 cm.



Two types of stratification are common in this unit: (A) stratification within the coarse to pebbly sandstone (229 - 231 cm); (B) stratification between (A) and the cobble conglomerate (224 - 240 cm).

Gradational Contact

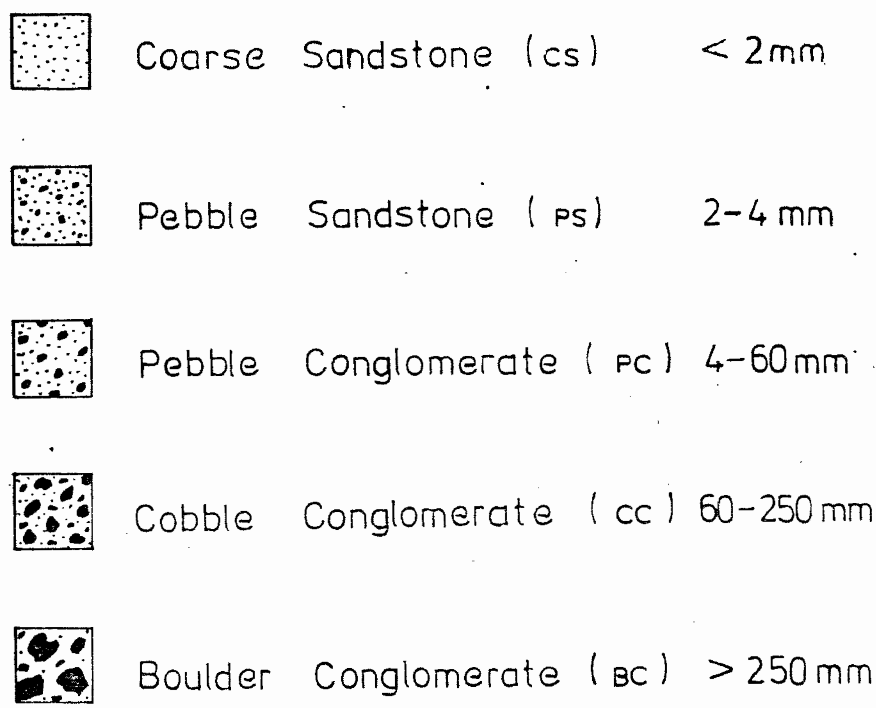
Internal stratification is more pronouned in the upper parts of the unit. The section from 187 cm to 205 cm is representative of a stream channel deposit. The top of the unit, from 205 cm to 223 cm, is typical of a sheetflood deposit.

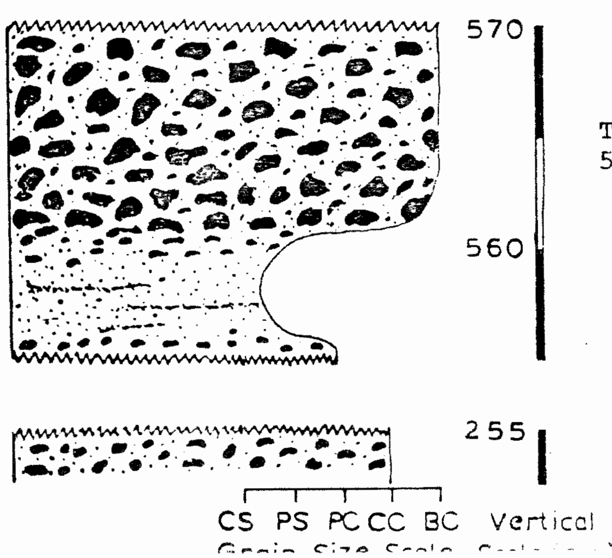
Erosional Contact

There is no relationship between the bedding thickness and clast size.

Figure 5a

Representative stratigraphic section of the Horton conglomerates that occur 1.5 km northwest of Ballantyne Cove.





The sedimentology of the deposits above 570 cm is similar to that already described.

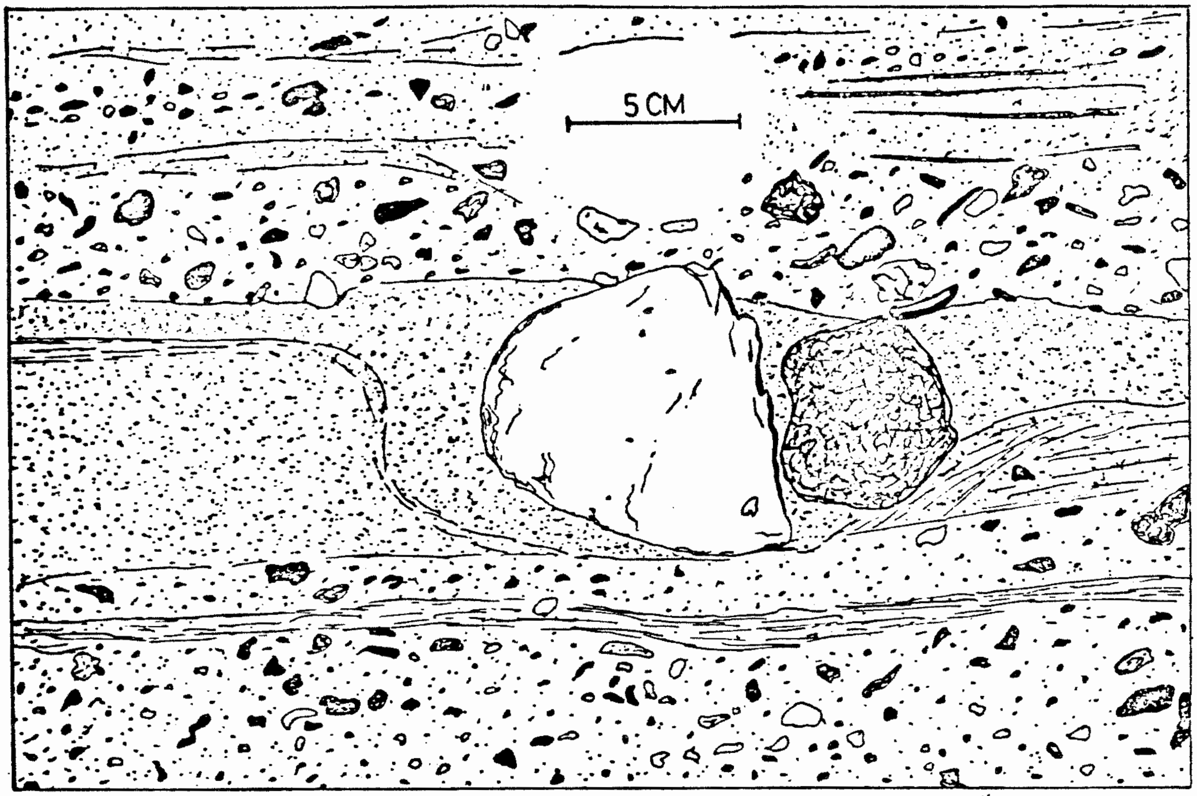


Figure 5b

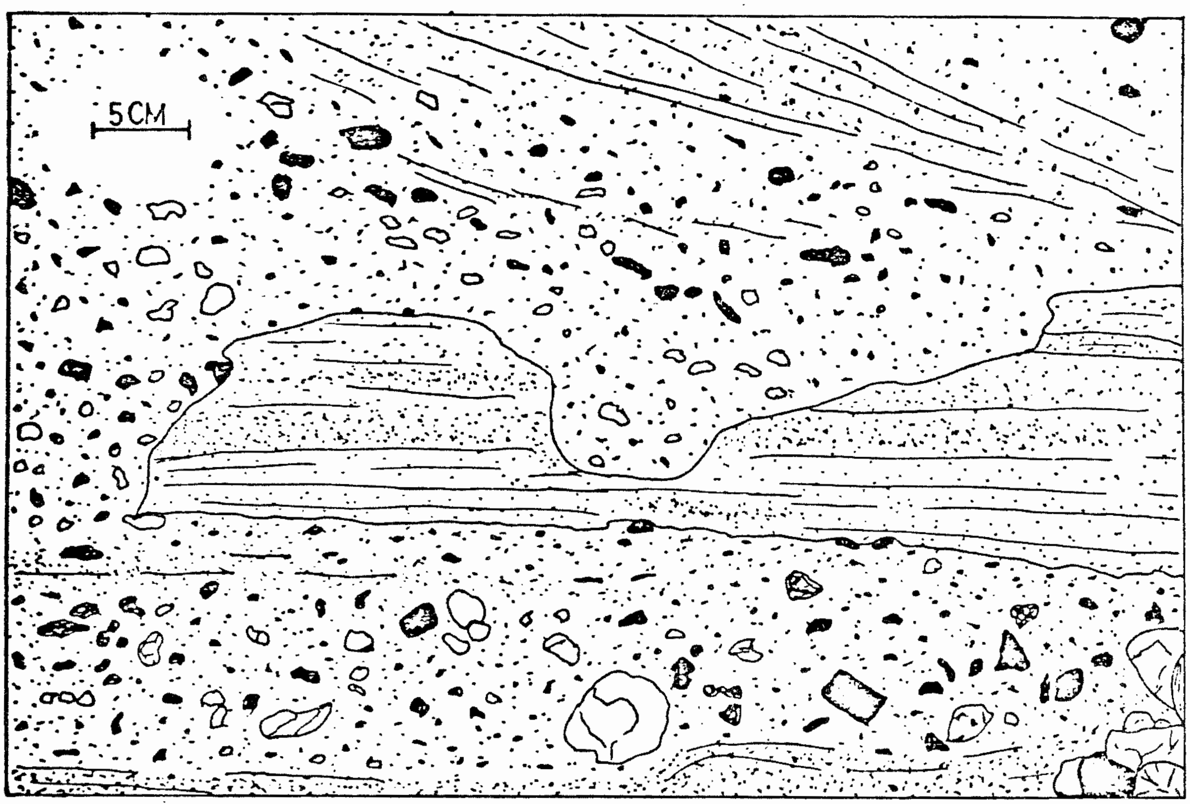


Figure 5c

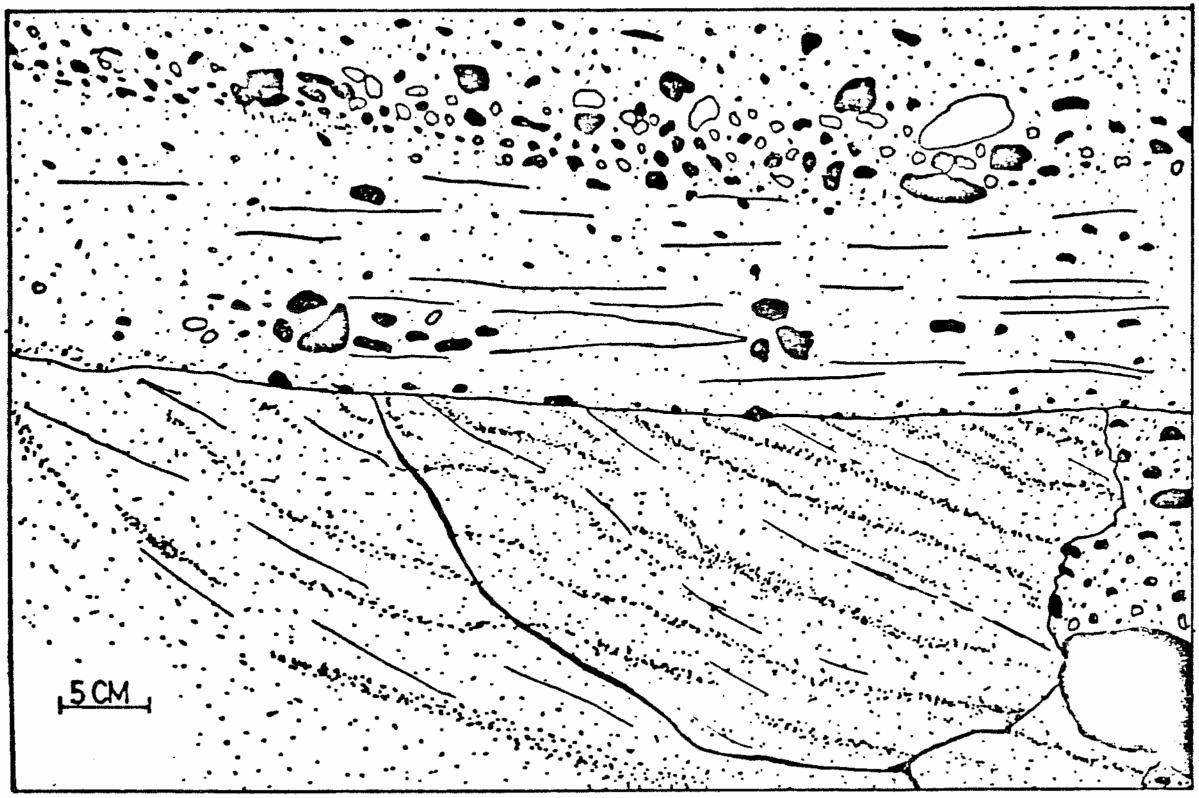


Figure 5d

Figure 5b   Poorly sorted orthoconglomerate showing scour structure and pebble imbrication. Current direction is from left to right.

Figure 5c   Reworking of parallel laminated, medium-grained sand by a medium-grained orthoconglomerate resulted in the scour near the centre of the sketch. Note the inclined stratification near the top-right hand corner.

Figure 5d   Large scale cross stratification between an underlying coarse-grained sandstone and an overlying orthoconglomerate. Note the well stratified appearance of the rocks. The sketch represents 80 cm - 110 cm of the stratigraphic colume (Figure 5a).

Bedding laminations and small scale cross stratification occur in the medium to coarse-grained sandstone units. The sandstone units overlying lag gravel deposits generally show the greatest degree of cross stratification. The laminations that are commonly observed in the sediments are restricted to the finer-grained sandstone units. These laminated structures appear to be the result of alternate consecutive layering between the coarser-grained quartz-rich layers and the darker, finer-grained layers.

Scour marks and large scale cross stratification are common features in the sediments of northern Cape George. These sedimentary structures are common to both, the fine-grained and the coarse-grained sediments.

Parting plane lineations (McBride and Yeakel, 1963) are apparent in the parallel laminated coarse-grained sandstone strata in the outcrops along the road near Ballantyne Cove (Figure 5d). McBride and Yeakel (1963) suggest that parting lineations are related to the internal rock fabric.

Stratigraphic Subdivision of the Northern Cape George Sediments

The Carboniferous section of northern Cape George has been subdivided by the writer into three informal lithozones based on the relative percentage of the various clast lithologies. The variation in clast abundance is greatest for the limestones and granites. Such clasts have subsequently been used as standards with which to subdivide the sediment.

The stratigraphically lowermost lithozone of the section covers the area from the Ballantyne - Livingstone Fault to the southern boundary of the northern fault complex (refer to map 3 in the folder). This lithozone has an average thickness of 1000 m. Because the strata have a consistent northerly dip and show only minor deformation this lithozone informally called the 'undeformed conglomerate'. This zone has been chosen by the writer to be representative of the Carboniferous sediments having an average amount of the common clast types (carbonates, granites, volcanic clasts, metaquartzites, and sandstones) and is the standard zone against which other stratigraphic subdivisions were defined.

The middle lithozone is approximately 100 m thick and covers the southern region of the northern fault complex. This lithozone shows major deformation in the form of faulting and is subsequently referred to by the writer as the "fractured conglomerate". Defined as a separate lithozone on the basis of the limestone and granite percentages the fractured conglomerate has the greatest concentration of granite clasts in the entire northern Cape George section. No limestone clasts are observed in this unit.

The uppermost lithozone covers the northern tip of Cape George where it is bound on the south by the fractured conglomerate and on the north by the upper boundary of the fault complex (refer to map 3 in the folder). This lithozone is approximately 180 m thick and consists predominantly of fine-grained conglomerate. The zone is notably faulted but, more characteristically, has a large overturned fold. Because of the folding the writer has termed this zone the "folded conglomerate". Unlike the lower two lithozones the folded conglomerate has an exceptionally high concentration of limestone clasts and no granite clasts.

Grain Size Distribution

The Carboniferous sediments of northern Cape George show regional patterns in the grain size distribution (refer to map 4 in the folder). These patterns occur as strips of varying thickness that trend east-west across the area parallel with the lithologies defined by clast composition. The writer has subdivided the region according to the average clast size and has subsequently classified the various subdivisions as silty (average clast size 3-25 mm), sandy (average clast size 13-25 mm), and coarse (average clast size 25-76 mm) conglomerate.

The coarse conglomerate is best represented in the fractured lithozone in the northern region of the thesis area. This zone displays a small variation between the maximum and average clast size. Several other occurrences of the coarse conglomerate can be observed near Ballantyne Cove and along a stream section north of Livingstone Cove.

The sandy conglomerate, represented by the sediments having an average clast size of 13-25 mm, is only observed in the regions near the upper and lower contacts of the undeformed lithozone. The sandy conglomerate covers nearly half of the area in northern Cape George and approximately 75 percent of this half is in the area directly north of the Ballantyne - Livingstone fault.

Approximately 90 percent of the total amount of silty conglomerate occurs in the central regions of northern Cape George where it is bounded on the north and south by sandy conglomerate of the undeformed lithozone. The change from sandy to silty conglomerate is very gradational and hence, the contacts between the two are best described as occurring over several hundreds of metres. Further to the north the remaining 10 percent of the silty conglomerate occurs in the folded lithozone where it is somewhat finer-grained than its southern equivalent.

Clast Descriptions

The clasts in the conglomerates of northern Cape George are subrounded to subangular and range from less than 3 mm to over 1.3 m. The lithologies consist predominantly of coarse-grained foliated granite, mottled gray-red limestone, undeformed purple-brown rhyolite and porphyritic rhyolite, mafic volcanics, green quartzite and red sandstone. The minor clast percentages are represented by white quartzite, quartz arenite, and fossilferous carbonate (refer to Appendix 1 and 2 for clast percentages).

Granites

The granites constitute about 16 percent of the total number of clasts in the northern Cape George conglomerates. These clasts are coarse-grained and generally display some deformation and weathering. The granite clasts are divided into three main groups according to their colour: the red granites, the white granites, and the pink granites. The red granite is the most common and constitutes about 40 percent of the total number of granite clasts. The white granite, being the second most abundant of the three, constitutes about 35 percent of the total. The least abundant pink granite makes up the remaining 25 percent of the total number of granite clasts.

The red granite clasts are commonly the smallest of the three granite types. They contain 50-60 percent potassium feldspar, about 30 percent quartz, and less than 10 percent mica and hornblende. They generally have a size range from 5 to 60 mm.

The pink granite clasts have an average size greater than that of the red granite. The average composition ranges from 20-30 percent quartz, 50-55 percent feldspar, and 20-25 percent mica and hornblende. They generally display a foliation and a minor amount of weathering. The clasts are normally coarse-grained and display a homogeneous texture.

The white granite clasts are similar to the pink variety with the exception of having a greater percent of white feldspar. The clasts are generally coarse-grained and show minor degrees of weathering.

Rhyolites

The rhyolite clasts rank as another major type of clast among the sediments of northern Cape George. They constitute about 8 percent of the 3600 clasts counted (refer to Appendix 1 and 3). The rhyolites have an average size of 3 cm and a maximum size of 12 cm. They are undeformed and display varying degrees of chemical weathering. The writer has observed two types of rhyolite clasts and based on physical appearance has subsequently grouped them into a purplish-brown rhyolite group and a porphyritic rhyolite group.

The purplish-brown variety are generally no larger than 1 or 2 cm. They have a sugary, homogeneous texture and closely resemble brown quartzite.

The porphyritic rhyolites are equal in abundance to the purplish-brown variety. Based on a typical porphyritic rhyolite clast the writer has determined the composition to be 7 percent free quartz, 23 percent feldspar (potassium feldspar and plagioclase), 23 percent amphibole, and 47 percent red-brown matrix. The groundmass probably consists of feldspar and quartz (Jamieson, per. comm., 1980). The larger grains of the clasts are angular to subangular and generally display chemical alteration. The amphibole grains have been strongly altered and consist almost entirely of chlorite.

Carbonates

The carbonate clasts constitute about 10 percent of the 3600 clasts counted. They are generally only a couple of cm in size, but several are over 30 cm. Nearly all the carbonate clasts observed are gray-red mottled. Less than 1 percent of the carbonate clasts are grey and contain an abundant fossil content.

The majority of the carbonate clasts are fine-grained and possess a notable amount of reddish brown insoluble residue. The insoluble matter consists of fine clay flakes and forms a mottled texture with the grey-green carbonate. Such a rock type has been referred to by Kaminsky (1953) as marly limestone. Dunbar and Rodgers (1957) define marlstone as a calcareous argillaceous rock having between 25 and 75 percent lime carbonate. This range of percent of lime carbonate is consistent with the mottled clasts.

Several of the mottled limestone clasts have a relatively rich fossil content. The fossils are best described as being slightly curved, elongated fragments filled with secondary calcite.

Another type of carbonate clast observed by the writer contains an abundance of fossilized fragments. Only one such clast was found and within it are gastropods, crinoid fragments, bivalves, and crenulated structures (possibly brachiopods).

Mafic Volcanic Clasts

The mafic volcanic clasts constitute approximately 14 percent of the 3600 clasts counted. They range in size from 6 cm to 1 m (rare). The clasts are generally a blackish-grey colour and display extensive weathering. The soft clasts crumble when removed from the conglomerates and as a result good representative samples are different to obtain.

Metaquartzites

The green metaquartzites constitute about 20 percent of the total number of clasts counted. They generally average 5 cm in size but can be as large as 1 m (rare). The clasts are dark to light green and sometimes display a sugary texture. They are subangular to subrounded and display varying amounts of spherocity.

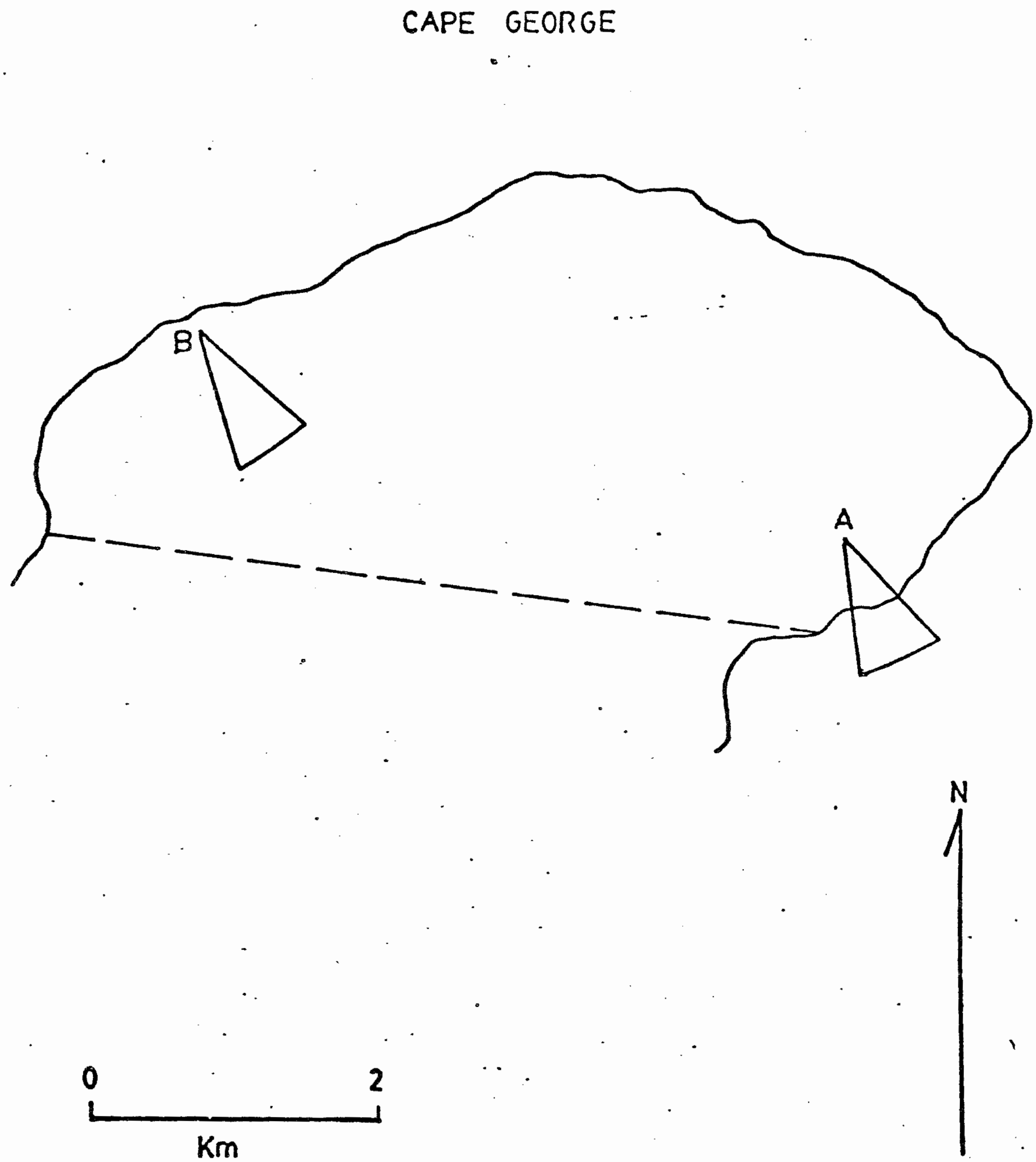
Dispersal Patterns

The sedimentary structures mentioned earlier serve as primary indicators of current direction. In areas of little structural deformation, they may also serve as indicators of source direction if the depositional environment is known.

A concentration of paleocurrent indicators occurs in the sediments along the shore approximately 800 m northeast of Ballantyne Cove (Figure 10). These indicators consist predominantly of pebble imbrications and cross stratification. The structures are well displayed but do not provide a clear indication of the paleocurrent direction and, therefore, are best used only as general vectors for current direction. Two of the outcrops in this area that display pebble imbrication and cross stratification provide a paleocurrent direction from the northwest ranging in azimuth from 135° to 173° (refer to Appendix 4). Similar structures in the sediments along the shore about 1.5 km north of Livingstone Cove suggest an average current vector of 146°.

Approximately 800 m northeast of Ballantyne Cove, several outcrops of conglomerate along the west side of the road are interstratified with coarse to medium-grained sandstones that clearly display primary current lineations. These sedimentary structures are of the parting plane type described by McBride and Yeakel (1963) and consistently give a paleocurrent sense ranging from 160° - 020° to 173° - 007°. Assuming that the unidirectional vectors (pebble imbrication and

Figure 10



Simplified map of Cape George showing the range in direction of sediment dispersal.

cross stratification) indicate a reliable general direction of the paleocurrent then the primary current lineations are more likely to suggest a southeasterly rather than northwesterly current direction. The paleocurrent vectors, therefore, are probably from the north.

The paleocurrent indicators within the sediments of northern Cape George suggest a general current direction from the northwest. Since the writer has only measured 12 paleocurrent vectors here, then there is a low probability that the general direction indicated is completely reliable.

DEPOSITIONAL ENVIRONMENT OF THE NORTHERN CAPE GEORGE SEDIMENTS

The sediments of northern Cape George consist of lithic, feldspathic and arkosic arenites and conglomerates. They are red, coarse-grained, poorly sorted sediments with a grain size ranging from 1.5 m (boulder) to less than 0.5 mm (medium to fine sand). The coarse-grained, poorly sorted nature of the sediments suggests that the depositional environment was probably very close to the source area. After a comparison of the Cape George sediments to the geologic studies carried out by Bluck (1967), Friend and Moódy-Stuart (1970), Blissenbach (1954), Bull (1968) and Allen (1974) it is suggested by the writer that the sediments of northern Cape George are representative of subaerial deposition on a semi-arid alluvial fan.

To support the interpretation that the Cape George conglomerates were deposited on semi-arid alluvial fan, a comparison will be made between the Cape George conglomerates and the alluvial fan deposits studied by other authors. Bluck (1967) studied Old Red Sandstone alluvial fan sediments of Scotland. The studies resulted in his recognition of four conglomeratic facies which he labelled A, B, C, and D (refer to table 1 and Figure 6). Bluck (1967) interpreted Facies B and D as being the result of sheetfloods and streamflows. Blissenbach (1954) studied the structures on semi-arid alluvial fans and interpreted the deposits as being the result of sheetfloods, streamfloods and streamflows. The streamflows are common to humid alluvial fans and are not a dominant depositional mechanism on semi-arid fans (Blissenbach, 1954).

Table 1

	Description	Interpretation
Facies A	poorly sorted sediments with matrix supported clasts (paraconglomerate)	results from high viscosity mud flows
Facies B	coarse-grained gravel lag overlain by smaller sets of sandstone (orthoconglomerate)	sheetflood deposit
Facies C	lenticular bedding with extensive cross-stratification; no correlation between clast size and bedding thickness	results from multiple reworking in stream channels
Facies D	lenticular bedding common; large lenses associated with scours; no correlation between clast size and bedding thickness	stream deposits

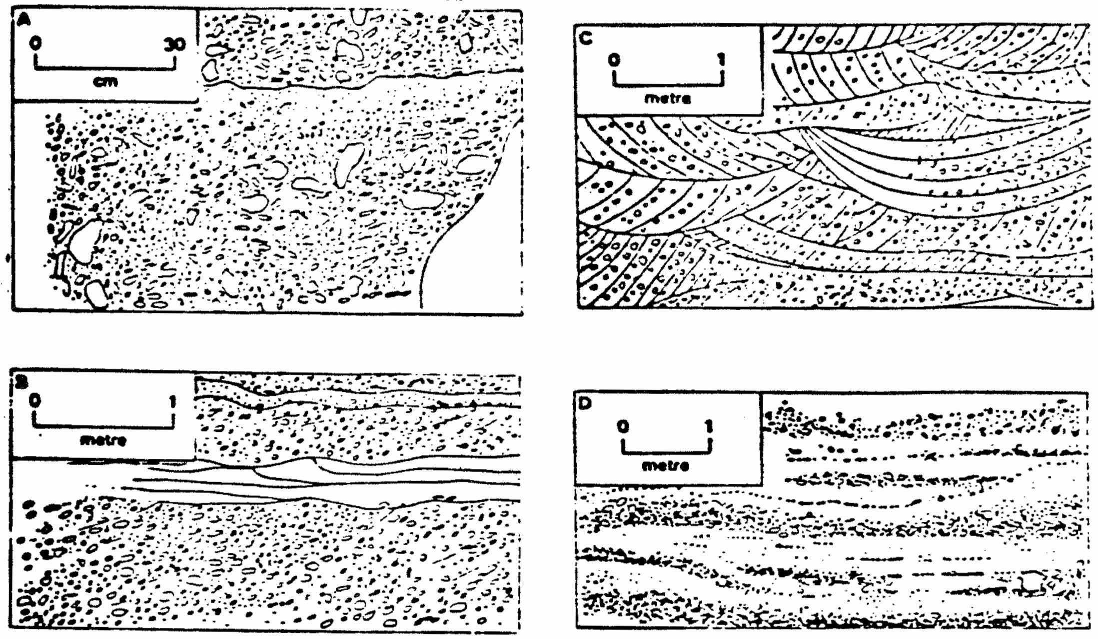


Figure 6

Four conglomeratic facies recognized in Old Red Sandstone alluvial fan **sediments**, Scotland. (A) is a paraconglomerate; (B), (C) and (D) are **or**thoconglomerates (after Bluck, 1967).

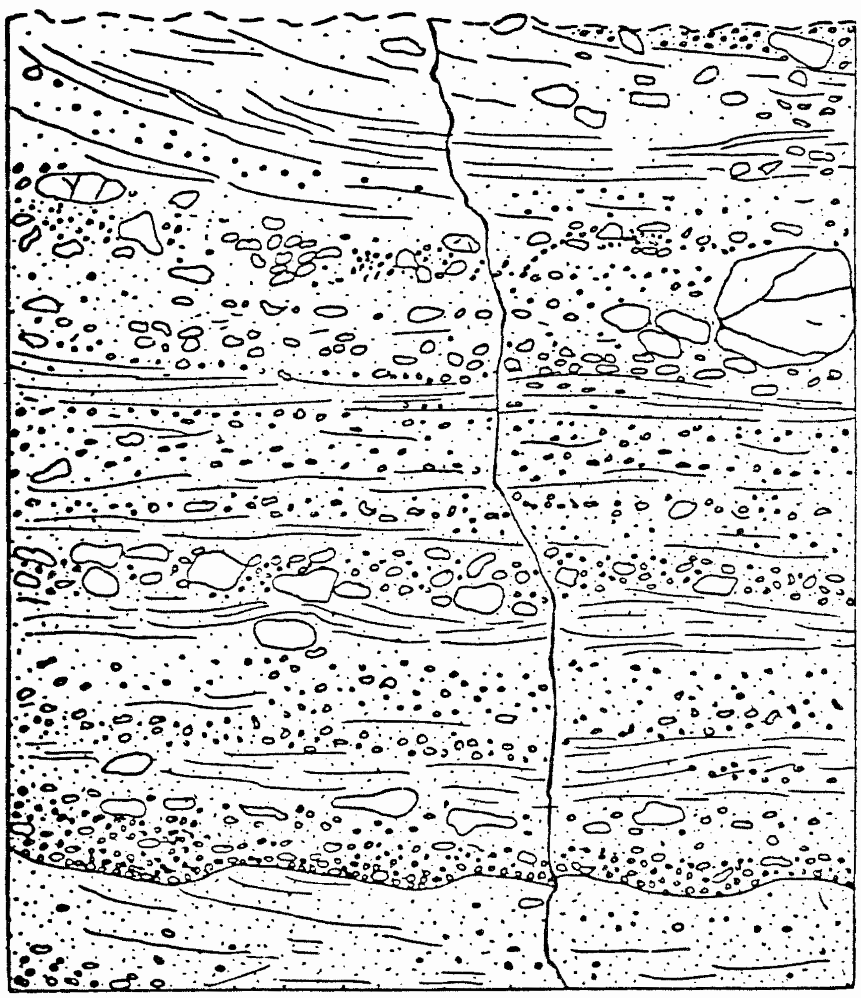


Figure 7

Typical sedimentary features of the orthoconglomerates in the vicinity of Ballantyne Cove. The largest clast in the sketch is 7 cm in diameter.

Blissenbach (1954) interprets sheetflood and streamflood deposits as resulting from a sudden discharge of an abundant water and sediment supply from a mountain canyon. The sudden decrease in hydralic gradient, as the flow reaches the alluvial fan, results in a rapid deposition of the sediment (Bull, 1968). Such deposits commonly display poor sorting, pebble imbrication, well-developed stratification (sheetfloods) and cross stratification (streamfloods) and are generally blanket-shaped (sheetfloods) or linear (streamfloods) in plain view (Blissenbach, 1954). The streamflow deposits result from a steady, rather than abundant supply and recharge of water from the mountains. They commonly form lenticular shaped deposits of poorly sorted sand and gravel (Bull, 1968). The are common on humid allivial fans where braided distributary channels are continuously reworking the sediment (Bull, 1968). Such sedimentary deposits as those discussed above are common to the sediments in northern Cape George.

The writer has compared the sedimentary features of the Cape George sediments to the sedimentary features that Bluck (1967), Blissenbach (1954), and Bull (1968) describe and state as being typical of alluvial fans. Facies B and D of Bluck's (1967) classification (Figure 6) are similar to the sedimentary deposits in northern Cape George (Figures 5a, 7). The writer suggests that the close resemblance between the sedimentary deposits in the conglomerates of Cape George and those in Facies B and D may be an indication that the Cape George sediments were partly deposited by sheetfloods and streamflows. The sedimentary structures that Blissenbach (1954) describes and states as being typical of sheetflood and streamflow deposits are common in the conglomerates at Cape George. These sedimentary structures (well-developed stratification, pebble imbrication, cross stratification) are common to alluvial fans (Blissenbach, 1954).

Bull (1968) describes two basic types of alluvial fans (Figures 8a, 8b). The type shown in Figure 8a has the area of deposition adjacent to the mountain front. The upper parts of the fan receive the greatest amount of sedimentation (Bull, 1968). The type in Figure 8b results from channel entrenchment in response to a climatic change (Bull, 1968). The upper part of the alluvial fan does not receive any sedimentation and is subsequently eroded by the streams and deposited further downslope (Bull, 1968). The type of alluvial fan shown in Figure 8b can be used to explain the presence of marly limestone clasts in the Cape George conglomerates.

There is a remarkable similarity between the marlstone clasts in the conglomerates at Cape George and those described by Friend and Moody-Stuart (1970). They studied the marlstones of the Wood Bay Formation in Spitsbergen and stated that an abundance of slightly curved, elongated fossils were common in the rocks. They identified the fossils as ostracods and charaphyte algae and stated that such fauna and flora were common in the carbonate deposits of floodplain lakes. Elongated structures similar to those described by

Friend and Moody-Stuart (1970) were observed in several of the marlstone clasts in the Cape George conglomerates. From this information the writer suggests that since there are no carbonate paleosols in the Cape George sediments then the marlstone clasts may have been derived from outside the area of deposition. Such clasts may have come from the upperslope areas of a fan similar to that shown in Figure 8b (refer to Figure 9).

In summary, it may be said that the coarse-grained poorly sorted nature of the conglomerates in northern Cape George, together with their sedimentary structures, suggests that the sediments were deposited in an alluvial fan environment. The similarity between the sedimentary features in the Cape George sediments and those described and stated by Bluck (1967), and Blissenbach (1954) as being typical of streamflood, streamflow, and sheetflood deposits suggests that the Cape George sediments were part of a semi-arid alluvial fan. The presence of marly limestone clasts in the conglomerates and the absence of any carbonate paleosols suggests that the original alluvial fan may have been of a type similar to that shown in Figure 8b.

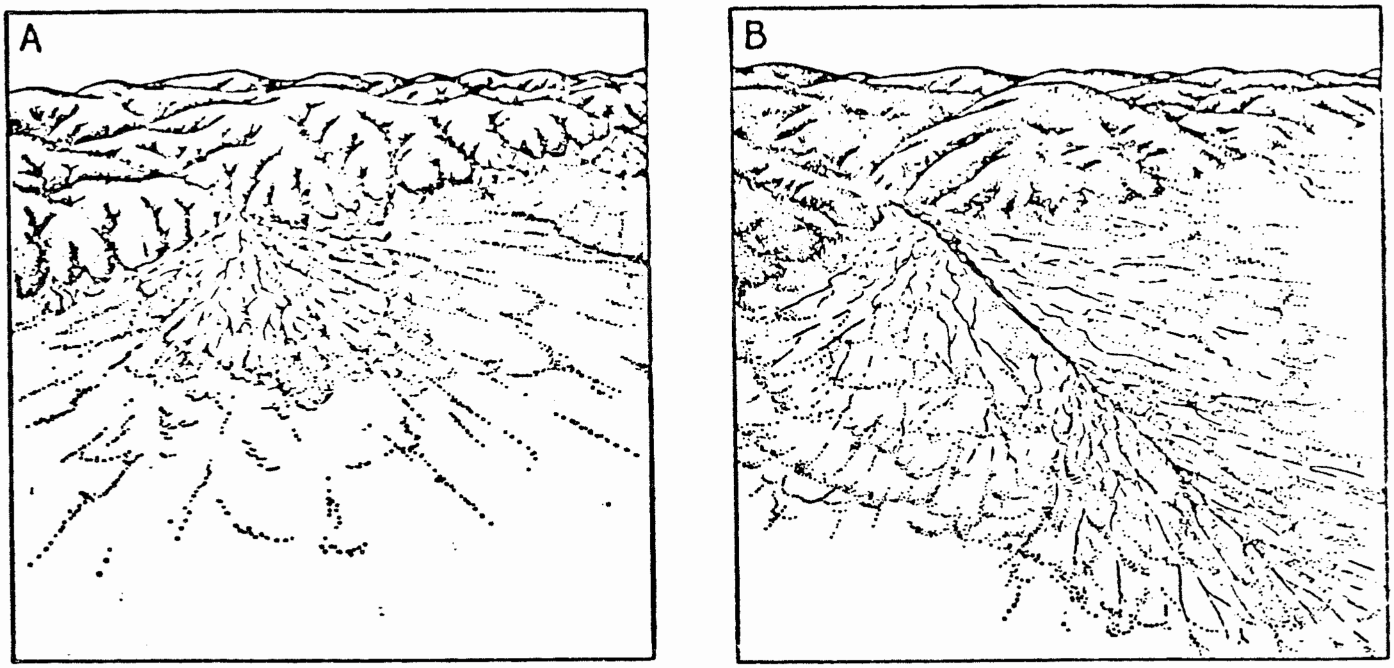


Figure 8

Two types of alluvial fans. A) area of deposition adjacent to the mountains; B) area of deposition downfan from mountain front due to entrenchment (after Bull, 1968).

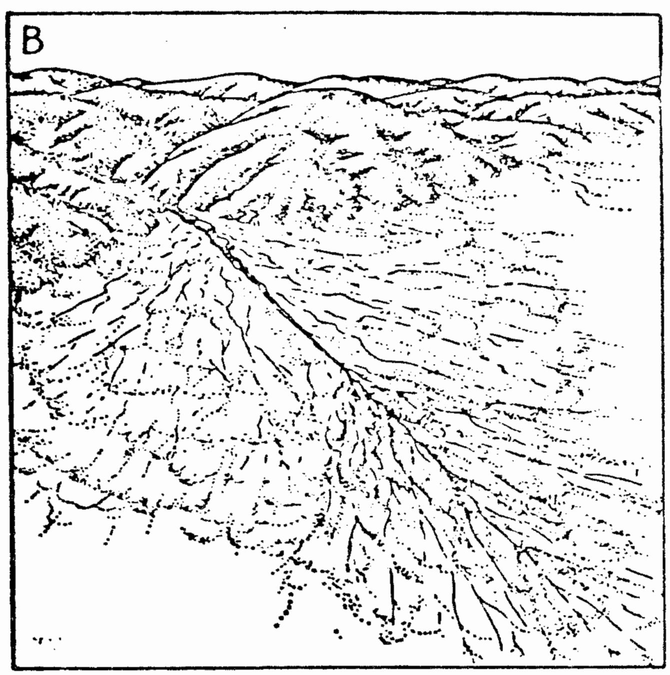


Figure 9

On an entrenched alluvial fan the overbank deposits are eroded from upfan (yellow) and carried to the area of deposition (blue) (after Bull, 1968).

A GEOLOGIC MODEL FOR THE CAPE GEORGE CONGLOMERATES

General Statement

The writer will begin by giving his definition of a source region. Following this, dicussions will be given on the composition and probable geographic locations of the source area for the sediments of northern Cape George. The concluding part of this section will include a descriptive model of the source region from which the Cape George conglomerates were derived.

Definition of a Source Area

In relation to sedimentary rocks, the writer defines a source region as the geographic area(s) from which the constituents of a sediment are derived. The source area may be several kilometres from the area of deposition or adjacent to it. In relation to the depositional environment of the Cape George conglomerates (refer to previous section) the source area, as defined by the writer includes the upper parts of the entrenched alluvial fan as well as the mountainous region behind it. When speaking of a source region, one must speak of the entire region from which sediment has been transported.

Composition and Age of the Source Area Rocks

The clast lithologies in a conglomerate reflect the rock types of the original source area. The clasts in the Cape George conglomerates suggest that the original source area consisted of granite, green metaquartzite, purple rhyolite, porphyritic rhyolite, mafic volcanics, marly limestone, fossiliferous carbonate, quartz arenite and sandstone. The relative abundance of the clasts in the conglomerates may indicate the relative abundance of the respective rock types in the source area. The green metaquartzites, marly limestones, granites, volcanics and sandstones are major constituents of the conglomerates and constitute more than 86 percent of the 3600 clasts counted. Such a high percentage may suggest that those rocks are the major constitutents of the original source area.

The writer has not argued as to whether or not the relative abundance of clast types is related to differential weathering of the source rocks or their proximity to the area of deposition. It was mentioned earlier that the marlstone clasts were probably derived from the upper part of the entrenched fan so that they were transported only minor distances before being deposited. The soft marlstones are easily weathered so that their relative abundance in the Cape George conglomerates is probably the result of their closeness to the area of deposition. It is not to be said that the marlstones are of minor abundance in the source region, but it must be considered that these rocks were probably common only to a small part of the source region (upper parts of the alluvial fan) and that they may have constituted only a small volume of the original source rocks. The relative abundance of red sandstone clasts (14 percent of 3600 clasts) in the Cape George conglomerates probably results from a situation similar to that for the marlstones. Many of the sandstone clasts reach apparent maximum diameters of approximately 30 cm. Sandstone is generally a relatively soft rock and to have boulder-size sandstone clasts in the conglomerates suggest that the distance of transport has not been far. Greater distances of transport can be assumed for many of the rounded rhyolite, green metaquartzite and granite clasts. Their roundness, their relative abundance in the Cape George conglomerate and their resistance to weathering suggests that these rocks may have been at a much greater distance from the area of deposition than the marlstone and sandstones and probably constituted a much greater volume of the source region. The green metaquartzites, granites and rhyolites were probably the most abundant rock types in the original source area. A determination of the relative ages of these rocks would assit in finding a source area.

Relative ages between the granites, rhyolites and green metaquartzites can be estimated by looking at the deformational and metamorphic textures in the clasts. A comparison between the foliated granites and the undeformed volcanics (refer to Appendix 3) suggests that the volcanic rocks experienced less orogenic activity. Displaying a lack of deformation, the volcanic clasts may have developed either at a time during which the last major orogenic event was occurring or at a time post-dating this event. The foliated granite clasts subsequently experienced the last major orogenic episode. The interlocking grains of the green metaquartzites suggests that these rocks experienced a major metamorphic event. A considerable amount of time is required to form a metaquartzite. This suggests that the metaquarzite is probably the oldest rock of the three being compared. The foliated granites, pre-dating the last major orogenic event, are probably second oldest, leaving the undeformed rhyolites as the youngest.

In summary, the green metaquartzites, granites, volcanics, sandstones and marlstones are the most abundant types of clasts in the conglomerates of northern Cape George. The sandstones and marlstones are probably from the upper part of the entrenched fan and do not represent a major volume of the source area. The green metaquartzites, granites and volcanics are probably the most abundant type of rocks present in the source region. Textural features in the metaquartzites, granites and volcanics suggest that, as listed, they range in order of decreasing age.

Possible Geographic Locations for the Source of the Cape George Conglomerates

The paleocurrent measurements obtained from the Cape George conglomerates suggest that possible source areas for these sediments lay northward, or even northwestward, of the present location of Cape George. To determine the reliability of the paleocurrent measurements the following three factors must be taken into consideration:

(1) The paleocurrent vectors were obtained from only two areas of the thesis region (Figure 10).

(2) The probablity is high that northern Cape George is representative of only a section of an alluvial fan. Reading (1978) states that any one place on an alluvial fan will show a fairly close grouping of paleocurrent vectors, though over the entire fan a difference of up to 180° might be expected.

(3) Southward thrusting of the Cape George section may have resulted in a rotation of the paleocurrent vectors.

In considering the above factors, the writer suggests that the paleocurrent vectors may be reliable. Current vectors measured on the sediments suggest that the source area for the conglomerates was northwest from the present location of Cape George. Although the paleocurrent measurements were obtained from only two areas of Cape George, these areas are far enough apart to account for any regional changes in the current direction. As stated by Reading (1978) any one place on an alluvial fan will show close grouping of paleocurrent vectors. The similarity in the direction of the current vectors in the two areas of Cape George suggests that the northern Cape George section represents part of a larger alluvial fan.

For reasons discussed earlier (refer to map 2 in the folder), it may be assumed that the conglomerates of northern Cape George were thrust southward with only minor amounts of rotation. Assuming that northern Cape George is an unrotated thrust block from a larger alluvial fan, then it can be shown by means of paleocurrent vectors that the source area is to the north (Figure 11). In Figure 11 it is shown that regardless of whether the original fan was orientated with its axis pointing east, west or south, the individually displaced blocks of the fan will have paleocurrent vectors that suggest a general southerly direction of sediment transport. Ideally, blocks A, B, and D best explain the current vectors observed in the Cape George sediments; however, the schematics are only to show that unless the thrust block is rotated, the Cape George sediments could not have come from any direction other than the north.

Studies done in the Cape George region suggest there is a low probability for the source area of the Cape George sediments being southward of Cape George. Kaminsky (1953) studied several of the major clast lithologies in the Cape George conglomerates and concluded that the granites were not comparable to those of the SouthSide Antigonish Harbour, James River Granite, Georgeville granite or the granodiorite from Glen Bard and William Point. He also studied the rhyolites and limestones and concluded that the rhyolites are more purple and feldspathic than the volcanics of Wilkie Brook and that the

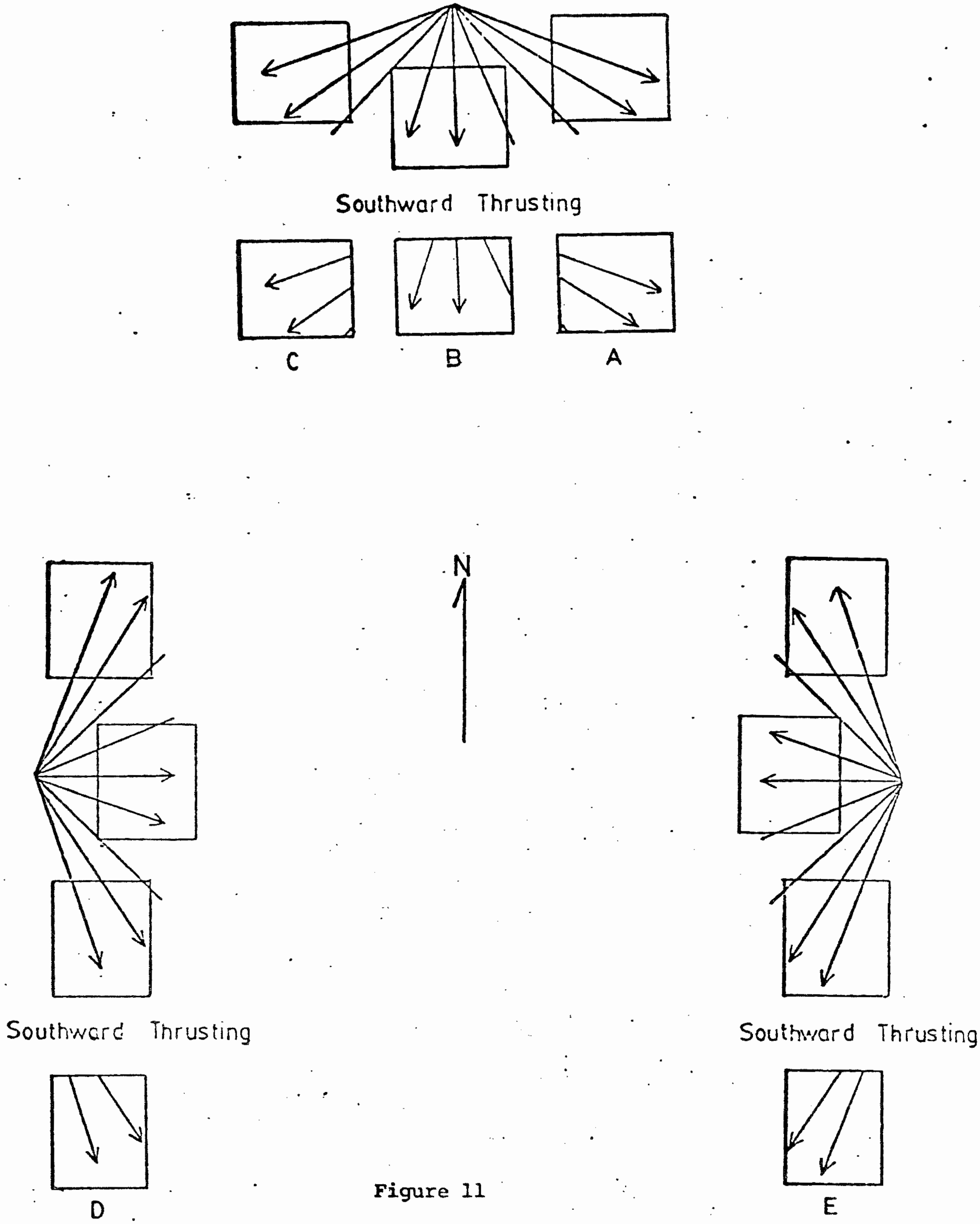


Figure 11

Blocks A, B, and D show paleocurrent vectors that have a similar **ori**entation to those in the Cape George Conglomerates. The model **assu**mes that no tectonic rotation resulted from the thrusting.

pink, marly limestones are not representative of the type found in the Arisaig Group. Kaminsky did state however, that the fossiliferous grey limestone clasts are typical of the Upper Arisaig Group. Since Kaminsky (1953) could not find a source area for the Cape George sediments in the region south of Cape George then the writer might suggest the source area be found in the region north of the Cape.

A Northern Source Area for the Cape George Sediments

The source region for the Cape George conglomerates should ideally contain the same lithologies as are present in the conglomerates themselves. It was mentioned earlier that the most abundant types of clasts in the conglomerates are the green metaquartzites, granites, volcanics, limestones, and red sandstones. The source for the latter two clast types was discussed earlier and will not be discussed further in this section. The green metaquartzites, granites and volcanic clasts are considered to be representative of the major rocks in the source area and as such will receive the closest attention in this section.

The most obvious region north of Cape George in which to begin searching for a source area is the western coastal section of Cape Breton Island. A variety of rock types occurring there are potential sources for the conglomerates of northern Cape George.

The nearest northerly occurrence of porphyritic rhyolite to Cape George is in the Fisset Brook Formation of western Cape Breton Island. The Upper Devonian - Lower Carboniferous Fisset Brook Formation occurs intermittentlythroughout the length of western Cape Breton Island and consists predominantly of basalt, rhyolite, tuff and continental redbeds. On the basis of spore analysis Cormier and Kelly (1964) have stratigraphically dated the Fisset Brook Formation in the Cheticamp area of Cape Breton Island as earliest Mississippian. The volcanic rocks of the Fisset Brook post-date the Acadian Orogeny (Keppie and

Dostal, 1980) and as such lack deformational textures. The writer has examined several samples of porphyritic rhyolite from the Fisset Brook Formation and noted their remarkable resemblance to the porphyritic rhyolite clasts present in the conglomerates of northern Cape George.

A northerly source of volcanic rocks nearer to Cape George than those of western Cape Breton Island would have a greater potential as a source area. Information concerning the occurrence of volcanic rocks northwest of Cape George comes from drilling of the H.B. Fina F-25 well (Figure 12). Drilled approximately 22 km northwest of Cape George the Fina well intersected interbedded basalt and sedimentary rock between the depths of 2580.1 m and 2950.5 m (Keppie, Giles and Boehner, 1978). The volcanic rocks consist of basalt and range in age from Middle Devonian to Late Devonian (Keppie, Giles and Boehner, 1978). The basalts in the Fina well have a similar age to those in the Fisset Brook Formation. This suggests that the northerly region above Cape George was volcanically active during the Late Devonian to Early Mississippian and as such may have been the source area of the volcanic clasts in the Cape George conglomerates.

Granitic plutons are presently exposed in western Cape Breton Island and as such are potential sources for the Cape George sediments. The writer has been unable to compare samples from these granitic plutons to the granite clasts of the Cape George conglomerates. The various types of granite clasts in the sediments suggests that several granitic sources may have been supplying debris to the conglomerates. The writer is uncertain as to the northerly source of the granite clasts.

H.B. FINA F-25

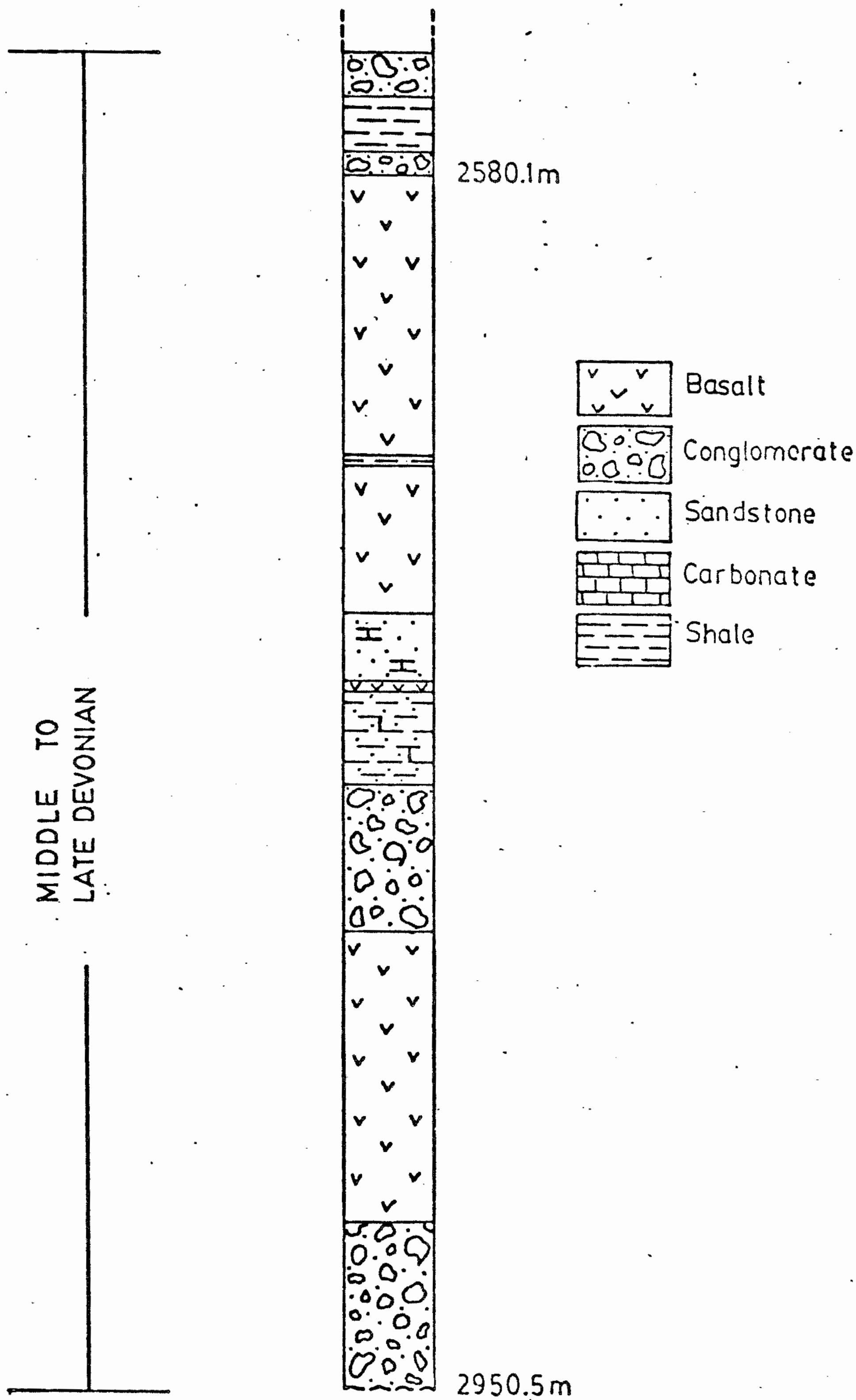


Figure 12

The green metaquartzites constitute approximately 20 percent of the clasts in the Cape George conglomerates. These clasts are resistent to weathering and as such may have been recycled. The large size (several decimeters) of many subangular to subrounded green metaquartzite clasts suggest that they were derived from a proximal source. To the writer's knowledge, the only potential source of green metaquartzite is the exposure at School Brook Cove. The green metaquartzite that outcrops there is less altered than many of the metaquartzite clasts and as such cannot be the only source of this rock. No other potential sources of green metaquartzite outcrop north of Cape George.

Summary and Conclusions About the Source Area for the Conglomerates of Northern Cape George

In summary, the original source area for the Cape George sediments consisted predominantly of green metaquartzite, granite, volcanics, marlstone and sandstone as indicated by the clast lithologies in the conglomerates. The marlstone clasts and at least some of the sandstone clasts were derived from the upper parts of the alluvial fan. Their origin of proximal derivation is indicated by their low resistance to weathering, yet their large size and abundance in the Cape George conglomerates. The source of the volcanics is less certain. The porphyritic rhyolite clasts closely resemble the porphyritic rhyolites of the Fisset Brook Formation in western Cape Breton Island and as such may have been derived from the Fisset Brook volcanics or equivalent rocks that were situated further west during the Late Devonian - Early Carboniferous. Middle Devonian - Upper Devonian (Keppie and Dostal, 1980) basalts were discovered 22 km northwest of Cape George during the drilling of the H.B. Fina F-25 well. The presence of those basalts suggests that the region north of Cape George was a volcanic zone during the Middle Devonian - Late Devonian and as such may have been a source for the volcanic clasts in the conglomerates. No probable source area could be found for the granitic clasts. The variety of granite clasts in the conglomerates suggests that more than one source of granite was supplying debris to the Cape George sediments. There is no known exposure of green quartzite north of Cape George and as a result a source of this rock type could not be found.

In conclusion, the source area of the Cape George sediments was originally northward from the present position of Cape George. This is indicated by the southward directed paleocurrent vectors and by Kaminsky's (1953) studies where he concluded that no southerly source for the Cape George sediments could be found. The acidic and mafic volcanic rocks are Uppermost Devonian to Lowermost Carboniferous in age and developed in a volcanic zone near the western coastal region of Cape Breton Island. These volcanic rocks are probably not exposed today, yet their presence during the Late Devonian - Early Carboniferous is indicated by the Fisset Brook acidic volcanics and the Fina well mafic volcanics. No definite metaquartzite or granitic sources could be located and as such have probably been eroded or buried.

CONCLUSIONS

The sandstones and conglomerates of northern Cape George are of a probable Lower Mississippian age. This is based on the polymict nature of the conglomerates and on the presence of undeformed porphyritic rhyolite clasts resembling porphyritic rhyolites of the Upper Devonian - Lower Carboniferous Fisset Brook Formation. Pebbles in Mississippian conglomerates are often polymict and as such suggest major uplift during the Devonian (Boucot et. al., 1974). Major uplift in Devonian time and extensive block faulting during the Early Mississippian (Kaminsky, 1953) resulted in thick accumulations of sediment in a basin and range structure. The conglomerates of northern Cape George were probably formed within such a structure. The block faulting probably opened extensive fractures through which magma was channelled. The basic volcanics detected in the Fina well and the acidic volcanics of the Fisset Brook Formation are Middle Devonian to Carboniferous in age (Keppie, Giles and Boehner, 1978; Cormier, 1964) and probably formed during the Late Devonian uplift and faulting.

Extensive uplift during the Late Devonian resulted in the unroofing of deeply buried metaquartzites and granites. These rocks were extensively eroded and their debris deposited in the Early Mississippian fault basins. Evidence for extensive uplift comes from the abundance of green metaquarzite and granite clasts in the Cape George conglomerates. The abundance of undeformed volcanic clasts in the conglomerates suggests that the newly formed Mississippian volcanics were being eroded at this time and their debris transported to the block-faulted basins. As indicated by the coarse-grained, poorly sorted conglomerates at Cape George some of the intermontane sediment accumulated as thick alluvial fans.

As uplifted land equilibrated with the basins, sedimentation on the alluvial fans would become progressively less and the sediment being deposited would be much finer. Minor fluctuations in tectonic uplift would result in an increased amount of coarse sediment entering the fan. The grain size distribution in the Cape George sediments (refer to map 4 in the folder) suggests that perhaps tectonic fluctuations occurred after the initiation of deposition.

During the Early Mississippian the Cape George conglomerates continued to accumulate. As indicated by paleocurrent vectors, the sediment was transported from the north. Initial deposition of the sediment was probably adjacent to the mountain front. As the gradient of the fan slope decreased, due to equilibration of the hills with the valleys, marlstone deposits formed in overbank lakes near the bottom of the fan. Subsequent entrenchment of the fan, possibly resulting from a climatic change (Bull, 1968) resulted in shifting the area of deposition to the lower parts of the original fan. The upslope section no longer received sediment, but rather, was eroded and the debris carried further downfan. Evidence for this comes from the presence of marlstone and sandstone clasts in the conglomerates at Cape George. Sandstone generally has a low resistance to weathering so that the large size of many sandstone clasts suggests a minimal amount of transport. The marlstones are also very soft and long distances of transport would undoubtedly destroy them. The presence of ostracods and charaphyte algae fossils in the marlstone also suggest formation in a floodplain lake (Friend and Moody-Stuart, 1970).

During post-Horton to post-Windsor time (Boucot et. al., 1974) thrust faulting resulted in a southerly displacement of various parts of the alluvial fan. Evidence for this can be seen in the rocks near Ballantyne Cove and near the northern tip of Cape George. Near those locations fault planes can be seen to dip steeply to the north. North of the faults, overturned strata striking nearly parallel with the trend of the lineations suggest that only minimal rotation resulted during thrusting. This may be partly due to the short distance that the blocks were transported. (Huppi (1953) estimated a maximum throw of 1560 m on the Ballantyne - Livingstone Fault). Based on the presence of marlstone clasts in the conglomerates, the uppermost and lowermost lithozones of the Cape George section were probably displaced from the area of deposition of an entrenched fan. The middle lithozone is probably from the upslope part of the original pre-entrenched fan. The lack of granite in the folded conglomerate suggests that this lithozone may have been part of a separate alluvial fan that received sediment from a localized area.

Many of the original rocks in the source area have been eroded or deeply buried. The fossiliferous carbonate in the Upper Araisag Group and the porphyritic rhyolite in the Fisset Brook Formation are the only presently exposed potential sources of the Cape George conglomerates. The mafic volcanic rocks revealed in the H.B. Fina F-25 well are also a potential source of the Cape George sediments.

References

Bell, W.A. (1960). Mississippian Horton Group of Type Windsor Horton District, Nova Scotia. Geol. Surv. Can. Memoir 134, 1-14.

Blissenbach, E. (1954). Geology of Alluvial Fans in Semi-Arid regions. Bull. Geol. Soc. Am. 65, 175-190.

Bluck, B.J. (1967). Deposition of Some Upper Old Red Sandstone Conglomerates in the Clyde Area: A Study in the Significance of Bedding. Scott. J. Geol. 3, 139-167.

Boucot, A.J., Dewey, J.F., Dineley, D.L., Fletcher, R., Fyson, W.K., Griffin, J.G., Hickox, C.F., McKerrow, W.S., and Ziegler, A.M. (1974). Geology of the Arisaig Area, Antigonish County, Nova Scotia. Geol. Soc. Am. Spec. Paper 139, 117-124, 144-151.

Bull, W.B. (1968). Alluvial Fans. J. Geol. Educ. 16, 101-106.

Collinson, J.D. (1978). Alluvial Sediments. In: Sedimentary Environments and Facies (Reading H.G., ed.), 15-59.

Cormier, R.F. and Kelly, A.M. (1964). Absolute Age of the Fisset Brook Formation and the Devonian-Mississippian Boundary, Cape Breton Island, Nova Scotia. Can. J. Earth Sci. 1, 159-166.

Currie, K.L. (1977). A Note on Post-Mississippian Thrust Faulting in Northwestern Cape Breton Island. Can. J. Earth Sci. 14, 2937-2941.

Decker, R.W. (1946). A Study of the Upper Horton Sediments In Northern Nova Scotia and on Cape Breton Island. Annl. Report Mines.

Friend, P.F. and Moody-Stuart, M. (1970). Carbonate Deposition on the River Floodplains of the Wood Bay Formation (Devonian) of Spitsbergen. Geol. Mag. 107, 181-195.

Huppi, R.G. (1953). The Geology of Eastern Cape George S.M. Thesis, M.I.T.

Kaminsky, P.D. (1953). The Geology of Northern Cape George, Nova Scotia S.M. Thesis, M.I.T.

Keppie, J.D. and Dostal, J. (1980). Paleozoic Volcanic Rocks of Nova Scotia; In Proceedings: "The Caledonides in the U.S.A." I.G.C.P. Project 27: Caledonite Orogen: Department of Geological Science, Virginia Polytechnic Institute and State University, Memoir, no. 2, 249-256.

Keppie, J.D., Giles, P.S., and Boehner, R.C. (1978). Some Middle Devonian to Lower Carboniferous Rocks of Cape George, Nova Scotia. Nova Scotia Dept. Mines, paper 78-4.

McBride, E.F. and Yeakel, L.S. (1963). Relationship Between Parting Lineation and Rock Fabric. J. Sedim. Petrol. 33, 779-782.

Williams, M.Y. (1914). Arisaig - Antigonish District, Nova Scotia, Geol. Surv. Can. Memoir 60.

Selected Bibliography

Allen, J.R.L. (1974). Studies in Fluviatile Sedimentation: Implications of Pedogenic Carbonate Units, Lower Old Red Sandstone, Anglo-Welsh Outcrop. Geol. J. 9, 181-208.

Belt, E.S. (1968). Carboniferous Continental Sedimentation, Atlantic Provinces, Canada, In: Klein, G. DeV., ed., Late Paleozoic and Mesozoic Continental Sedimentation, Northeastern North America. Geol. Soc. Am., spec. paper 106, 127-176.

Blissenbach, E. (1952). Relation of Surface Angle Distribution to Particle Size Distribution on Alluvial Fans. J. Sedim. Petrol. 22, 25-28.

Bluck, B.J. (1964). Sedimentation of an Alluvial Fan in Southern Nevada. J. Sedim. Petrol., 34, 395-400.

Hooke, R.L. (1967). Processes on Arid-Region Alluvial Fans. J. Geol. 75, 438-460.

Kramer, J.R. and Phinney, W.C. (1953). The Geology of Cape George, Nova Scotia, B.Sc. Thesis, M.I.T.

McGee, W.J. (1897). Sheetflood Erosion. Bull. Geol. Soc. Am. 8, 87-112.

APPENDIX 1

Factor Analysis Matrix

VARIMAX ROTATED FACTOR MATRIX

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
GQTT	-.15703	-.03897	.03944	-.29151	.09027	-.18413
WQTT	-.21271	.01885	.49261	-.14870	-.30265	.00766
WQTZ	.07312	-.23522	.35877	.15827	.11824	.40573
RSST	-.38418	.03006	-.16621	-.00521	.23784	-.04612
WSST	-.33413	.27550	.02500	.16770	-.23596	-.02923
GSST	.03980	-.05952	.13742	-.03251	.61600	.03709
QARE	.35029	.22838	-.13582	.00217	.05286	-.21131
PGRT	-.12289	-.12389	.05167	.56267	-.07939	-.02950
RGRT	.20179	.32187	-.12285	.24806	.01521	.02824
WGRT	.03792	-.08199	-.12565	.53002	-.00904	-.01594
RCHT	.07336	-.11767	-.21883	-.14535	-.05906	.54572
WCHT	-.04050	.18598	.01448	.05368	.01488	.53825
BCHT	.02597	.63439	.09561	-.12070	-.04046	-.00459

VARIMAX ROTATED FACTOR MATRIX cont'd

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
MVOL	.44915	.15786	-.04254	-.03950	-.02111	-.02516
BQTT	-.17261	-.00497	-.16783	-.14223	.46772	-.01566
SYEN	.09787	.08806	.63983	.01124	.014943	-.09511
LIST	.02206	-.22822	-.13948	-.33709	-.36300	.06866
AVOL	.45716	-.11629	.10588	-.05931	.00060	.08197
GUNK	-.15892	.36799	-.02578	-.04427	.08067	.37629

FACTOR MATRIX USING PRINCIPAL FACTOR WITH ITERATIONS

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
GQTT	-.33899	.14715	-.02736	.10500	-.04763	-.06446
WQTT	-.02523	.16932	.49211	.25099	-.11182	-.23554
WQTZ	.14415	.06208	.45313	-.16630	.27931	.23959
RSST	-.09153	.39067	-.23539	-.13085	-.01661	-.03224
WSST	.28739	.25088	-.02462	.09843	-.20601	-.27304
GSST	-.19290	.22369	-.08600	.01647	.45044	.32878
QARE	.02915	-.29302	-.29445	.24435	.06175	.06187
PGRT	.36966	.03856	.02665	-.25817	.24436	-.30280
RGRT	.35189	-.12478	-.23516	.13135	.03852	.09244
WGRT	.35707	-.09423	-.13648	-.27207	.22460	-.16040
RCHT	.06059	-.05919	.15088	-.30152	-.28898	.43032
WCHT	.32760	.16940	.15708	-.05836	-.15025	.37760
BCHT	.21589	.11751	-.13008	.54979	-.19123	.11101

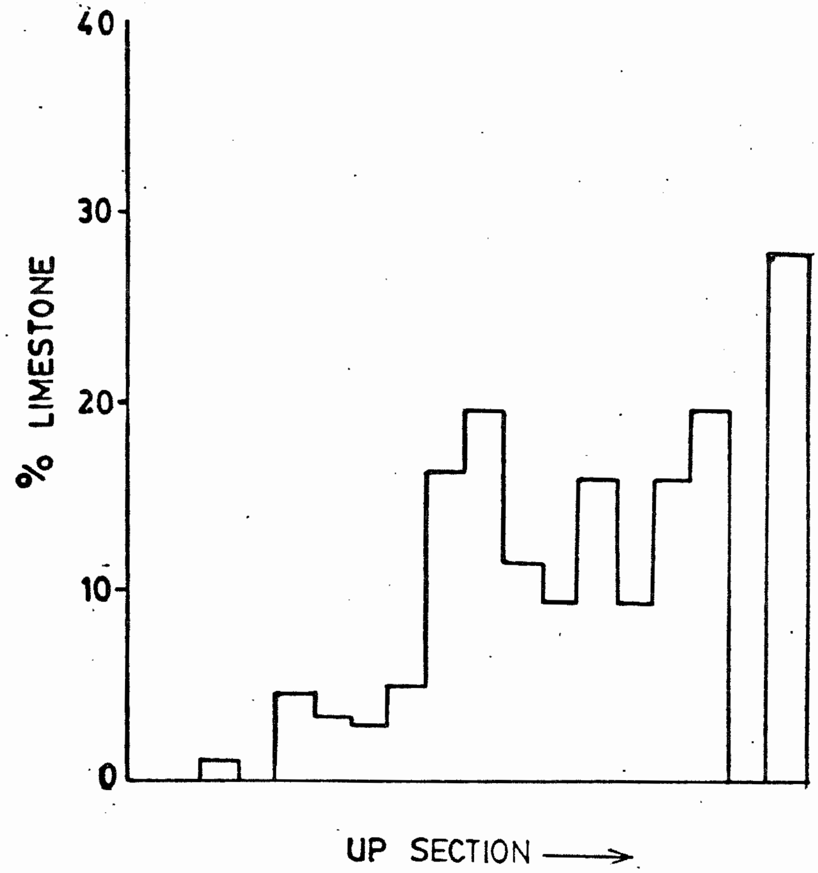
FACTOR MATRIX USING PRINCIPAL FACTOR WITH ITERATIONS cont'd

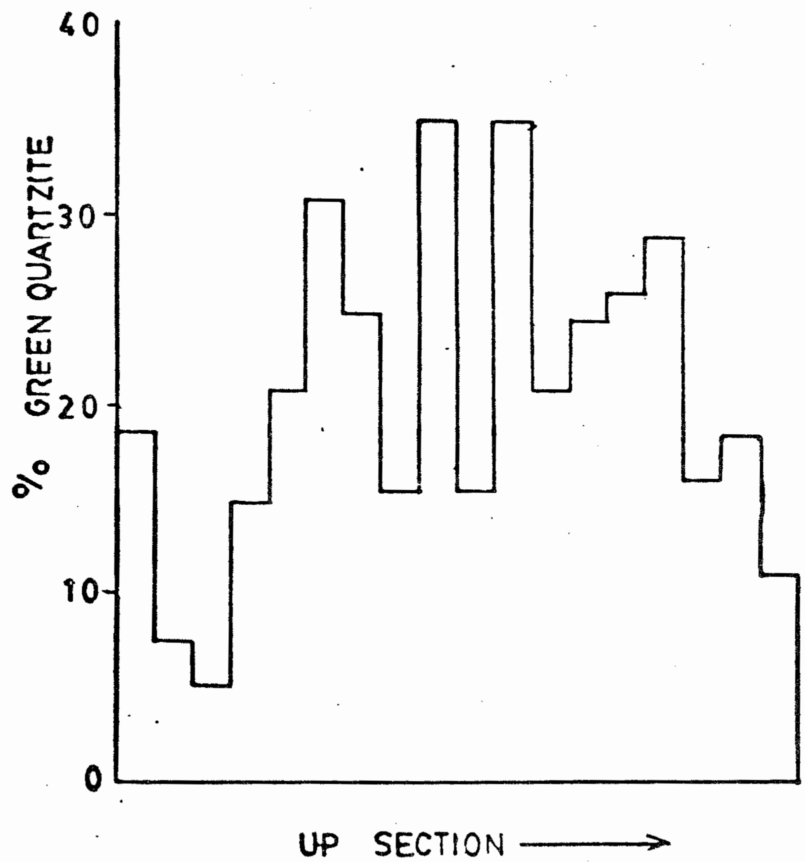
	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
MVOL	.06202	-.37271	-.09062	.21433	.03122	.18228
BQTT	-.24783	.29802	-.28036	-.08155	.11890	.21817
SYEN	-.01043	.09668	.34045	.41323	.04198	-.02280
LIST	-.24094	-.21365	.18730	-.13462	-.40460	-.03931
AVOL	-.04224	-.38360	.15679	.05984	.14263	.21570
GUNK	.25271	.30422	-.01623	.10941	-.20678	.31621

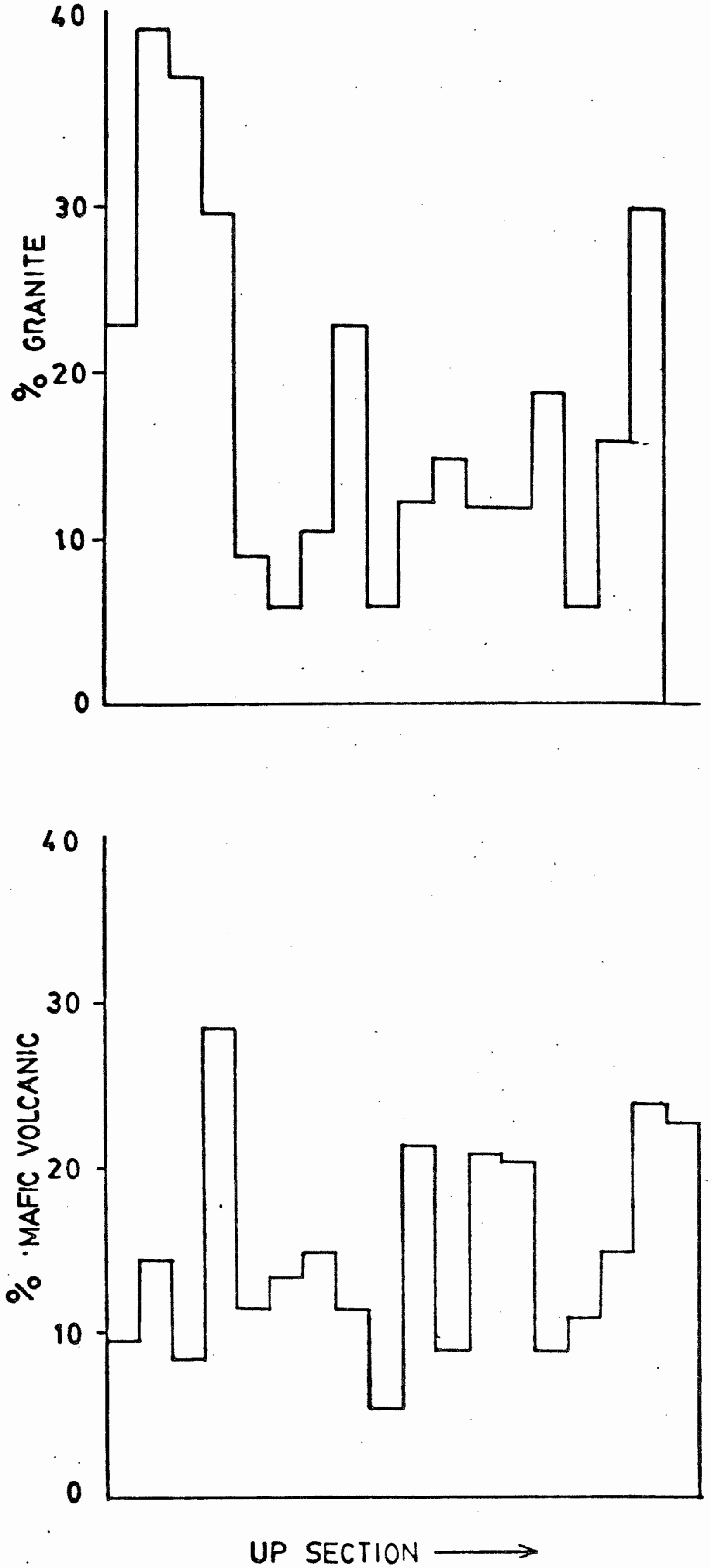
Stations	Green Quartzite	White Quartzite	White Quartzite	Red Sandstone	White Sandstone	Green Sandstone	Quartz Arenite	Pink Granite	Red Granite	White Granite	Red Chert	White Chert	Brown Chert	Mafic Volcanic	Brown Quartzite	Syenite	Limestone	Acid Volcanic	Unknown
3	33	2	2	39.5	1.5	0.5								4	17				0.5
5	5	7	11	17.5	3.5			13.5	8.5	15.5	0.5	1		8.5		0.5	1	6	1
6	7.5	5	3.5	17	7.5			14	11	16				14.5	0.5			3.5	
8	18.5	6.5	6	16.5	9			4.5	12.5	6		1	2	9.5	2.5	1.5		2.5	1.5
4-2	21	12	5.5	22	2			4.5	4	0.5			1	11.5	4.5	0.5	4.5	6	0.5
4-4	25	9	9.5			0.5		3.5	4	3				15	4	4	3	10.5	
4-7	31	13	4.5	17	2.5			2.5	1	15			0.5	13.5	1	4	3.5	4.5	
5-2	15	1.5	1.5	5.5			3	2.5	18.5	8.5			1	28.5	0.5	0.5		13.5	
5-3	15.5	5.5	9.5	15	1.5			8.5	8	6.5		0.5		11.5	1.5	1	5	10.5	
5-6	21	4.5	6	14				2	6	4	0.5	0.5		21	2	0.5	9.5	8.5	
5-9	24.5	5.5	2.5	9	0.5			1	6	5	1			20.5	0.5		16	8	
6-1a	18.5		1	13			3	8	8.5	13.5			0.5	24	0.5	1		8.5	
6-2a	11	7	5	8	1		3							23	1		28	13	
6-5	35	3.5	5.5	13				2.5	6	6.5				9	2.5		11.5	5	
6-9	26	3	10.5	8			1	4	4.5	10.5				9	3	0.5	9.5	10.5	
6-14	15.5	3.5	7.5	11	0.5			3	6	3.5				21.5	2	0.5	10.5	15	
7-1	16	4	3	11.5				4	5.5	6.5				15	4	0.5	19.5	10.5	
7-5	29	7	2.5	17.3	3		0.5	1.5	3.5	1.5				11	3.5		16	3.5	
7-12	35	5.5	1.5	15	0.5			1	4	1				5.5	2.5	0.5	16.5	11.5	

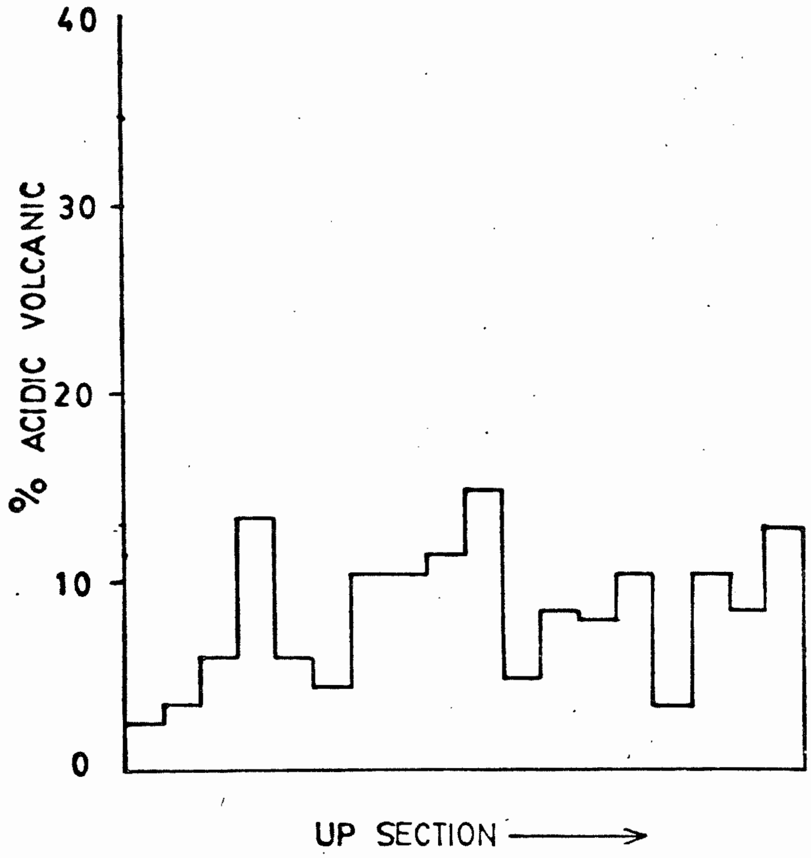
APPENDIX 2

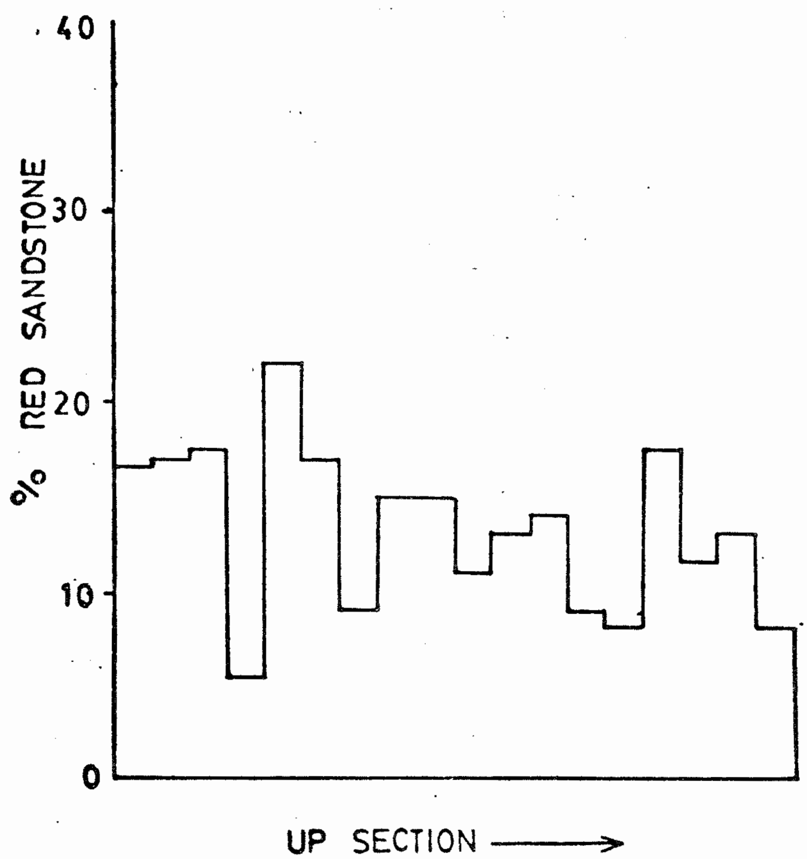
Histograms of Clast Percentage vs Distance Upsection


40
30
20
10
0
% LIMESTONE
UP SECTION


40
30
20
10
0
% GREEN QUARTZITE
UP SECTION


40
30
20
10
0
% GRANITE
40
30
20
10
0
% MAFIC VOLCANIC
UP SECTION


40
30
20
10
0
% ACIDIC VOLCANIC
UP SECTION


40
30
20
10
0
% RED SANDSTONE
UP SECTION

APPENDIX 3

Sample Descriptions

Rock Descriptions

Sample 4

Grain Constitutents	Percentage
Quartz	50%
Lithic Fragments	20-25%
Feldspars	23%
Magnetite	<1%
Sulfides	<<1%
Mica	<<1%

Matrix: consists of calcite and constitutes about 15% of whole rock volume

Texture: subrounded to subangular clasts, poorly sorted, stratification apparent

Rock Type: Feldspathic Lithic Arenite

Sample 6-2

Grain Constitutes	Percentage
Quartz	50%
Lithic Fragments	20-25%
Feldspar	25-30%
Magnetite	<1%

Matrix: consists of calcite and constitutes about 15% of whole rock volume

Texture: subrounded grains, very poorly sorted, subtle stratification

Rock Type: Arkosic Arenite

Sample 6

Grain Constituents	Percentage
Quartz	50%
Lithic Fragments	30%
Feldspar	20%

Matrix: consists of calcite and constitutes less than 10% of rock volume

Texture: subrounded grains, well sorted, graded stratification, cross stratification

Rock Type: Lithic Arenite

Clast Descriptions

Sample C-1

Constituent	Percentage
Quartz	7%
Feldspar (Potassium Feldspar + Palgioclase)	23%
Amphibole	23%
Matrix	47%

Remarks: Amphiboles are entirely chloritized, some plagioclase altered to epidote, matrix is probably quartz + feldspar

Rock Type: Rhyolite - Dacite

Sample C-2

Constituent	Percentage
Quartz	>90%
Feldspar	
Amphiboles	<10%

Remarks: Amphiboles are chloritized, very fine-grained texture

Rock Type: Rhyolite

Sample C-3

Constituent	Percentage
$CaCO_3$	65%
Clay	35%

Remarks: fine-grained, mottled texture, rarely show fossils

Rock Type: Marlstone

Sample C-4

Constituent	Percentage
$CaCO_3$	100%

Remarks: contains bivalves, gastropods, brachipods, crinoids

Rock Type: Fossilferous Limestone

Sample C-5

Constituent	Percentage
Quartz	20-30%
K-feldspar	50-55%
Mica	20-25%
Hornblende	

Remarks: no phenocrysts, minor lineation development, pinkish colour

Rock Type: Pink Granite

Sample C-6

Constituent	Percentage
Quartz	>30%
Feldspars	50%
Mica	20%
Hornblende	

Remarks: greater muscovite content than C-5, less pink feldspar than C-5 and more white feldspar, whitish colour

Rock Type: White Granite

Sample C-7

Constituent	Percentage
Quartz	30%
K-Feldspar	>55%
Mica + Hornblende	<10%

Remarks: extensive weathering, reddish colour

Rock Type: Red Granite

APPENDIX 4

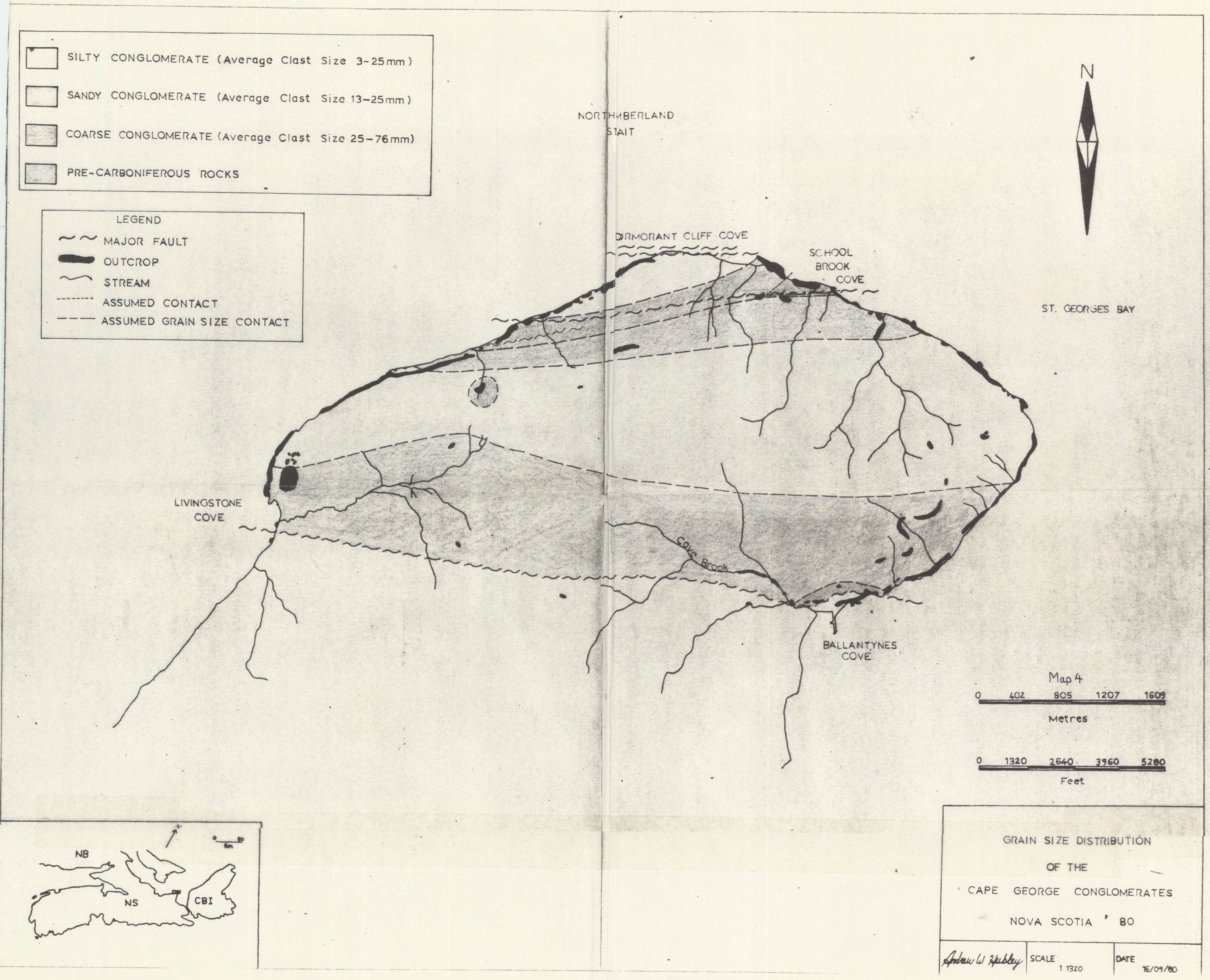
Paleocurrent Data

Station	Sedimentary Feature	Azimuth
4-2	scour	135°
	pebble imbrication	
4-3	scour	
	pebble imbrication	136°
4-5	pebble imbrication	162°
4-8	cross stratification	140°
5-7	cross stratification	130°
5-8	scour	163°
6-6	pebble imbrication	170°
	parallel current lineation	173° - 353°
	parallel current lineation	160° - 340°
	parallel current lineation	168° - 348°

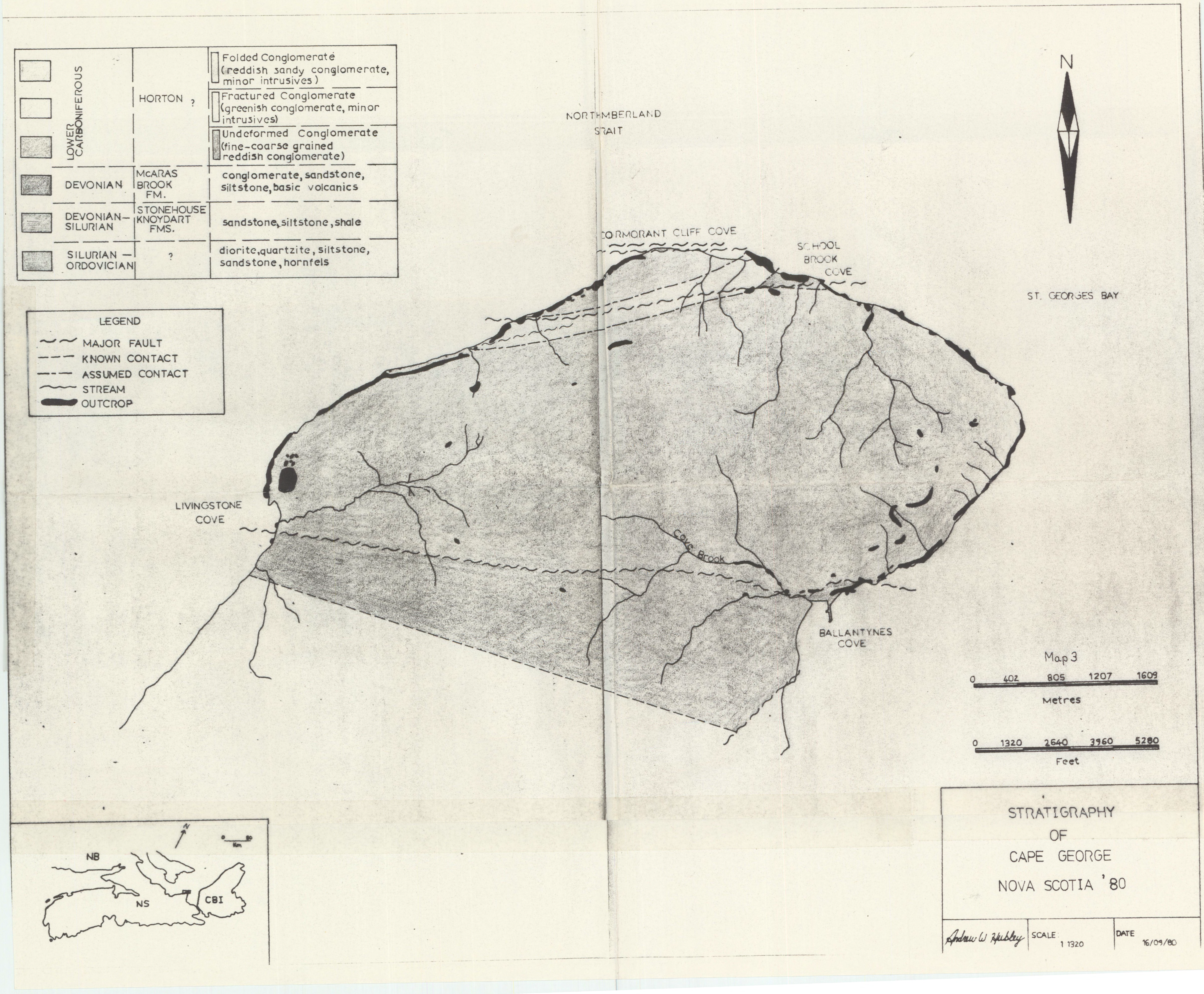
Stations 5-7 and 5-8 belong to location B (Figure 10). Stations 4-2, 4-3, 4-5, 4-8 and 6-6 belong to location A (Figure 10).

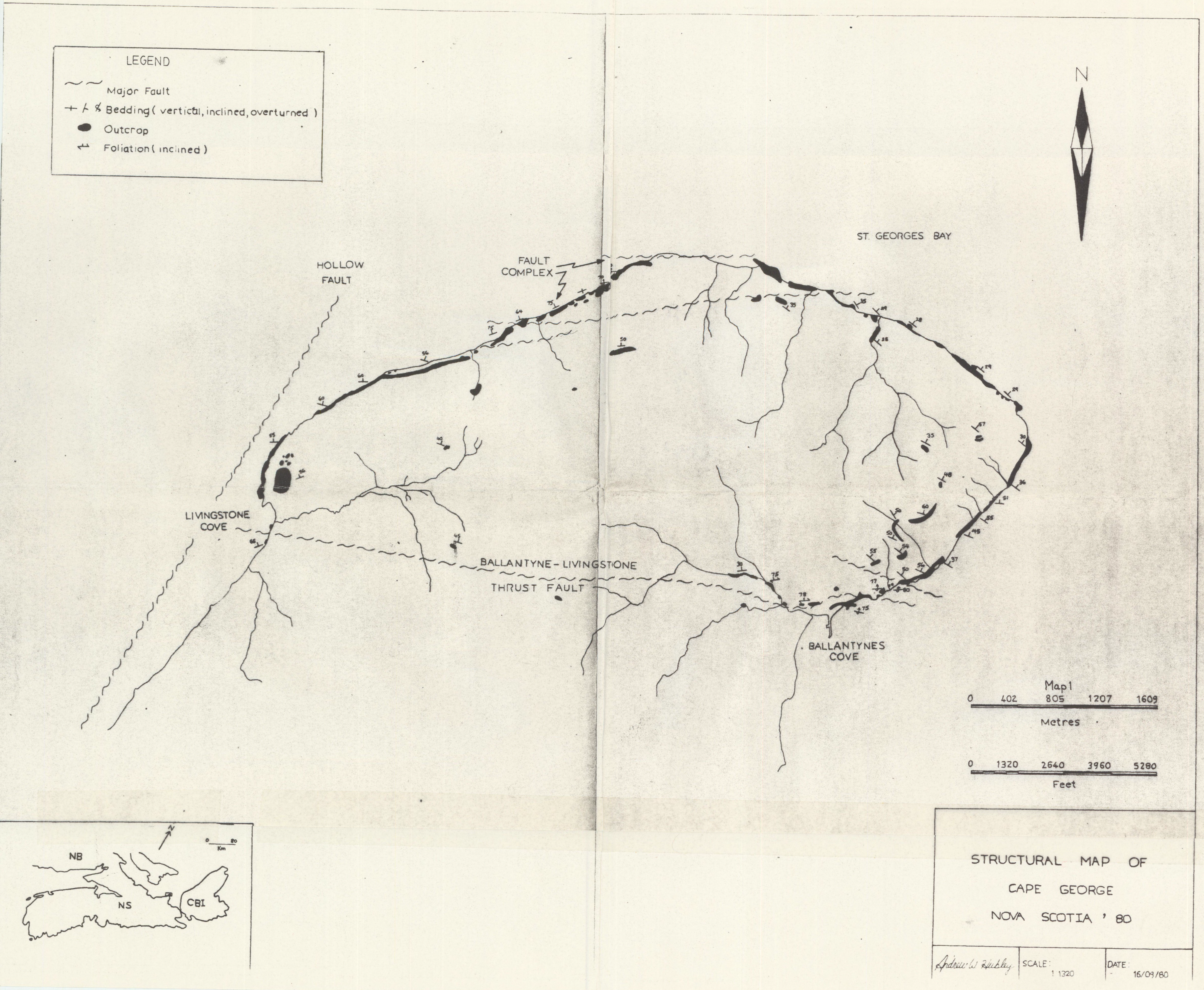
Time Spent

ITEM	HOURS
Field work	70
Laboratory work	30
Research and writing	200
Drafting	150
TOTAL	450


SILTY CONGLOMERATE (Average Clast Size 3-25mm)
SANDY CONGLOMERATE (Average Clast Size 13-25mm)
COARSE CONGLOMERATE (Average Clast Size 25-76mm)
PRE-CARBONIFEROUS ROCKS
LEGEND
MAJOR FAULT
OUTCROP
STREAM
ASSUMED CONTACT
ASSUMED GRAIN SIZE CONTACT
NORTHUMBERLAND
STAIT
N
CORMORANT CLIFF COVE
SCHOOL
BROOK
COVE
ST. GEORGES BAY
LIVINGSTONE
COVE
Cove Brook
BALLANTYNES
COVE
Map 4
0 402 805 1207 1609
Metres
0 1320 2640 3960 5280
Feet
NB
NS
CBI
GRAIN SIZE DISTRIBUTION
OF THE
CAPE GEORGE CONGLOMERATES
NOVA SCOTIA '80
Andrew W Hubley
SCALE
1 1320
DATE
16/09/80

BALLANTYNE – LIVINGSTONE
THRUST
ST. GEORGE BAY
METERS
LEGEND
THRUST FAULT
FAULT
SHORELINE
BACK OF
SHORELINE
BEDDING
inclined
overturned
MYLONITE
MISSISSIPIAN
HORTON
GROUP
DEVONIAN
McARAS BROOK
FORMATION
inclined strata
Conglomerate
Sandstone
overturned strata
Conglomerate
Sandstone
Basalt
Conglomerate
Sandstone
SCALE 1 : 50,000
0
3
KM
N
CAPE
GEORGE
THESIS MAP 2
GEOLOGY OF
BALLANTYNES COVE
NOVA SCOTIA '80
Andrew W. Hubley
DATE:
05/09/80


LOWER CARBONIFEROUS
HORTON ?
Folded Conglomerate (reddish sandy conglomerate, minor intrusives)
Fractured Conglomerate (greenish conglomerate, minor intrusives)
Undeformed Conglomerate (fine-coarse grained reddish conglomerate)
DEVONIAN
McARAS BROOK FM.
conglomerate, sandstone, siltstone, basic volcanics
DEVONIAN-SILURIAN
STONEHOUSE KNOYDART FMS.
sandstone, siltstone, shale
SILURIAN — ORDOVICIAN
?
diorite, quartzite, siltstone, sandstone, hornfels
LEGEND
MAJOR FAULT
KNOWN CONTACT
ASSUMED CONTACT
STREAM
OUTCROP
NORTHMBERLAND SRAIT
N
CORMORANT CLIFF COVE
SCHOOL BROOK COVE
ST. GEORGES BAY
LIVINGSTONE COVE
Cove Brook
BALLANTYNES COVE
Map 3
0 402 805 1207 1609
Metres
0 1320 2640 3960 5280
Feet
NB
NS
CBI
N
Km
STRATIGRAPHY OF CAPE GEORGE NOVA SCOTIA '80
Andrew W Hubley
SCALE 1:1320
DATE 16/09/80


LEGEND
Major Fault
Bedding (vertical, inclined, overturned)
Outcrop
Foliation (inclined)
N
ST. GEORGES BAY
HOLLOW FAULT
FAULT COMPLEX
LIVINGSTONE COVE
BALLANTYNE - LIVINGSTONE
THRUST FAULT
BALLANTYNES COVE
Map 1
0 402 805 1207 1609
Metres
0 1320 2640 3960 5280
Feet
N
0 80
Km
NB
NS
CBI
STRUCTURAL MAP OF
CAPE GEORGE
NOVA SCOTIA ' 80
SCALE: 1:1320
DATE: 16/09/80