Structural Analysis of the George River Group at North Mountain, Cape Breton, Nova Scotia.

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Honours Thesis

(Submitted in partial fulfillment of the requirements for the degree of Bachelor of Science with Honours).

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ABSTRACT

Several different explanations of the structure of the George River rocks at North Mountain have been suggested in the past, none of which has proved to be very satisfactory.

Milligan has proposed that the structure is that of diverging, fan-like folds plunging westerly at about 40 degrees. This hypothesis was tested by plotting the detailed information on fold axis plunges, gathered by Keating, on stereonets and comparing the predicted and observed plunges. The results proved to be quite different from what was expected.

Further analysis of the distribution of rock types, combined with the stereogram results, suggested that more than one period of folding had occurred and that the structure is that of a primary set of folds plunging very steeply to the southeast on which a secondary set of folds, plunging to the west-southwest at about 30 to 40 degrees, have been superimposed.

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CHAPTER I

INTRODUCTION

Over the last century, mapping of the remnants of the George River Group in Cape Breton, Nova Scotia, has concentrated on the description of the rocks and their general distribution. It is now known that the structure is complex. Several investigators have considered North Mountain as a small area which might be expected to reveal the major characteristics of the structural history of the whole group, and several interpretations have been proposed. In recent years, very detailed studies and mapping have been conducted in the area and it is hoped that this information will lead to a satisfactory explanation of the structure.

LOCATION

North Mountain, located about 10 miles northeast of the Strait of Canso (Figure 1, page 2), is the second largest of four highlands in western Cape Breton. The mountain is bounded to the southeast by West Bay, an arm of the Bras d'Or Lake, and to the northwest by a partly-drowned river valley known as the Denys Basin. The mountain trends northeast and is about 15 miles long by 3 1/2 to 4 miles wide.

The George River Group occurs as a narrow strip along the north shore of West Bay, whence it continues across the mountain to River Denys. There it disappears under Mississippian rocks. The group is intruded by granite and granodiorite which outcrop on the top of the mountain. The southern shore of the mountain marks where Mississippian rocks, beneath the lake, were faulted against those of the George River Group.

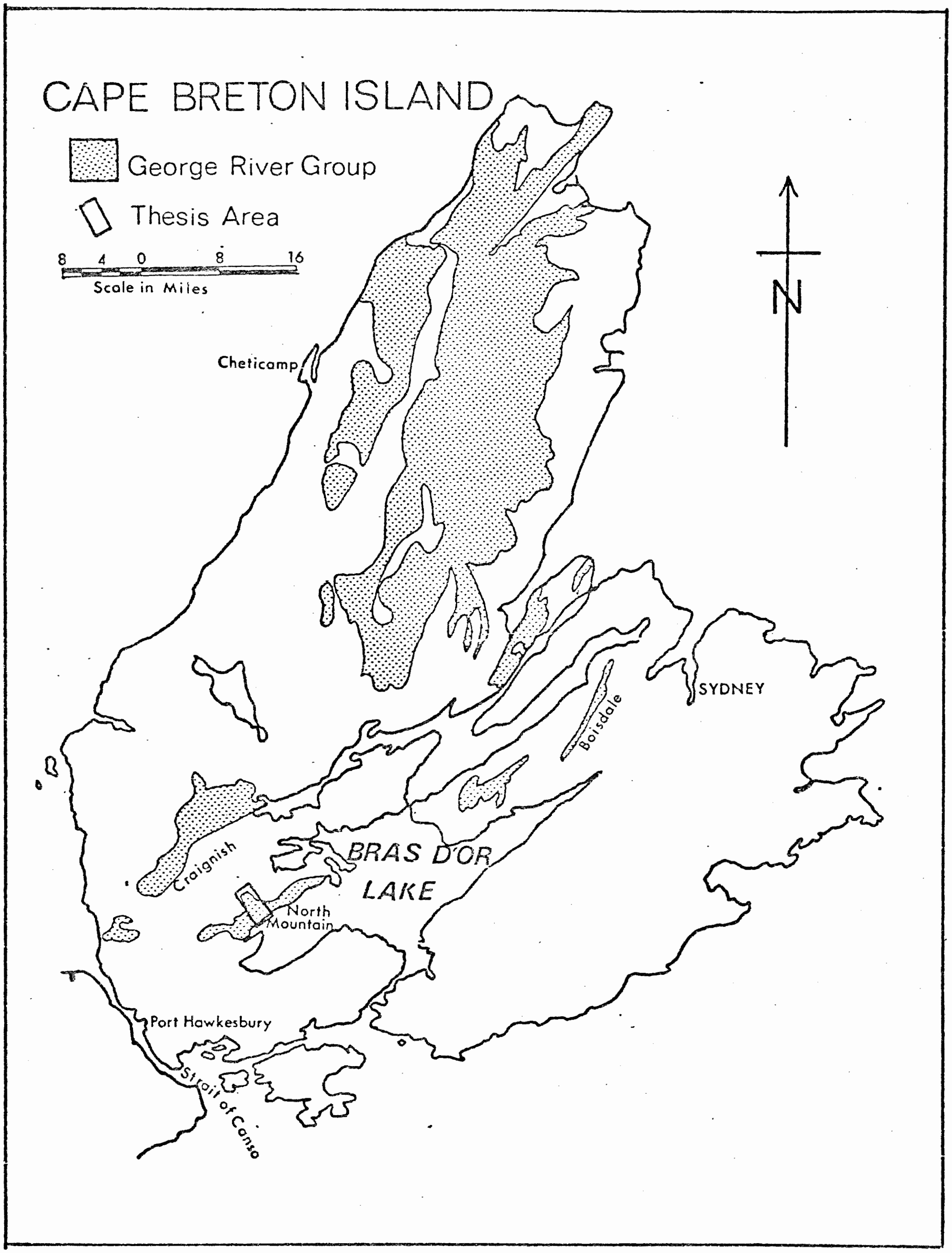

Figure 1: Location map.

Rock outcrop in the area is good in the vicinity of streams but elsewhere exposures are poor and rather scattered.

PREVIOUS WORK

During the years 1876 to 1884, Hugh Fletcher, of the Geological Survey of Canada, worked on a geological survey of the whole of Cape Breton Island. Only the Report of Progress for 1879-80 (Fletcher) contains information about the geology of North Mountain. Fletcher divided the rocks into two groups, Carboniferous and Precambrian. The latter was divided into the George River Limestone, and into syenitic, gneissoid and feldspathic rocks. He believed the George River Limestone to be unconformable on the igneous rocks of the area.

In 1927, T.P. Guernsey published a map (Guernsey, 1927a) of the North Mountain - River Denys area to accompany Part C of the G.S.C. Summary Report for 1927 (Guernsey, 1927b). His main concern was the defining and describing of the principal formations present and their structural relations.

In 1962, the area was mapped by G.C. Milligan and R.C. Parsons, the results of which were published in Nova Scotia Department of Mines Memoir 7 (Milligan, 1970).

Starting in 1963, and assisted for five weeks of that year by Professor W.A. Sims, Dr. B.J. Keating spent two complete field seasons in the area; many shorter periods followed, prior to his death in 1973.

All of Keating's data were made available to Milligan and are the basis for this study. The map in the back pocket was compiled in 1975 from Keating's notes and field maps.

ACKNOWLEDGEMENT

I wish to thank Mrs. B.J. Keating for making available for this study the notes and field maps of her husband, the late Dr. B.J. Keating of St. Francis Xavier University.

CHAPTER II

ROCK TYPES

CRAIGNISH HILLS

In the Craignish Hills, which may be considered a typical section, the George River Group contains roughly equal amounts of dark quartzites, feldspathic quartzites, slates, limestones, and light-coloured quartzites, each about 3,000 feet thick. Amphibolites, possibly of volcanic origin and up to 1,500 feet thick, are found between the slates and limestone there, but elsewhere are a minor part of the group. Because good primary depositional features are absent, it is not clear whether the white quartzites are the bottom or the top of the succession. It is customary to consider them as the youngest part of the group.

NORTH MOUNTAIN

The George River Group at North Mountain consists of three rock types: slates, limestones and quartzites.

SLATES

Slates at North Mountain are black or grey, conformable with, and in many places interbedded with, a limestone and dolostone unit. A black graphitic slate occurs on the eastern tributary of Campbell Brook. The slates are well cleaved and crenulations are abundant. In some areas argillaceous and arenaceous layers lie parallel to the cleavage. Guernsey (1927b) reports that slates exposed in the area of the upper forks of Campbell Brook dip steeply to the south and are much contorted further north. There the beds are cut by veinlets of carbonate and quartz.

In the area between the two eastern tributaries of Dallas Brook, some rocks have been described as sericite schist, but such are not reported anywhere else in the area.

The limestones and slates are the most abundant rock types of the George River Group at North Mountain. The contact between the two rock types is gradational through a narrow zone of interbedded limestones and slates. On the map (in pocket) this zone is included with the slate unit for easier structural analysis.

LIMESTONES (MARBLES)

Limestones display a wide variety of colours and textures, a variation of the content of acid-insoluble material, as well as a range of dolomite content. The most common varieties of limestone are coloured bluish-white or grey and blue-grey to bluish-black. This variation in colour is dependant on the amount of silicate contained in the limestone. They are crystalline and generally of coarse texture except, where metamorphism is minimal, the texture can be fine and banding is prominent.

Under the classification of limestone on the map (in pocket), limestone and dolostone have been grouped as one unit. Dolostone is found as local thickenings but is commonly interbedded with the limestone at the top (according to Craignish stratigraphy) of the limestone unit. It is, therefore, in some places difficult to designate an outcrop as dolostone or limestone on the basis of content of one or the other.

Just northwest of the MacMillan farm (see map in pocket), the limestones form resistant ridges and have distinctive colours: brown, red-grey, grey-blue, buff and blue-white. On two traverses across these ridges, the general sequence of colours of limestones is similar (Appendix I, page 25) but correlations between the two traverses is made difficult by complex folding and the possibility of minor faulting in the area.

Metamorphism has destroyed many of the depositional features of the limestone.

A rather unusual limestone at the head of Dallas Brook and in the area to the northwest between Dallas Lake and the upper branches of Campbell Brook was described by Chatterjee (Milligan 1970, page 26) as containing oolites and some very doubtful algal forms. Also, boulders from the top of the southeastern wall of Marble Mountain quarry have silicate particles which have an alignment that strongly resembles the convolutions produced by algal stromatolites.

QUARTZITES

At North Mountain there are three varieties of quartzites present: a buff to brown type, a blue-white type and a dark greyish type. The quartzites are relatively minor components of the stratigraphic sequence at North Mountain.

The blue-white quartzites occur at the River Denys end of Campbell Brook near the Mississippian unconformity. They are found interbedded with limestones, dolostones and slates in the zone between the slate and limestone units (described page 6) and are also included in the slate unit on the map in the back pocket.

The buff quartzite outcrops as a highly brecciated unit adjacent to the limestones in the area near the Mississippian unconformity (see map in pocket). This relationship is similar to the relationship between the limestones and upper quartzites of the Craignish Hills.

The greyish "quartzites" occur in the area of Dallas Lake and in the valleys of Dallas and Campbell Brooks. They are dark, fine grained, impure grits and greywackes, which appear to pass into slates and schists, as do also the lower quartzites of the Craignish Hills. Banding is noticeable in some localities and bedding is evident in less disturbed rocks. In thin section, quartz is the dominant constituent, as single or composite grains, with minor feldspar. The macroscopic shearing and banding is not evident in thin section.

AMPHIBOLITE

An unusual, nondescript, fine-grained, black, mafic, schistose rock, resembling a greenstone, was found along the shore road of West Bay where the road crosses Dallas and MacInnis Brooks. It has numerous lenticular openings, which resemble gas vesicles, and a faint suggestion of pillowed structure. The outcrop at Dallas Brook has thin bands resembling flow layering.

INTRUSIVE ROCKS

Most of the top of North Mountain is underlain by granodiorite, which intrudes the George River Group and has an irregular contact. The granodiorite is unfoliated, in many places is porphyritic and weathers to a spotted light grey. The mineral proportions are; grey feldspar, 70-75 percent; quartz, 10-15 percent; hornblende, altered to biotite, 10-15 percent.

Associated with fractures and dykes in the granodiorite is a red granite which is a later intrusion. Red feldspar in the granodiorite at these sites is presumably related to the intrusion of the red granite.

Outcrops of "greenstone" are also found southwest of the buildings on the abandoned MacMillan farm. These rocks are medium to fine grained with 60 percent grey feldspar and 40 percent black hornblende, which is partially altered to biotite. The outcrops form long narrow mounds. These are interpreted as diabase dykes which intrude the George River Group and are therefore younger. In some cases, dykes are found along fault lines, suggesting an association with a period of faulting.

CHAPTER III

STRUCTURE

STRUCTURE SUGGESTED BY MILLIGAN

Milligan (1970) interpreted the structure of the George River Group at North Mountain as nearly isoclinal folds which plunge 25 to 40 degrees towards the southwest and merge westwardly into a monoclinal block that is the limb of a very large fold, which dissappears beneath the Mississippian unconformity in the lower part of Campbell Brook. In order to achieve this, however, the stratigraphic sequence must be inverted in relation to that deduced in the Craignish Hills.

Keating found much greater complexity than Milligan had originally supposed. Milligan now proposes that the folds diverge from an area east of Dallas and Campbell brooks. This interpretation is based on the 2 inches to the mile map and the description in paragraph 4 of page 76 of his publication (Milligan, 1970).

The purpose of this thesis is to test Milligan's new hypothesis using Keating's data and, if proven wrong, to propose a new hypothesis as a possible explanation of the structure.

MILLIGAN'S HYPOTHESIS

Milligan's map is included here (Figure 2, page 11) and the trace of his unit 4 can be used to illustrate the structure he proposes. Starting at the lakeshore of West Bay near MacInnis' Brook and traversing the mountain along the strip of George River rocks, the folding can be described thus: a large anticline plunges at about 30 degrees towards the southwest under Dallas Lake; the adjacent syncline (minor) to the north, also plunges southwesterly; the next minor anticline to the north plunges towards the west-southwest; its adjacent syncline (erroneously shown as an anticline) plunges west-southwest; the next large anticline plunges towards the west, approximately parallel to the Lime Hill road. Just north of the Lime Hill road there is a large fault beyond which the attitude of the folds is confused by numerous minor faults. The general trend of the plunge of the folds is, however, still towards the west-northwest.

If we observe the trace of unit 4 across this structure, we see that although the degree of openness of the folds does not appear to change, the apparent thickness of the unit along the anticlinal axis appears to increase, suggesting a reduction in the plunge of the axis.

The structure deduced by Milligan and described above, is illustrated by Figure 3 (page 13).

TEST OF MILLIGAN'S HYPOTHESIS

In order to test Milligan's current hypothesis, described above, the area was divided into five overlapping areas, each about 3/4 of a mile in diameter (see Figure 4, page 14). The plunge of folds recorded by Keating and Sims in each area was plotted on stereograms to assess the plunge of the major structure in each area. The points on the stereograms (Appendix II, pages 28-32) represent the angle of plunge of the fold axis. For simplicity and as Milligan's hypothesis involves only one period of folding, we assume that the features plotted are all of a similar age.

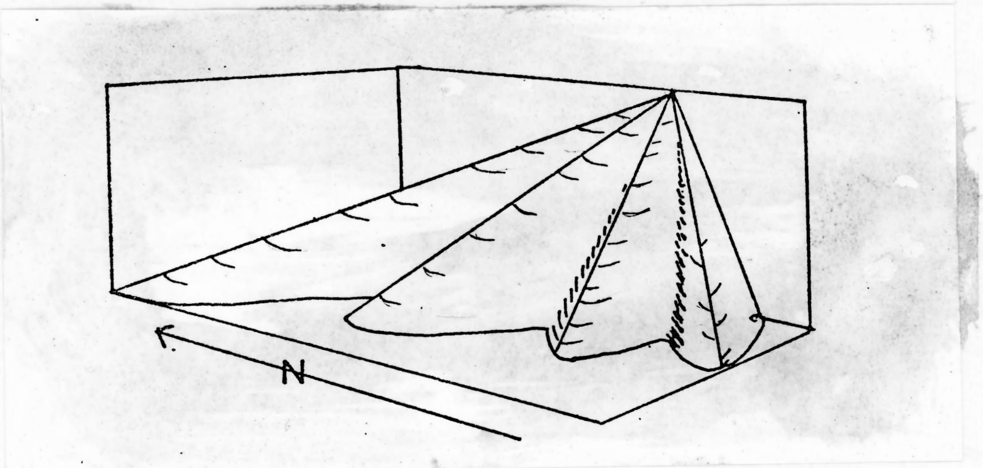

Figure 3: Folding proposed by Milligan for North Mountain as deduced from Nova Scotia Department of Mines, Memoir 7 (Milligan, 1970, page 76).

If Milligan's hypothesis is correct, we would expect to find a trend of southwesterly plunging folds in the Dallas Brook area, area 5, swinging around to shallow westerly or northwesterly plunging folds to the northeast of Campbell Brook in area 1.

This is not the case, however. In area 5 the structure behaves as predicted. The stereogram for area 4 has points clustered in the southern section, suggesting a general plunge towards the south at a steep angle, roughly 90 degrees to what we would expect. Stereonet plots in area 3 also show a rotation of the direction of plunge of the folds towards the south and east. Area 2 stereonet plots show folds plunging to the east and northeast as well as some at near vertical plunge. In area 1, plots show plunges towards the northeast with some near vertical plunges and some plunging towards the southeast, generally at 90 degrees to the direction of plunge expected.

CONCLUSION

The trend of the fold axes as described above is, with the exception of area 5, opposite to the trend of folding required by Milligan's hypothesis (page 10). We must conclude, therefore,

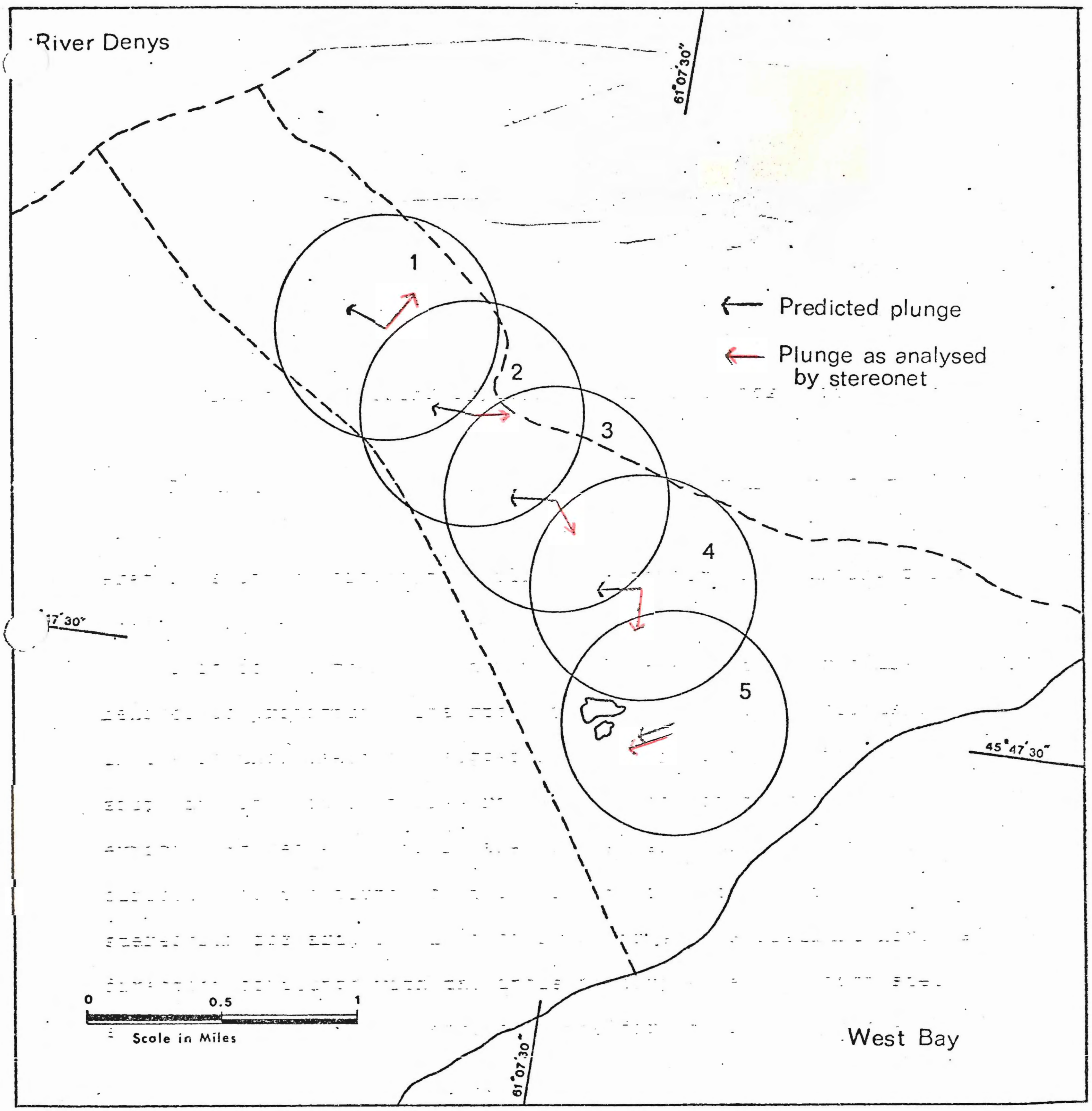

Figure 4: Areas of stereonet analysis and the predicted and observed plunge directions of George River Group rocks at North Mountain.

that the structure is not as proposed by Milligan, and an attempt to construct a new hypothesis using the stereogram results described on page 13 must be made.

PRESENT INTERPRETATION

EVIDENCE

The plunge of the structure in the northern section, as analysed by stereograms (Appendix II, pages 28-32), is towards the northeast and east. Such being the case, we have now changed Milligan's anticlines to synclines and vice versa. This will also have the effect of inverting the stratigraphic order of slates over limestones, as in Milligan's hypothesis (page 10), to limestones over slates as in the type section, the Craignish Hills (described page 5).

If we look at the map in the back pocket, the outcrop pattern is that of an anticline in the southeast and a syncline in the northwest, the limbs of which have minor drag folds. This anticline - syncline pair may be part of a larger fold system, in which case the linear features recorded by Keating have been measured on the smaller minor folds.

If the interbedded slates, limestones, dolostones, and quartzites (page 6) are the equivalent of the transition zone between slates and limestones, as found in the Craignish Hills, then their presence on the northeast, north and west sides of the limestones near the Mississippian unconformity at Campbell Brook suggests that the limestones occupy the trough of a syncline.

The interbedded slates, limestones, dolostones and quartzites also appear southeast of the MacMillan farm at the limestone - slate contact, suggesting that this area is on the limb of an anticlinal fold, the axis of which may be located south of Dallas Lake.

An attempt at correlating the distinctly coloured limestone bands found northwest of the MacMillan farm suggests that there is isoclinal folding in that area (see Appendix I, pages 25 and 26).

The stereogram suggests that the folds in area 5 plunge towards the west. Stereograms for areas 3 and 4 have several points which have a southerly plunge. The pattern of the limestone beds near MacMillan's farm (Appendix I, page 26) are "wavy" suggesting that something has disturbed the original folding.

DISCUSSION

When the plunges of folds were plotted on the stereonets, we assumed that only one period of folding was being represented. As the George River Group is Precambrian and lies within a belt which has been tectonically very active, it is probable that the original (primary) folds have a second generation of folds superimposed upon them. These folds trend northeast - southwest and plunge southwesterly. The intensity of folding is greatest along the lakeshore and decreases in intensity towards the northwest.

Ramsay's (1962) block diagram (below), shows the outcrop

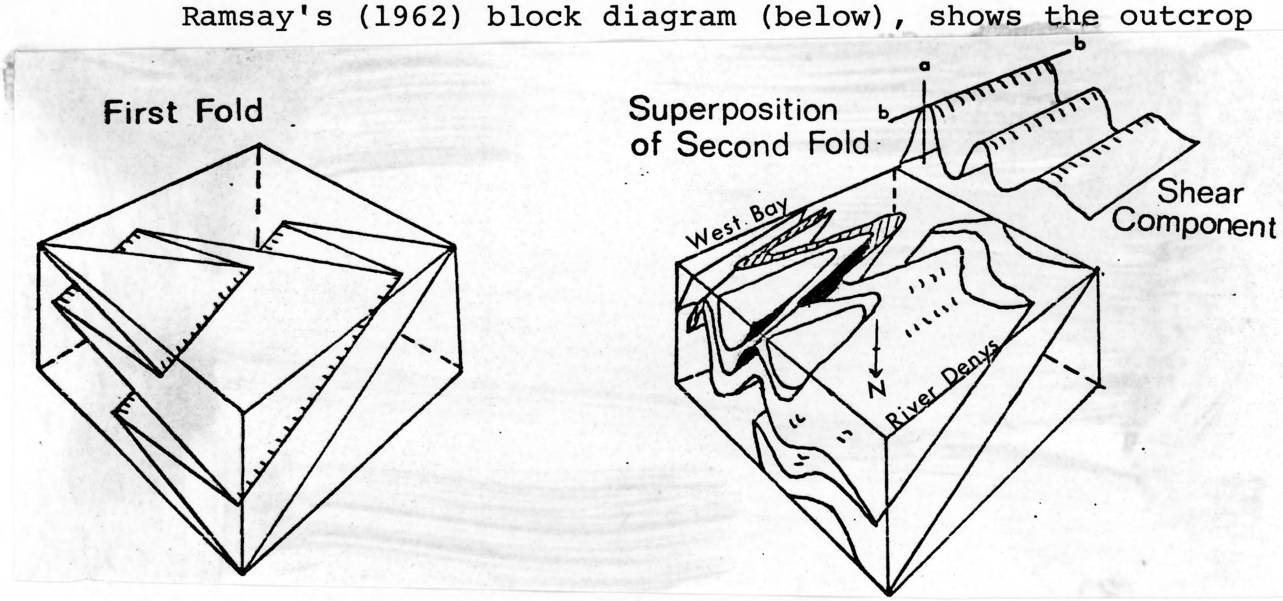

Figure 5: Ramsay's block diagram showing outcrop patterns that result from superimposed folds.

patterns which result from superimposition of two types of folds. This outcrop pattern is very similar to the pattern of outcrop at North Mountain, assuming the right, front part of the block diagram to be the River Denys area and the left, back part to be the shoreline of West Bay.

Secondary folding would also create a "bumpy" surface on any group of beds (Figure 6, below), which would account for radical changes in plunge directions within 1000 feet of each other as displayed near Dallas Brook (see map in pocket). Erosion of these "bumps" would result in isolated areas or patches of outcrop of an older rock unit, as displayed in the area of Dallas Brook.

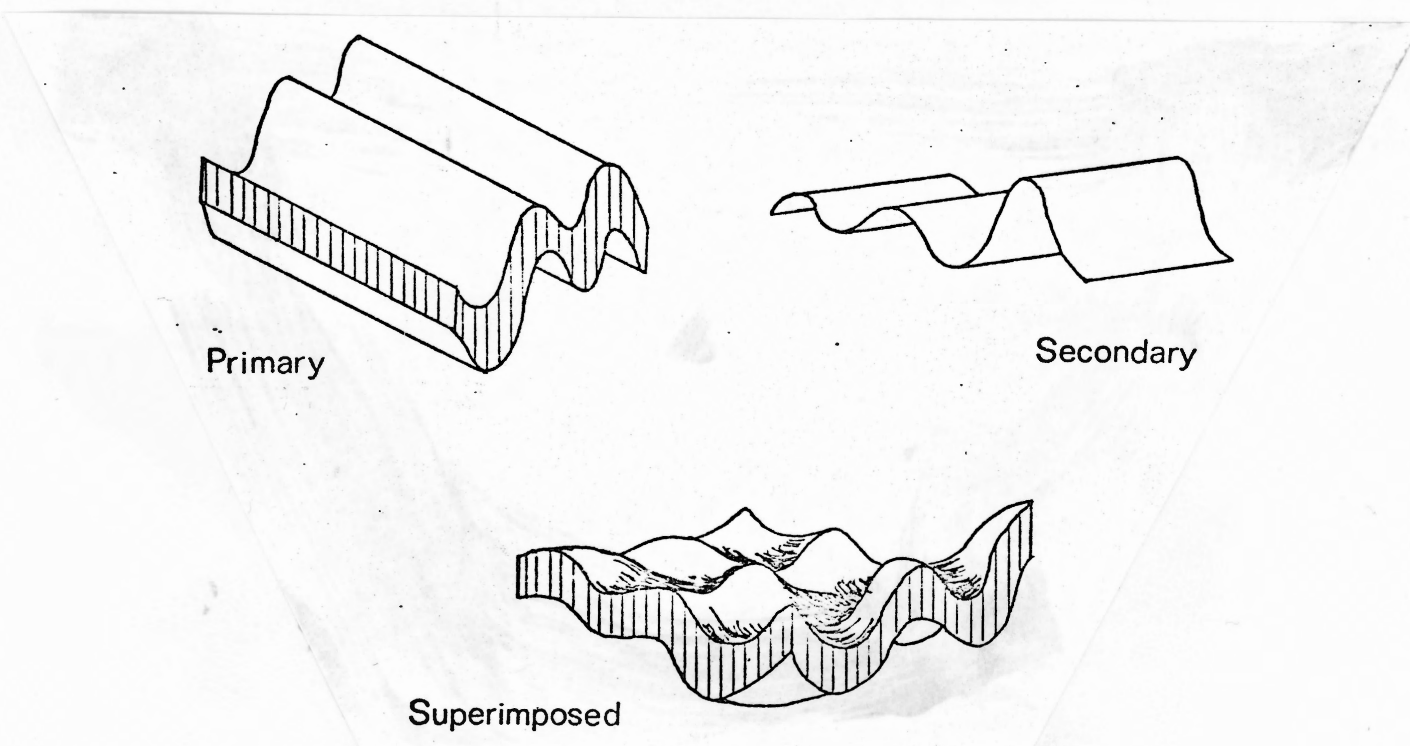

Figure 6: "Bumpy" surface generated on bedding by secondary folding.

CONCLUSION

From the analysis, we can outline the history of the structure of the George River Group at North Mountain. A diagram (Figure 7, below) by Turner and Weiss (1963) illustrates this history.

The group was initially very tightly folded into large folds, axes plunging southeast and with the traces of the axial planes trending northwest, on which there were smaller "drag" folds.

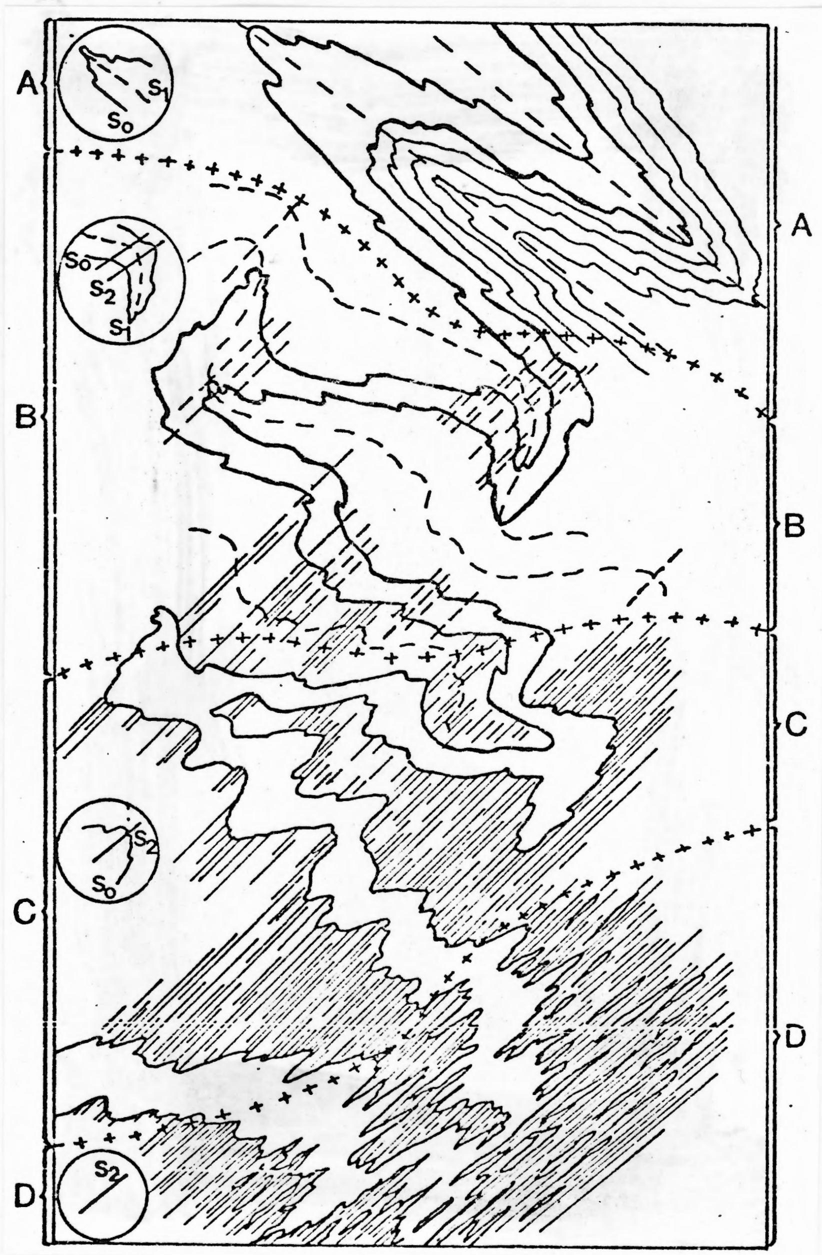

Figure 7: Turner and Weiss diagram of superimposed folding.

The anticline and syncline of one of these large folds is exposed at North Mountain, the common limb being about 2 to 2 1/2 miles long. The folds would then plunge towards the southeast and appear similar in outcrop pattern to part A of Figure 7 (page 18).

A second generation of folds, trending northeast, roughly parallel to the shore of West Bay and with intensity decreasing to the northwest was superimposed upon the primary folds. These secondary folds plunge to the southwest at about 30 to 40 degrees, perhaps due to upwarping of the eastern portion during the intrusion of the granodiorite.

Parts B, C and D of Figure 7 (page 18) show differing degrees of severity of secondary folding. The outcrop patterns at Campbell Brook are similar to those of part B and the patterns at Dallas Brook are similar to those of part C. The outcrop of the folds in part C also "wanders" as do the folds along the lakeshore and at Dallas Brook.

After these two periods of folding, the George River Group at North Mountain would appear as Figure 8 (page 20) which is a combination of Turner and Weiss' parts B and C (Figure 7, page 18). The second generation of folds plunge to the southwest, while axes of the earlier folds plunge to the northeast, east, or south depending upon their position within the secondary folds.

This structure was intruded by granite and granodiorite, then faulted, perhaps in more than one episode of each, subsided and was buried under Mississippian rocks then faulted and eroded during a post-Mississippian period to reveal the Precambrian - Carboniferous unconformity exposed at the north end of Campbell Brook. The end result is shown on the map in the back pocket.

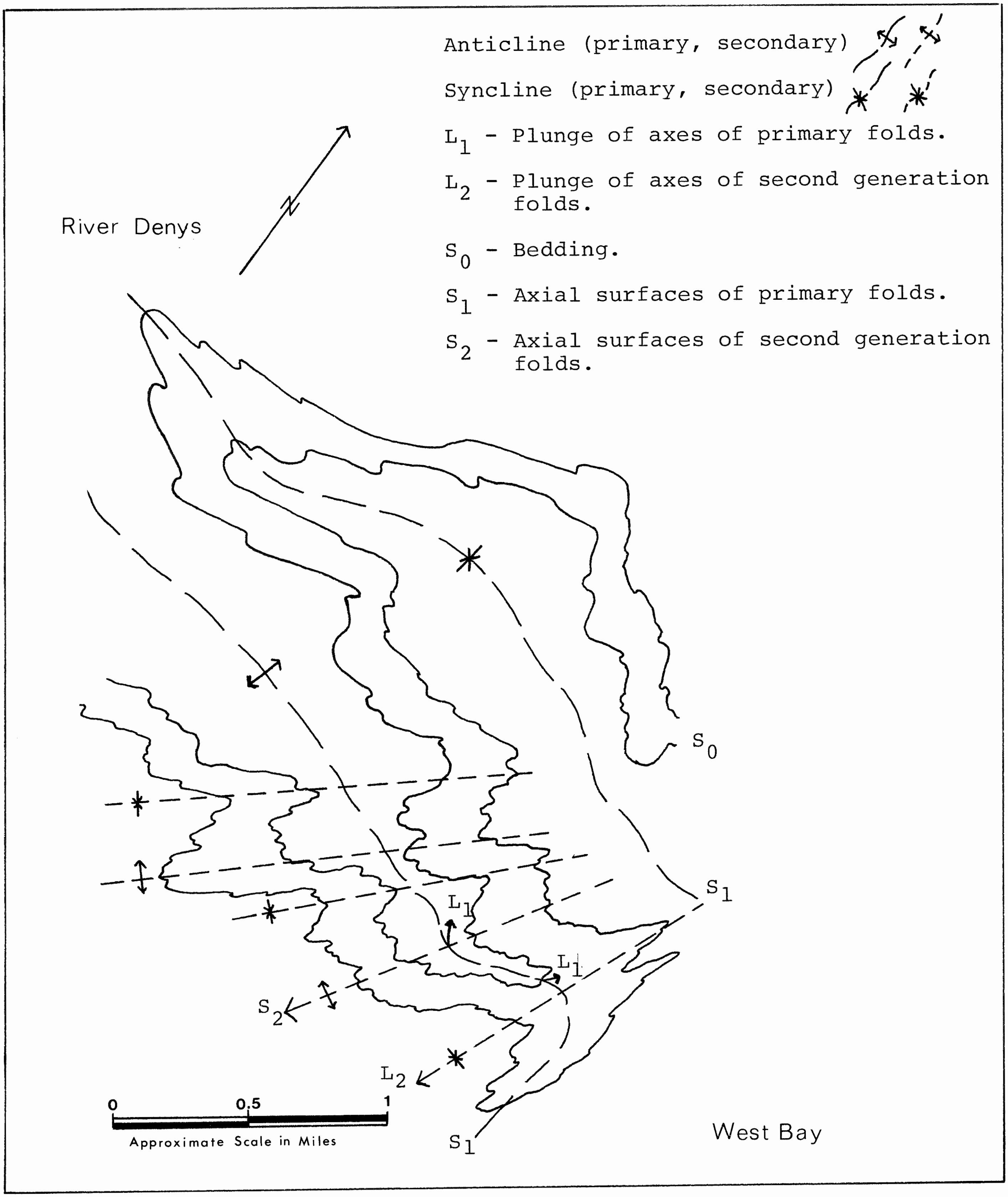

Figure 8: George River Group rocks of North Mountain prior to faulting and intrusion (diagrammatic).

CHAPTER IV

SUMMARY

The structure of the George River Group at North Mountain as proposed by Milligan, that of diverging folds, was tested using information gathered by Keating and Sims. This information did not support Milligan's proposal, but did suggest a different structure which is compatible with the assumed stratigraphy of the George River Group as determined in its type locality, the Craignish Hills.

The proposed structure of the George River Group at North Mountain based on Keating's data, is as follows: a large fold, of which both an anticline and syncline are present, plunging very steeply towards the southeast with smaller "drag" folds along its limbs; secondary folding, at approximately 90 degrees to the primary folds and of decreasing intensity across the mountain, superimposed on the primary folds and plunging about 30 to 40 degrees towards the southwest. The whole unit was intruded by Devonian granites and granodiorites and was faulted, buried, eroded, and then further faulted subsequent to the Mississippian time.

Work on the George River Group in this area is difficult as there are few marker horizons and most of the primary bedding features have been destroyed by metamorphisim. Also, most of the outcrops are along the stream beds with little lateral exposure for control and a high probability of faults in the area between the streams. It is suggested that any further work in the area be aimed at "walking out" and detailed mapping of the locations of the interbedded slate - limestone - quartzite unit (described on page 6). This unit might be usable as a marker horizon as it outcrops throughout the area and is always found between the limestone and slate units.

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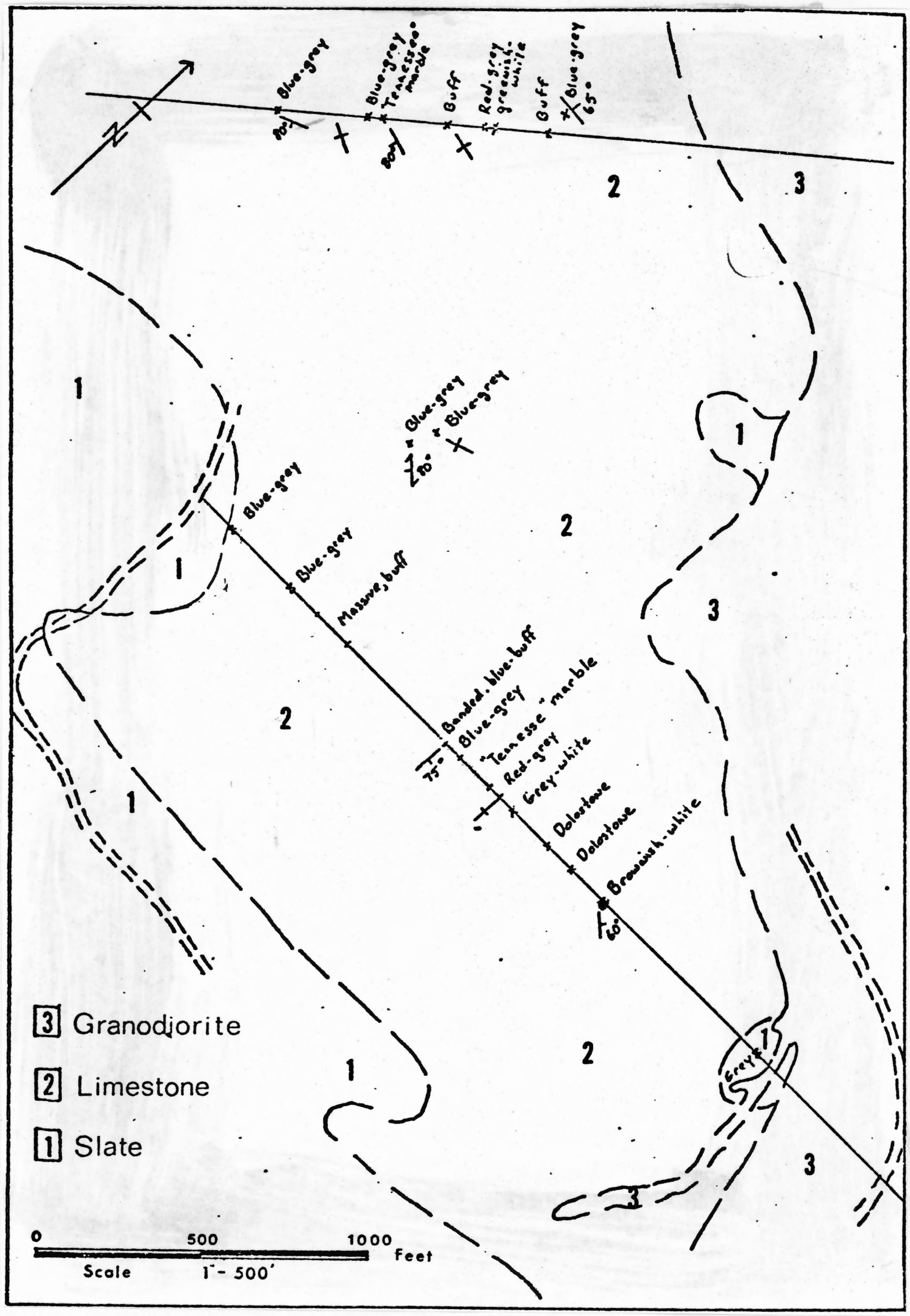
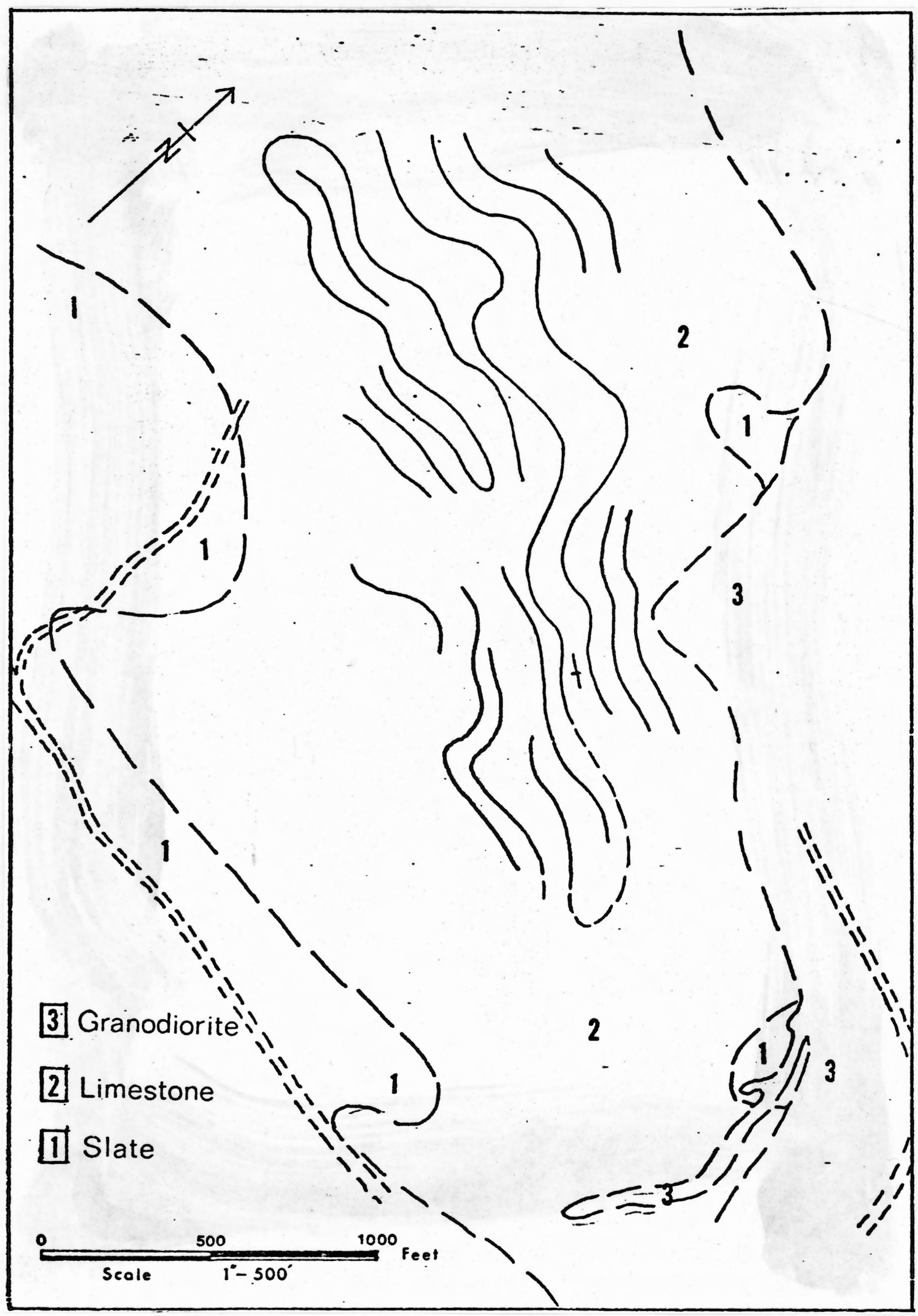
APPENDIX I

Limestones North of MacMillan's Farm



Distinctly Coloured Limestones North of MacMillan's Farm.



Folding of Limestones North of MacMillan's Farm.

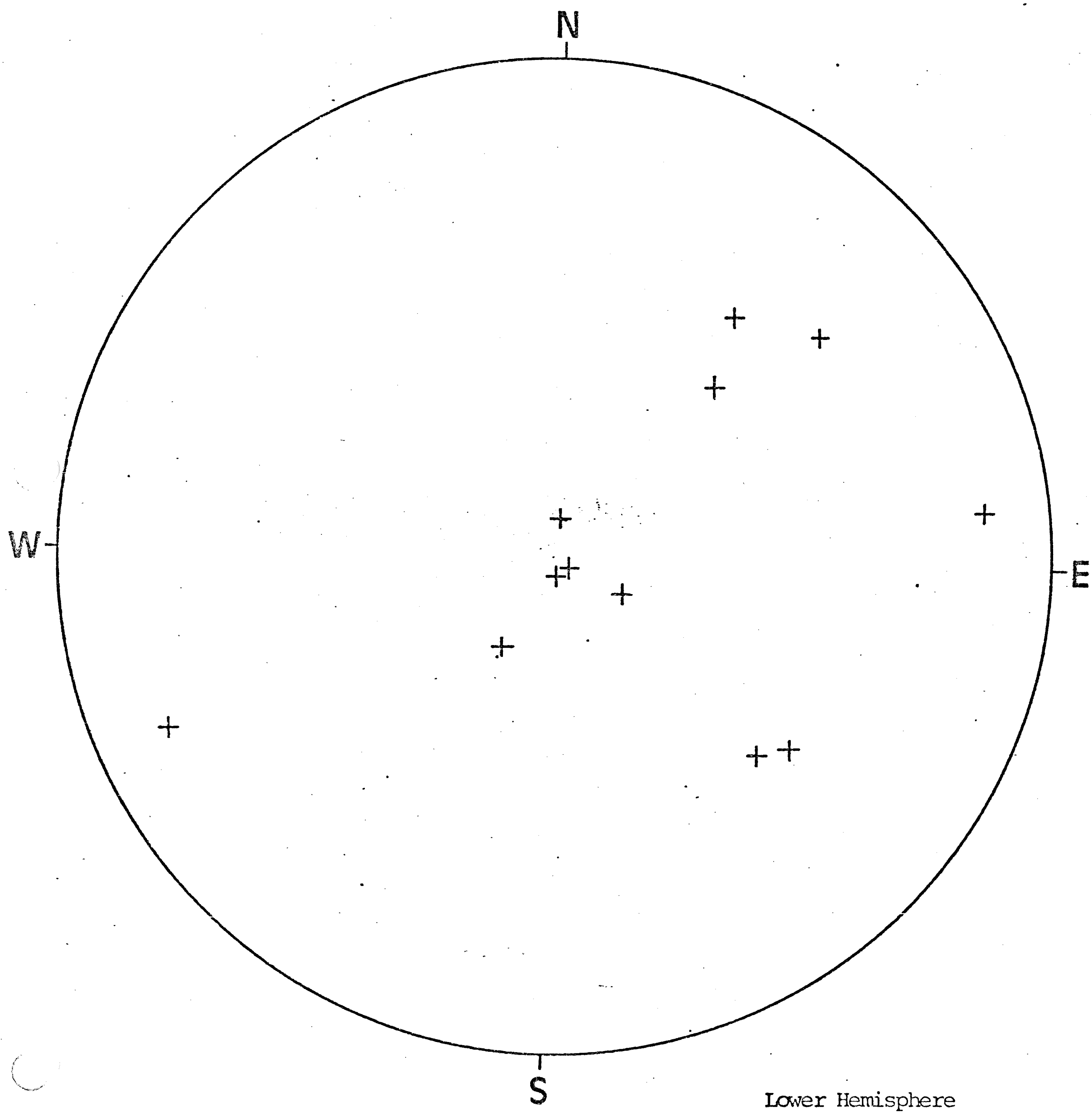
APPENDIX II

Stereonet Plots

DALLAS - CAMPBELL BROOK AREA

CAMPBELL BROOK END

LINEAR FEATURES AREA #1

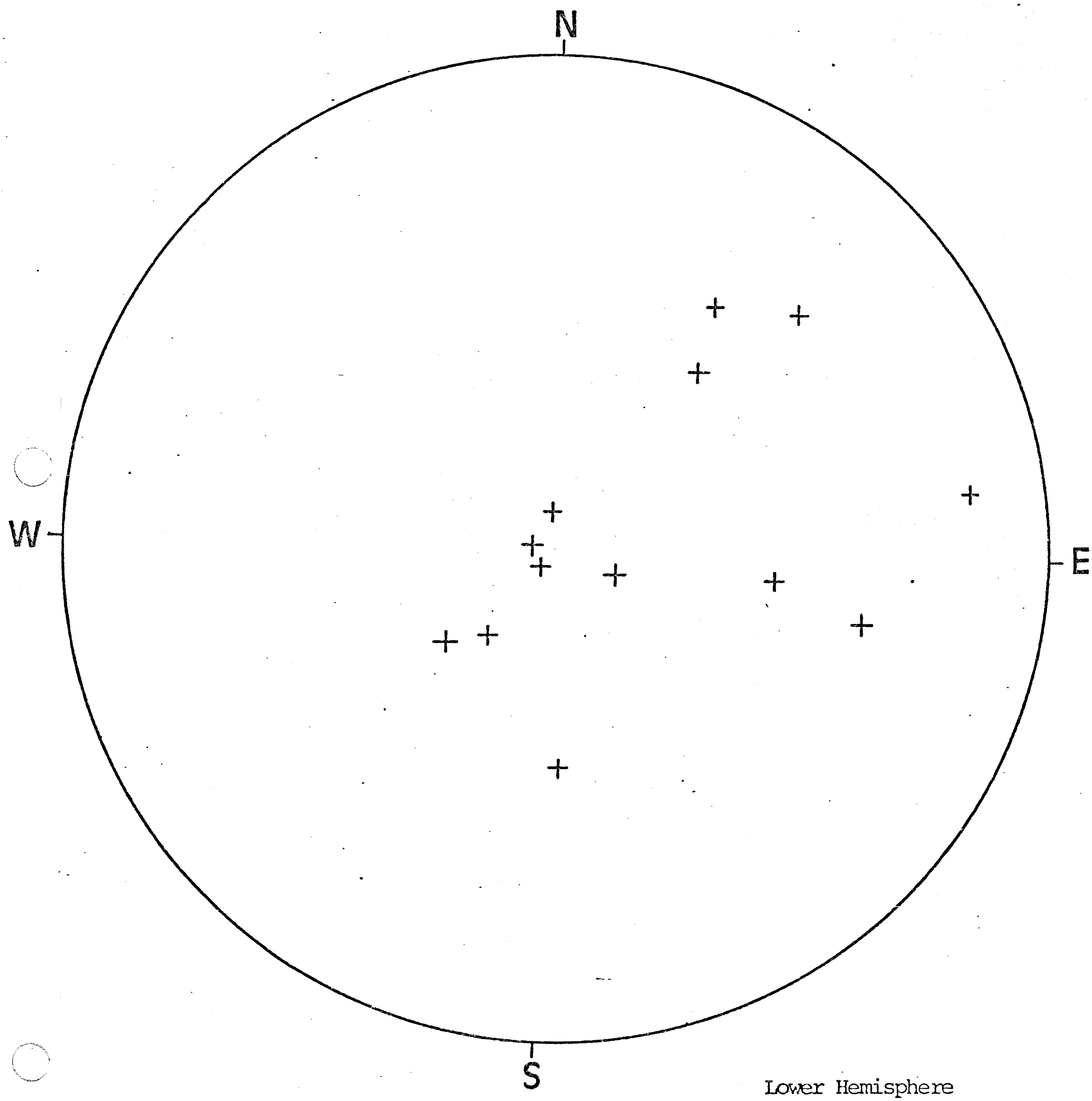


Lower Hemisphere

DALLAS - CAMPBELL BROOK AREA

NORTH OF MACMILLIAN FARM

LINEAR FEATURES AREA #2

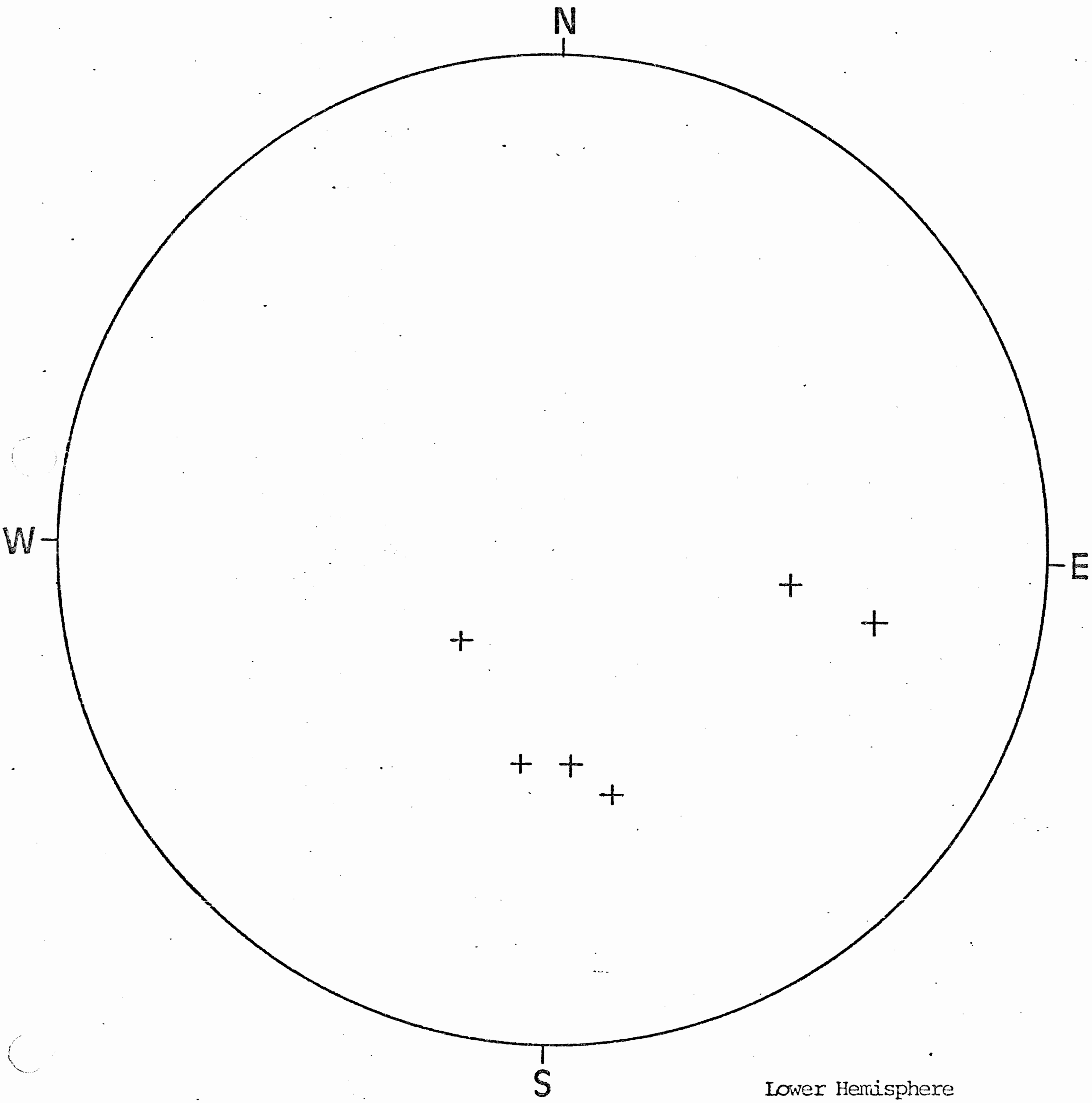


Lower Hemisphere

DALLAS - CAMPBELL BROOK AREA

MACMILLAN FARM AREA - NORTH

LINEAR FEATURES AREA #3

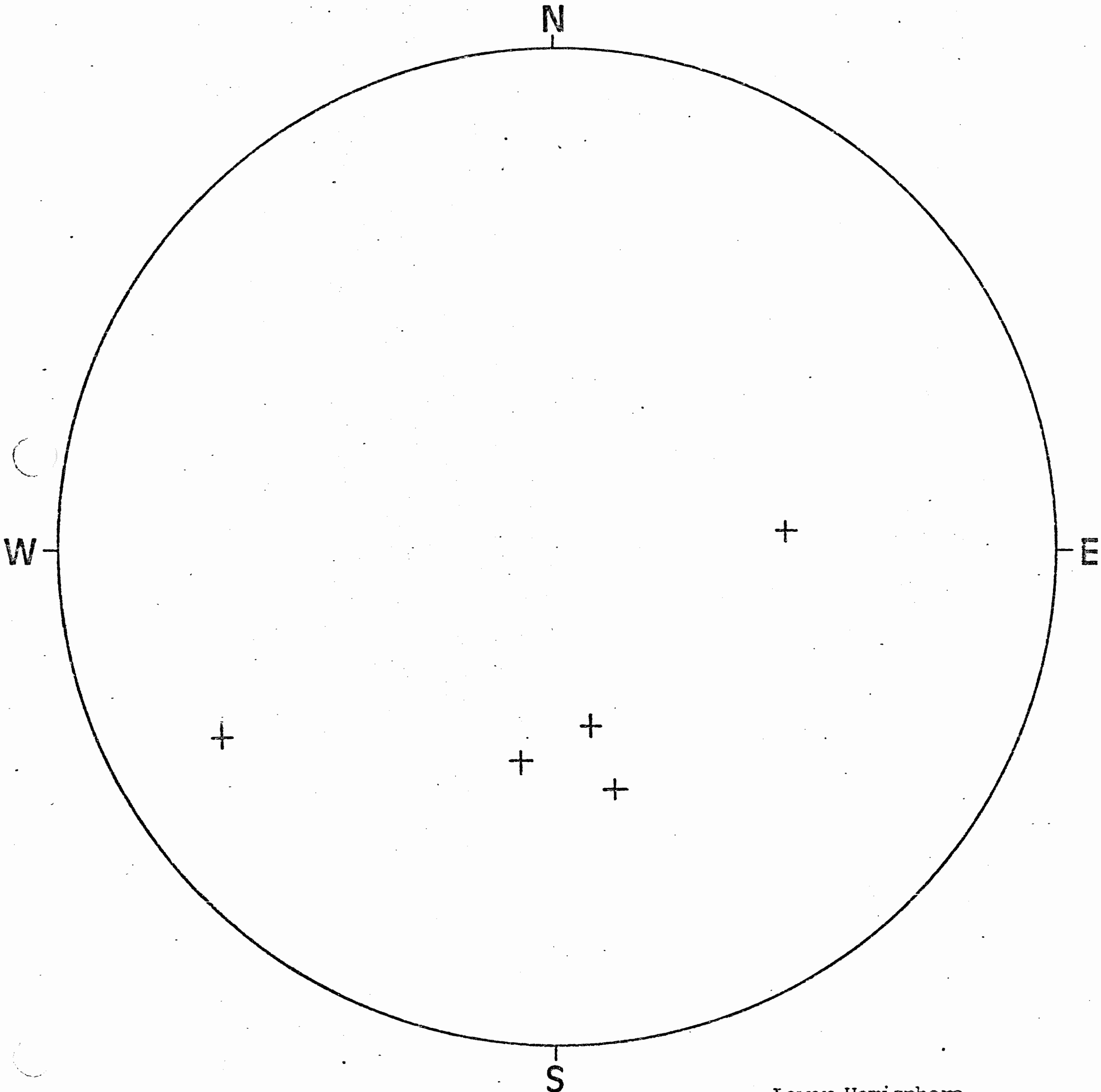


Lower Hemisphere

DALLAS - CAMPBELL BROOK AREA

MACMILLIAN FARM AREA - SOUTH

LINEAR FEATURES AREA #4

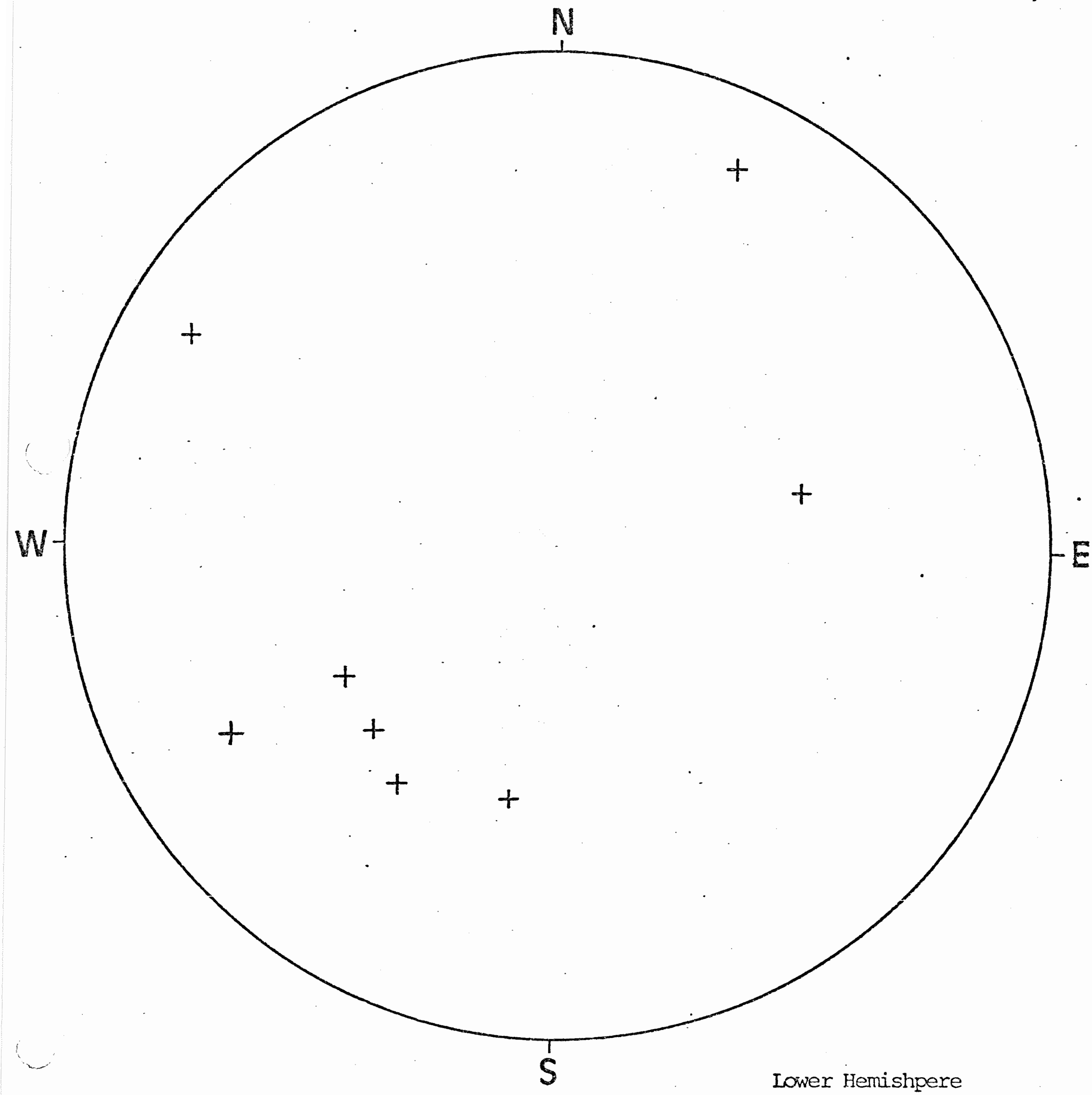


Lower Hemisphere

DALLAS - CAMPBELL BROOK AREA

DALLAS BROOK END

LINEAR FEATURES AREA #5



Lower Hemishpere

DEPARTMENT OF MINES
PROVINCE OF NOVA SCOTIA

LEGEND

MISSISSIPPIAN

WINDSOR AND HORTON

- 12 —

PALAEOZOIC

DEVONIAN OR EARLIER

- 11 Diorite and quartz diorite, minor granite
- 10 Gneiss
- 9 Granite
- 8 Granodiorite
- 7 Syenite

ARCHAEAN

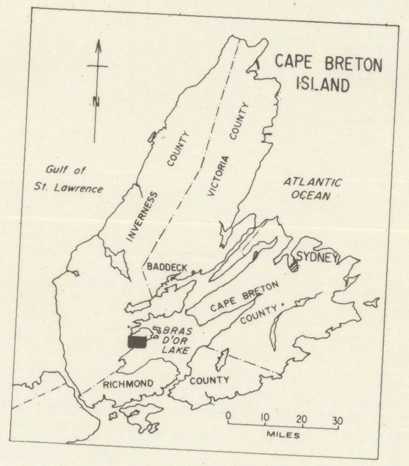
GEORGE RIVER GROUP

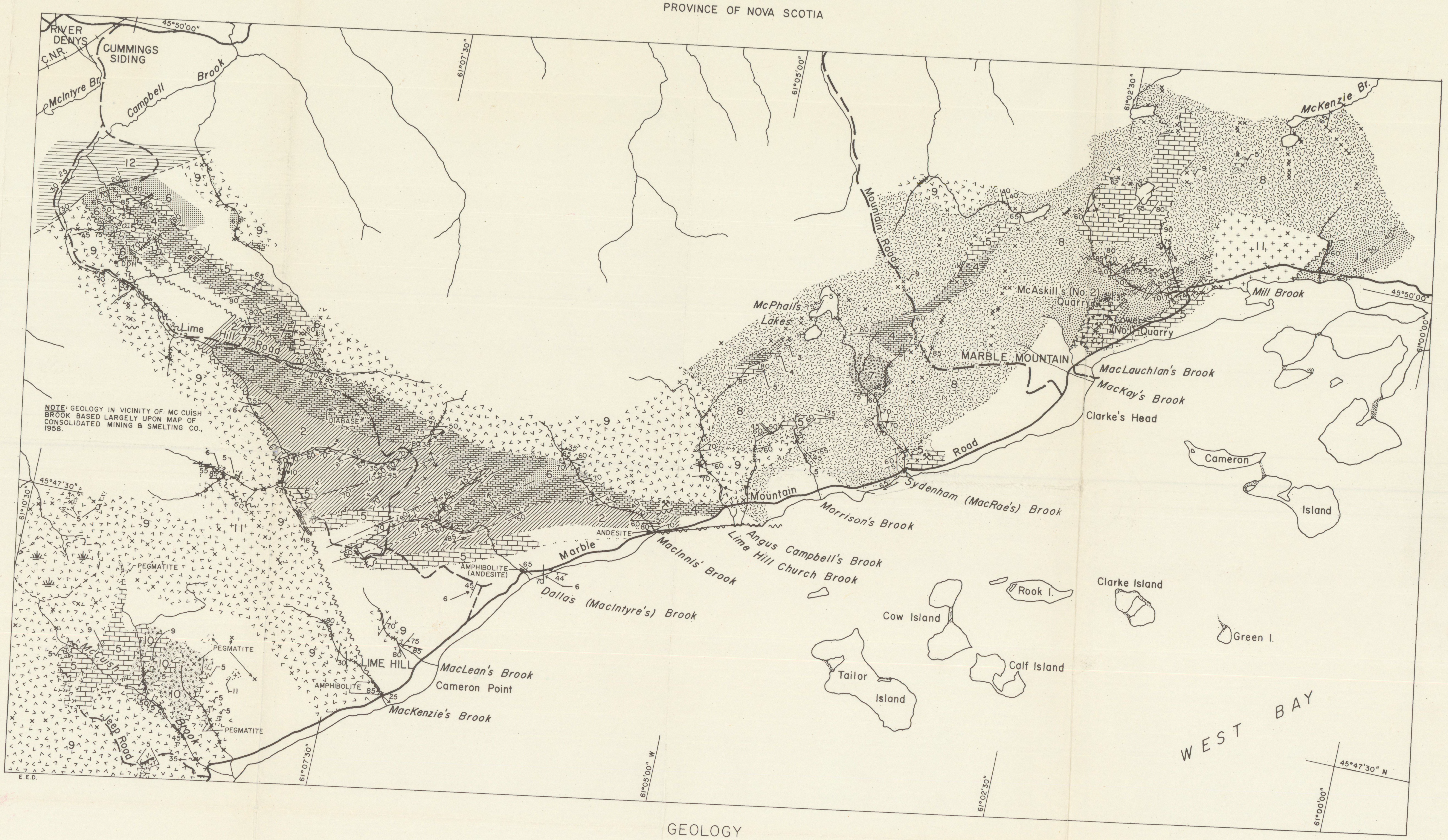
- 6 Quartzite
- 5 White to blue-white limestone
- 4 Blue to blue-black limestone
- 3 Dolomite
- 2 Slate
- 1 Feldspathic quartzite

(GEORGE RIVER: LITHOLOGICAL UNITS ONLY; NOT IN STRATIGRAPIC ORDER)

SYMBOLS

- Geological boundary (defined, approx., assumed)
- Fold axis (anticline, syncline) with plunge
- Bedding (inclined, vertical, dip unknown)
- Schistosity (inclined, vertical, dip unknown)
- Joints (inclined, vertical)
- Faults (defined, approximate, assumed, with plunge of linear feature)
- Drag fold, showing plunge and motion
- Quarry
- Outcrop





GEOLOGY

NORTH MOUNTAIN

INVERNESS COUNTY, NOVA SCOTIA.

0 — 2
SCALE IN MILES

Geology by G.C. Milligan and R.C. Parsons, 1962.


GEORGE RIVER GROUP
OF NORTH MOUNTAIN
INVERNESS COUNTY, NOVA SCOTIA
LEGEND
MISSISSIPPIAN
6 Conglomerate
DEVONIAN OR EARLIER
5 Granodiorite, Granite
4 Diabase
PRECAMBRIAN
GEORGE RIVER GROUP
3 Quartzite
2 Limestone and dolostone
1 Slate with minor interbedded quartzite, limestone and dolostone
Rock outcrop
Geological boundary (approximate, assumed)
Bedding (horizontal, inclined, overturned, vertical, unknown)
Schistosity (inclined, vertical)
Gneissosity (inclined, vertical)
Joint (inclined, vertical)
Sheet joint (inclined, vertical)
Shearing and dip
Drag fold (arrow indicates plunge)
Lineation with plunge (minor fold unknown)
Fault (defined, approximate, questionable)
Geology by B.J. Keating, 1963-1973
Cartography by G.H. McFall, 1975
Road (main, bush)
Lake
River, stream
Swamp
Escarpment
Bridge
Approximate magnetic declination 1975, 24°58' West decreasing 1.7' annually
500 0 500 1000 1500 Feet
Scale 1" - 500'
River Denys
Campbell
Lime Brook
Lime Hill Road
MacMillan Farm
Dallas Lake
Lime Hill
Mountain Road
Marble
Dallas Brook
MacKenzie's Brook
MacLean's Brook
WEST BAY