THE UNIVERSITY OF MANITOBA

STRUCTURAL ANALYSIS OF A SIMILAR-TYPE FOLD; BOOSTER LAKE, MANITOBA

by

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ABSTRACT

A similar-type fold is outlined by a unit of meta-conglomerate in the Booster Lake area of Manitoba. This anticline merges into a major syncline which extends 25 miles westward to Lac du Bonnet. The anticline has deformed an Archean sequence of metagreywacke, meta-conglomerate and a second unit of metagreywacke. A granite pluton was intruded into the core of the fold.

The orientation of the Booster Lake fold is defined by its plunge and the dip of its axial surface. On the basis of its orientation and closure, it is a tight inclined anticline.

Assuming cylindrical folding, a right section is constructed to enable classification of the style of folding. Three parameters: dip isogons; orthogonal thickness, t; and axial planar thickness, T, show the fold style to be complex. It almost ideally belongs to Ramsay's (1967) Class 2 in the hinge area but is of Class 1C in the limbs.

The style of folding, foliation, lineations, and textures are inconclusive in defining the type of strain which produced the fold, but four types of strain are considered possible: heterogeneous pure shear; homogeneous flattening superimposed on a flexural fold; flexural folding followed by heterogeneous or homogeneous pure shear and heterogeneous simple shear; and heterogeneous or homogeneous

pure shear followed by heterogeneous simple shear. The mechanism was that of passive flow contemporaneous with metamorphism. The granite pluton may have been involved in the folding as it was either syn-folding or post-folding.

TABLE OF CONTENTS

FIGURES

TABLES

CHAPTER I

INTRODUCTION

THE PROBLEM

The purpose of this study is: (1) to document and analyze the geometry of a fold outlined by a meta-conglomerate unit in the area immediately to the north of Booster Lake, Manitoba; (2) to investigate the nature of the strain producing the fold; (3) to relate the deformation to the metamorphism and (4) to examine the role of the granite pluton in the development of the fold.

LOCATION AND ACCESS

The Booster Lake area is approximately 90 miles northeast of Winnipeg, Manitoba and 35 miles northeast of Lac du Bonnet, Manitoba (Figure 1). The area is accessible by road; Provincial Road 315 cuts through the northern edge of the thesis area.

TOPOGRAPHY

Outcrop is plentiful in the area north of Booster Lake and there is a general relief of approximately 50 feet. The area has a good forest cover and thick moss covers most of the outcrop.

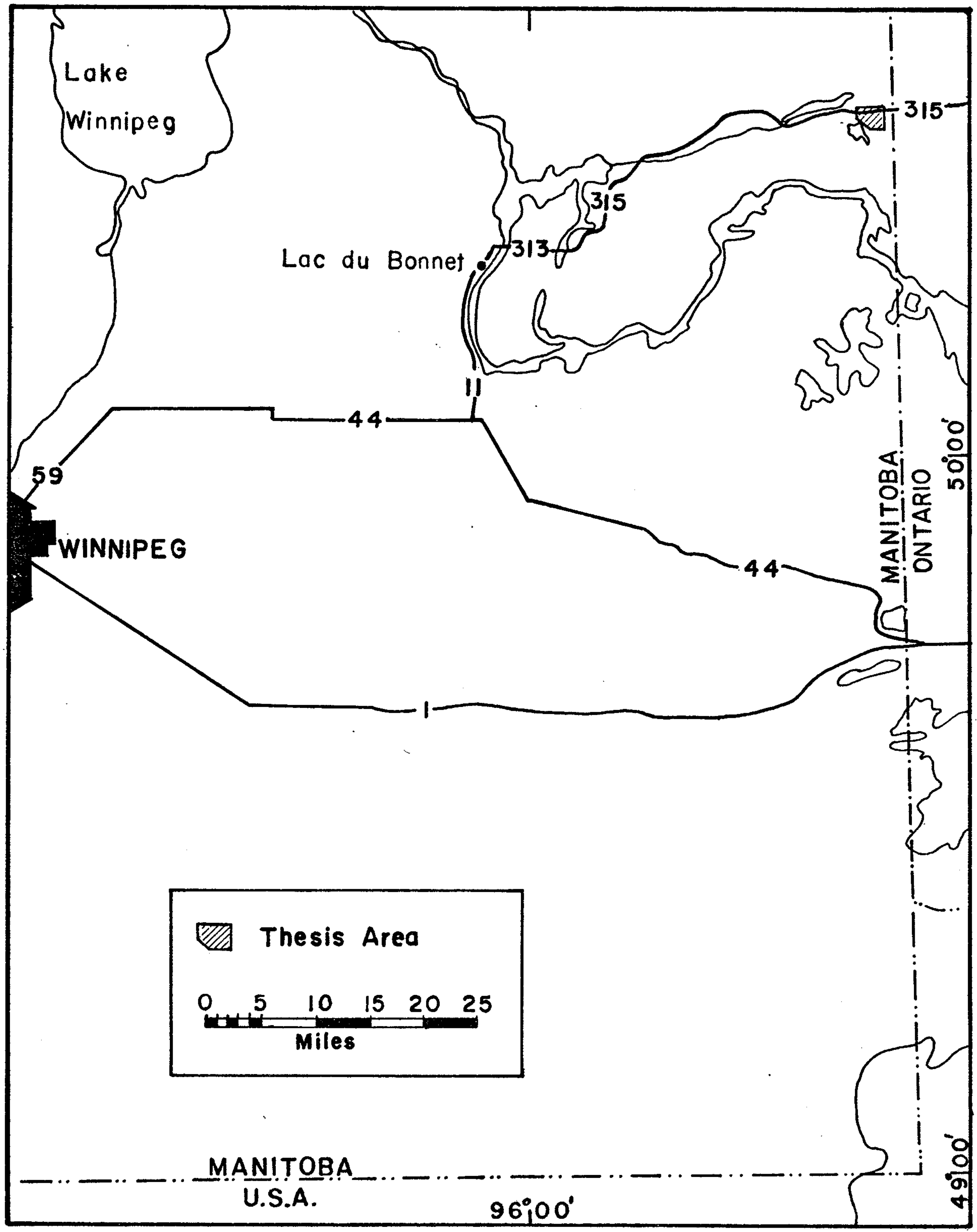


Figure 1: Map of southeastern Manitoba showing the location of the thesis area.

PREVIOUS WORK

Springer (1949) produced the first detailed geologic map of the area at a scale of one inch to one mile. It was not until the area was re-mapped by Davies (1956) at a scale of one inch to one thousand feet, however, that the conglomerate unit was found to outline a fold.

Butrenchuk (1970) carried out a study on the metamorphic grade of the rocks in the Bird River area, including those within the present area of study. He concluded that 3 periods of metamorphism have affected the metavolcanic and metasedimentary rocks of the Bird River area. The first period of metamorphism was a thermal event. The effects of this event have been obliterated in the Booster Lake area by the second metamorphic event. This second period of metamorphism was a dynamo-thermal type and produced a regional foliation parallel to the bedding in the volcanic and sedimentary rocks. During this period, the sedimentary rocks within the Booster Lake area were metamorphosed to the almandine-amphibolite facies (with epidote). The third period of metamorphism was dynamic and the effects were related to deformation of the regional foliation by faulting. This event does not appear to have affected rocks of the Booster Lake area.

PRESENT WORK

The field data were collected in the fall of 1970 over a period of ten days. Traversing, at a spacing of approximately 500 feet, was carried out across the nose of the fold. Less detailed work was done on the flanks and in the core of the fold. The geological map published by Davies (1956) was used as a basis for the field work. The area was not re-mapped, but more structural data were gathered to augment those gathered by Davies.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. W. C. Brisbin of the University of Manitoba Department of Earth Sciences for not only suggesting the topic, but also for his valuable assistance during the study.

The Manitoba Mines Branch prepared the thin sections used in the study.

Aerial photographs of the thesis area were taken by Abitibi Paper Company and are at a scale of one-quarter mile to the inch.

The geology of the area was mapped by Dr. J. F. Davies of the Manitoba Mines Branch in 1955 and his map (Davies, 1956) provided a valuable basis for the thesis.

D. L. Trueman carried out detailed studies in the Bird River area for the Manitoba Mines Branch and his comments and discussion have been very helpful.

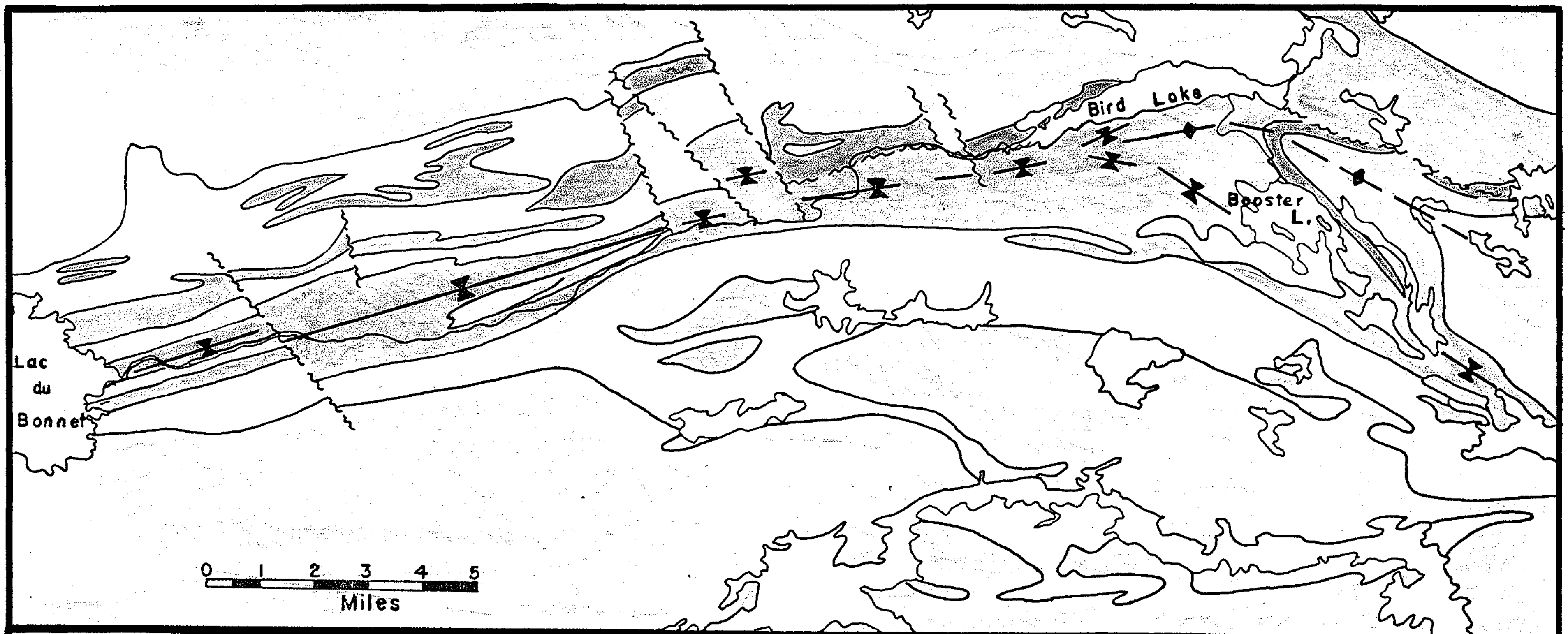
CHAPTER II

GENERAL GEOLOGY

REGIONAL GEOLOGY

A belt of metasedimentary and metavolcanic rocks extends eastward from Lac du Bonnet into the Booster Lake area (Figure 2). These rocks are Archean in age and belong to the Rice Lake Group (Springer, 1949; Davies, 1955, 1956). According to Davies (1955, 1956) the volcanic rocks are the basal rocks of the group (Table 1). The rocks of the belt have been folded into a syncline with the metasedimentary rocks now in the core of the fold. The axis of the syncline runs down the centre of the belt but bifurcates south of Bird Lake. The axis of the northern branch of the bifurcated syncline is cut off by the fault which passes through Bird Lake. The axial trace of the southern branch passes through Booster Lake. The anticline between the two subsidiary synclines is the subject of this study and is referred to as the Booster Lake anticline. The relationship of the anticline to the major syncline is shown in Figure 3. The metavolcanic and metasedimentary rocks have been intruded by basic rocks of the Bird River sill and by large granitic batholiths which bound the belt to the north and south.

D. L. Trueman (personal communication) has noted outcrops of conglomerate along the metavolcanic-metased-



LEGEND

Quartz diorite, granodiorite, granite	Geological boundary
Bird River Sill	Fault
Conglomerate	Trace of anticline
Greywacke, arkose, quartzite	Trace of syncline
Andesite, basalt	

Figure 2: Regional geology of the Lac du Bonnet-Booster Lake area (after Davies et al, 1962).

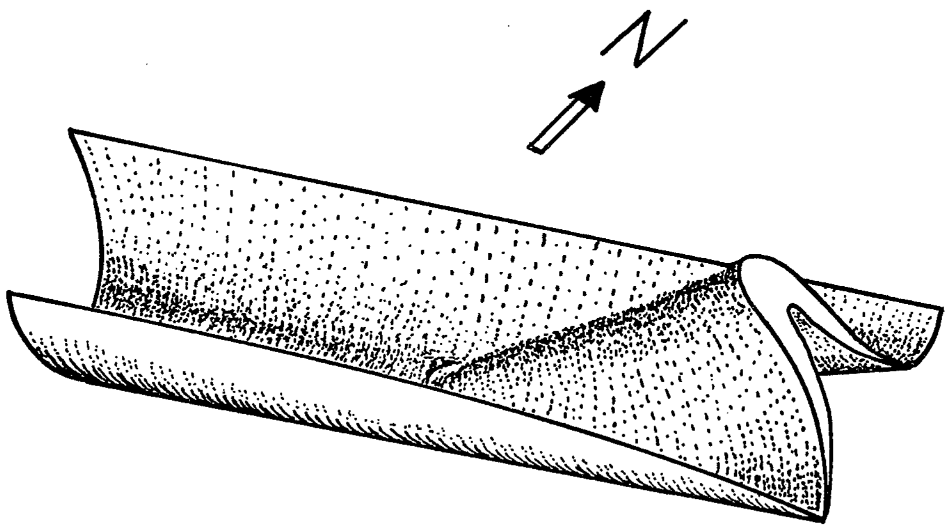


Figure 3: Three-dimensional sketch of the anticline in relation to the easterly trending syncline. This view of the structure is prior to faulting of the north limb.

Table 1: Table of Formations (after Davies, 1956)

Recent and Pleistocene		Glacial sand and clay
MAJOR UNCONFORMITY		
PRECAMBRIAN	Map Unit	
	6	Granodiorite
	5	Grey Granite
		—intrusive contact—
		Bird River Sill
		—intrusive contact—
		RICE LAKE GROUP
	4	Silicified Zone
	3	Metagreywacke
	2	Meta-conglomerate
	1	Metagreywacke
		Andesite, Basalt

Note: Map-unit numbers identify those rocks present in the Booster Lake thesis area.

imentary contact. Along this contact, the conglomerate contains clasts of metavolcanic rocks. Metavolcanic clasts are notably absent from the meta-conglomerate exposed within the Booster Lake area. The Booster Lake conglomerate may be straigraphically equivalent to the other conglomerate, but, at present, there is no basis for such an interpretation.

AGE RELATIONSHIPS AND STRATIGRAPHY

The oldest rocks within the thesis area (Figure 4) are the Rice Lake Group metasedimentary rocks consisting of metagreywacke, meta-conglomerate and a second unit of metagreywacke. Although the contact between units 1 and 2 (Table 1) was not exposed it would appear that it is gradational. Small pebbles of tonalite were found in exposures of the lower metagreywacke approximately 100 feet across strike from exposures of the meta-conglomerate, and the matrix of the meta-conglomerate is similar in composition to the metagreywacke.

These age relationships indicate that there was continuous sedimentation of greywacke composition on top of volcanic rocks. During the sedimentation, however, an influx of granitic and arkosic pebbles from an unknown source resulted in the intervening unit of conglomerate.

The silicification of the upper metagreywacke to form the silicified zone is of questionable age. The silicification process did not affect the meta-conglomerate nor any of the lower metagreywacke within the core of the fold.

The granitic intrusive rocks are definitely younger than the metasedimentary rocks. The lower metagreywacke has been locally deformed by intrusion of the granodiorite which also contains inclusions of the upper metagreywacke near the contact.

LITHOLOGY AND DISTRIBUTION OF ROCK TYPES

Metagreywacke (1)*

The lower metagreywacke unit underlies the meta-conglomerate and is exposed in the core of the Booster Lake anticline (Figure 4). This metagreywacke is medium to dark grey in colour, fine-grained and schistose. It is composed of quartz, plagioclase, biotite, and locally hornblende, all of which have been recrystallized. The quartz grains are strained and the biotite grains have a preferred orientation which imparts a schistosity to the rock. Hornblende, where present, also shows a preferred orientation. In spite of recrystallization, rounded feld-spar grains, comprising a relict clastic texture, were observed in thin sections from two localities. Bedding was observed locally in the metagreywacke. Davies (1956) also observed bedding at localities which the writer was unable to visit.

Meta-conglomerate (2)

This unit, which outlines the fold under study, is a

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* Map-units are shown in Figure 4.

metamorphosed polymictic conglomerate. It varies in true orthogonal thickness from 350 feet in the limbs to 3000 feet in the hinge area of the Booster Lake fold. The meta-conglomerate is poorly sorted and consists of tonalite pebbles and, to a lesser extent, of arkose pebbles in a grey, fine-grained, recrystallized quartzo-micaceous matrix. Both types of pebbles have been deformed such that their long dimensions plunge to the southwest in the plane of foliation. Layering was observed locally in the matrix of the conglomerate on the limbs of the fold, but was not found in the hinge zone.

The recrystallized matrix consists of quartz, biotite, and plagioclase. The quartz is strained and the biotite shows preferred orientation. Biotite is also concentrated around the margins of the arkose and tonalite clasts.

The pebbles of coarse-grained white tonalite range from 1 inch to 12 inches in diameter, and have responded more competently to deformation than the surrounding matrix. The tonalite pebbles have been recrystallized and the quartz and feldspar are anhedral but are not aligned. Biotite grains are poorly aligned, but this weak foliation is parallel to the foliation in the matrix. Quartz commonly forms pressure shadows at the ends of pebbles (Figure 5).

The arkose pebbles are white, fine-grained, and highly deformed in such a manner that they wrap around the tonalite pebbles (Figure 5). Biotite is only a minor con-

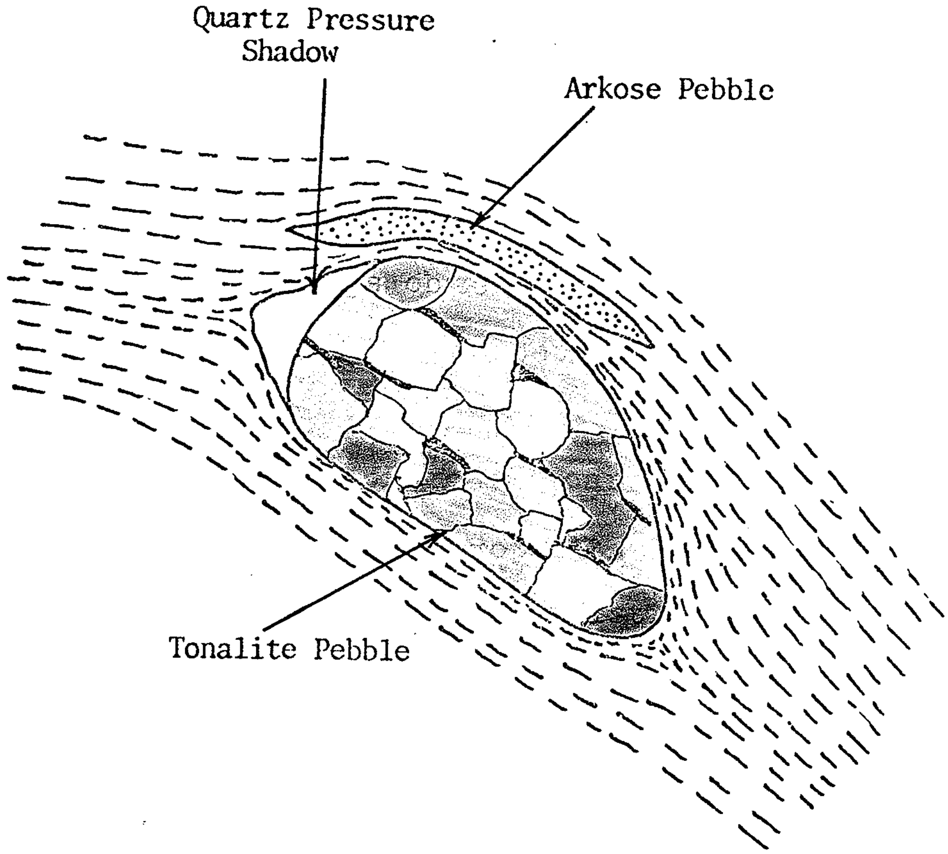

Figure 5: Tonalite pebble flattened in the plane of foliation with quartz pressure shadow. Arkose pebble is flattened and tends to wrap around the tonalite pebble.

stituent in these recrystallized pebbles, but again the grains are oriented parallel to those in the matrix.

Metagreywacke (3)

The upper metagreywacke unit bounds the upper surface of the meta-conglomerate and extends westward to Lac du Bonnet (Figure 2). Although this unit is of a different age than the lower metagreywacke unit, both are alike in all respects. Bedding was observed in the upper metagreywacke on the north shore of Booster Lake.

Silicified Zone (4)

A silicified zone outcrops at the nose of the anticline. This zone has an irregular distribution and is "probably the result of replacement of greywacke by silica-bearing and, in some cases, sulphur-bearing hydrothermal solutions." (Davies, 1956, p. 10).

These rocks are fine-grained, cream-coloured, cherty looking rocks with rusty surface weathering. Mineralogically, they are composed of quartz, microcline, muscovite, and pyrrhotite and pyrite.

Grey Granite (5)

Coarse-grained to pegmatitic grey granite occurs within the core of the fold around Marijane Lake (Figure 4). It forms a large body, the outline of which conforms to that of the fold itself. Several smaller isolated bodies also occur to the northwest of the main body.

The grey granite is a heterogeneous unit composed of quartz, microcline, plagioclase, and biotite in variable proportions. The composition of the rock ranges from a granite to a granodiorite. Springer (1949) also observed some quartz dioritic phases. The rock is massive to strongly gneissic and contains xenoliths of older rocks (Davies, 1956).

Granodiorite (6)

Several outcrops of grey, coarse-grained granodiorite occur to the south of Starr Lake (Figure 4). This unit is massive and contains xenoliths of upper metagreywacke adjacent to the contact with that unit. The granodiorite is composed of quartz, plagioclase, and minor biotite. Pyrite was found in the contact zones along with the xenoliths of metagreywacke.

STRUCTURAL GEOLOGY

The major structural feature within the thesis area is the Booster Lake anticlinal fold. Certain other structural elements including foliation, lineations, and a fault were recognized and are documented here because of their relationships to the fold.

The Fold

The Booster Lake fold, as outlined by the meta-conglomerate, appears to be a similar fold closing to the northwest (Figure 3). The meta-conglomerate unit is thin near Flanders Lake but thickens in the hinge zone, north of Booster Lake. The thickness of the meta-conglomerate in the north limb is not known because that limb has been faulted.

Foliation

The foliation in the metagreywacke units and in the matrix of the meta-conglomerate is produced by the preferred orientation of biotite and, to a lesser extent, quartz and plagioclase. The foliation is parallel to the layering in the limbs of the fold, but cuts across the bedding in the hinge area. The foliations for the north and south limbs respectively, converge in the hinge zone.

The foliation in the matrix of the meta-conglomerate is deflected around the deformed clasts (Figure 5). Biotite grains are concentrated at the margins of the pebbles and are oriented parallel to the biotite grains in the matrix.

A weakly preferred orientation of the biotite in the tonalite and arkose pebbles in the meta-conglomerate is parallel to the foliation in the matrix.

The pebbles in the meta-conglomerate have been flattened so that the plane of flattening coincides with the plane of foliation.

Lineations

The pebbles are elongate as well as flattened. The rounded nature of the outcrops permitted only the general observation that the pebbles have a moderate to steep southwesterly plunge in the plane of foliation.

A series of slabs was cut through several oriented samples enabling approximate measurements of the plunge. The plunges of the long axes vary but, in general, were found to be 30 to 50 degrees at 220° to 245°. This method was found to be slightly inaccurate due to difficulties in defining the exact long axis of each pebble. It must be concluded therefore that the above values of plunge are not completely reliable.

Faulting

An east-southeasterly striking fault cuts the meta-conglomerate in the northern limb of the fold. This fault was observed by the writer to be a large shear zone dipping steeply south. The distribution of the meta-conglomerate between Starr and Davidson Lakes (Figure 4) suggests that this fault has a right-lateral horizontal component of displacement of approximately 8000 feet.

CHAPTER III

ORIENTATION, CLOSURE, STYLE AND ASYMMETRY OF THE BOOSTER LAKE FOLD

ORIENTATION AND CLOSURE

Attitudes of the Limbs

The number of layering measurements taken in the field was insufficient to conduct a statistical stereographic analysis of the fold. Consequently, it was necessary to determine the character and orientation of the limbs in a less conventional way, making use of the metaconglomerate as a marker unit.

The orientation of each limb of the fold is defined by its respective strike and dip. The strikes of the north and south limbs could be measured (100 and 130 degrees respectively) from the plan view (Figure 4). These strikes coincide with those of the layering observed in the limbs of the fold (Figure 6). The dips of the layering are therefore assumed to represent the general dip of the limbs. The average dip for each given strike is assumed to be representative for that limb. The attitude of the north limb is 100°/54° S and that of the south limb is 130°/59° SW.

Plunge of the Fold

Ramsay (1964) points out that if the orientations

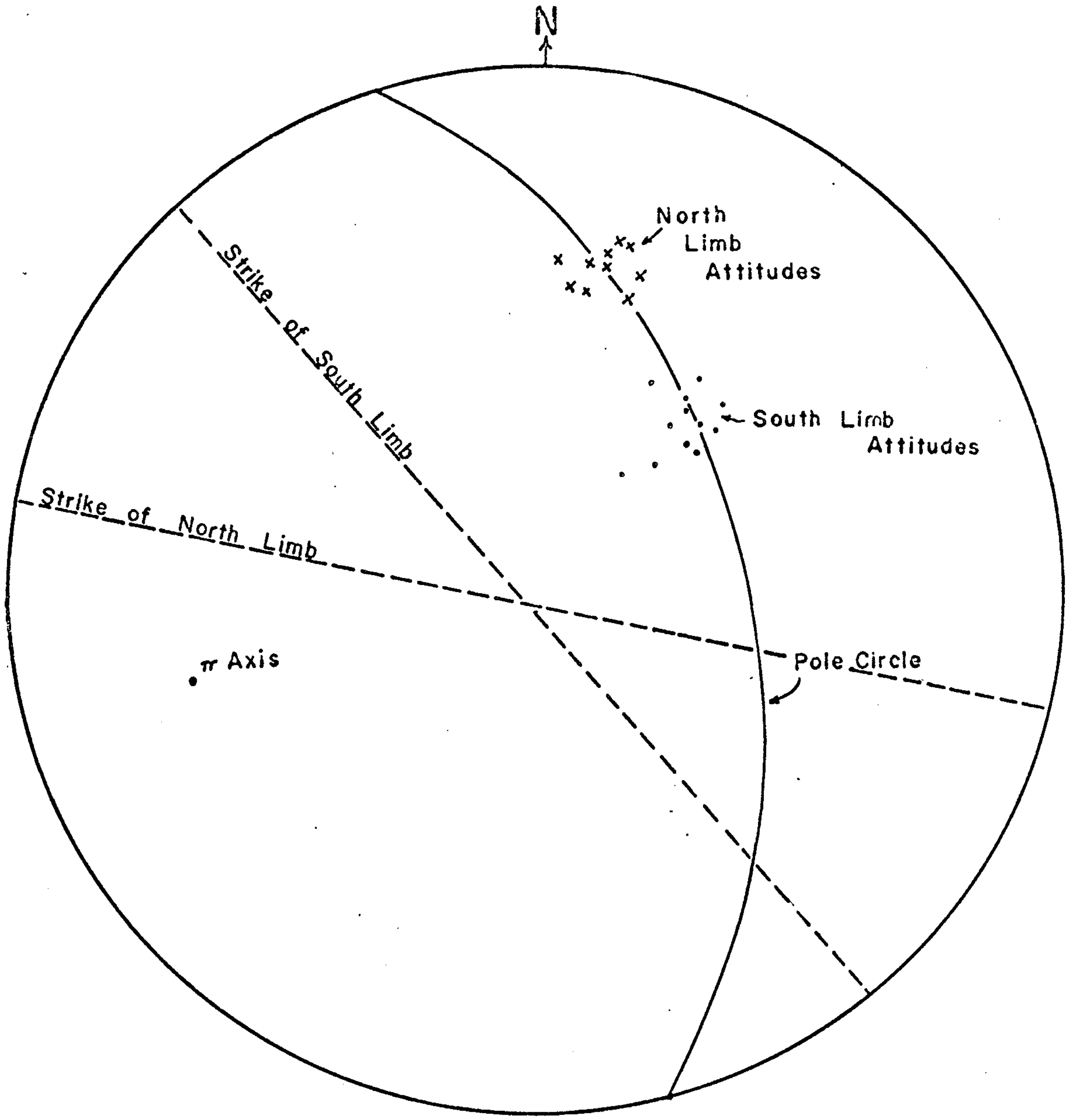

Figure 6: Equal area projection of poles to layering. The π axis is perpendicular to the pole circle and coincides with the fold axis. The strikes of the north and south limbs were taken from the geologic map (Figure 4).

of the bedding planes on the limbs of a fold are known, then their intersection (β axis) can be determined on a stereonet and it will be parallel to the fold axis. Figure 7 shows the intersection of the two planes representing the north and south limbs of the Booster Lake fold. These planes are normal to the point of maximum concentration of poles to layering (Figure 6) for their respective limbs. The fold axis plunges 36 degrees in the direction 251 degrees azimuth.

The Axial Surface

The axial surface of the fold is determined from the axial trace and the fold axis. The axial trace, drawn through the points of maximum curvature of the bedding planes of the meta-conglomerate, defines the strike of the axial plane. The axial plane contains both the strike line and the fold axis (Badgley, 1959) and is shown on Figure 7. The orientation of the axial surface is $295^\circ/46^\circ$ SE.

Interlimb Angle

The closure of a fold is given by the interlimb dihedral angle. The dihedral angle between the north and south limbs of the Booster Lake fold is 26 degrees. This angle is less than 30 degrees, and consequently the closure of the fold is classified as "tight" (Fleuty, 1964).

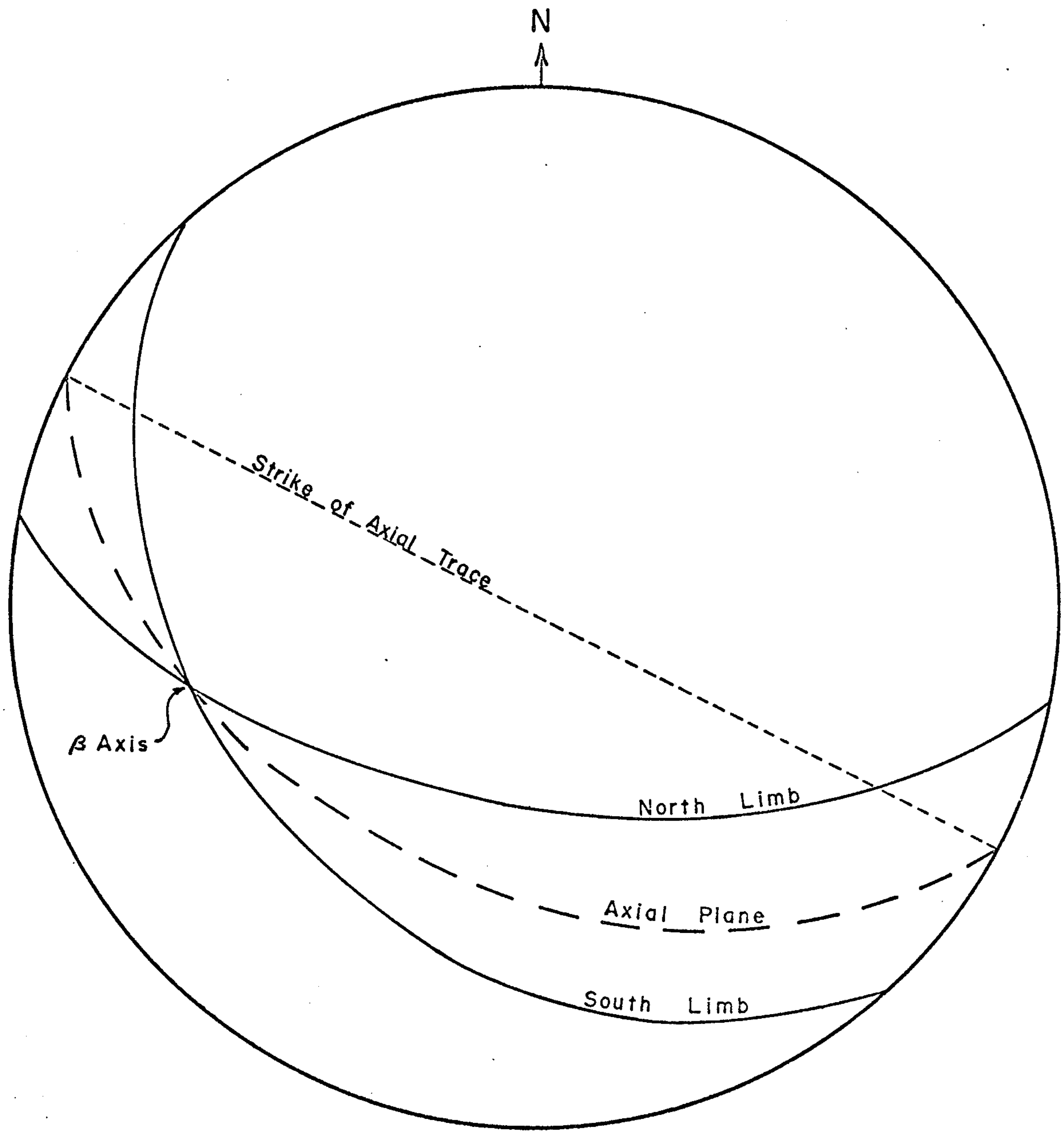

Figure 7: Beta-diagram showing the intersection of the planes of the fold limbs with the axial plane. The β axis is the line of intersection between the three planes and coincides with the fold axis. The strike of the axial trace was obtained from the geologic map (Figure 4).