Structural history and plutonic and metamorphic geology of the Central Southern Indian Lake Area, Manitoba

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ABSTRACT

This study of the plutonic, metamorphic and structural history of the Central Southern Indian Lake area consisted of field mapping followed by petrographic, structural and chemical analyses. The mapping of the 1000 square mile map-area was at a scale of 1/2 mile = 1 inch, while areas of greater structural and lithographic complexity were mapped at two times this scale.

All consolidated rocks in the map-area are Precambrian in age, and most exhibit regional metamorphism to the amphibolite facies. Wasekwan-type gneisses and migmatites derived from greywacke, and the later, Sickle-type gneisses and migmatites, derived primarily from arkose, are separated by post-Wasekwan-type basic igneous rocks of intermediate age. The Sickle-type gneisses were subsequently intruded by basic igneous rocks and then by granitic intrusions. Pegmatites and aplites intrude most units but their relative age is uncertain. Lamprophyre and diabase are the youngest rocks in the area though neither forms mappable bodies.

The area has undergone two, and possibly three, events of prograde regional metamorphism, plus localized retrograde development of chlorite and epidote associated with shearing (late-tectonic D_4). The first event (M_1), amphibolite facies, is found effecting only the Wasekwan-type gneisses. There is indirect evidence for a second event (M_2), effecting only Wasekwan rocks (pre-Sickle). The third event (M_3), amphibolite facies but with lower temperatures than M_1, effects Wasekwan and Sickle rocks.

The map-area exhibits effects of polyphase deformation. The following events have been interpreted and are presented chronologically from youngest to oldest in the following list.

D_4	post-granitic faulting and fracturing;
$D_3 - F_3$	folding of both gneissic sequences and Wasekwan-type metavolcanic rocks;

D_1 and D_2 is accompanied by faulting and shearing of uncertain relative age;

$D_2M_3 - F_2$	folding of Wasekwan-type gneisses and migmatites, initial folding of Wasekwan-type metavolcanic rocks and Sickle-type gneisses and migmatites;
M_2	
$D_1M_1 - F_1$	folding of Wasekwan-type gneisses and migmatites.

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Chapter I

INTRODUCTION

Statement of Problem

The objective of this study is to interpret the metamorphic, plutonic and tectonic history of the central block of Southern Indian Lake, Manitoba. The study is based on: (1) detailed field mapping; (2) structural and petrographic laboratory studies; and (3) interpretation of aeromagnetic data. The field mapping phase of the study was conducted in connection with extensive geological investigations by the Manitoba Mines Branch in the Southern Indian Lake area, Manitoba (Figure 1). The geologic maps included with this presentation were published by the author under the auspices of the Manitoba Mines Branch (Frohlinger, 1972). Several difficulties, such as lack of outcrop and lack of suitable marker horizons caused some of the interpretations to be tenuous, but where possible, these interpretations were further based on aeromagnetic and input electromagnetic data.

This presentation is divided into separate chapters, each dealing with a specific aspect of the geological history; the final chapter presents a synthesis where the geologic history and its inplications are discussed and summarized.

Location and Access

The Southern Indian Lake central area (Figures 1 and 2), which comprises approximately 1000 square miles, is located 85 miles east of Lynn Lake. National Topographic Series coverage of the area includes

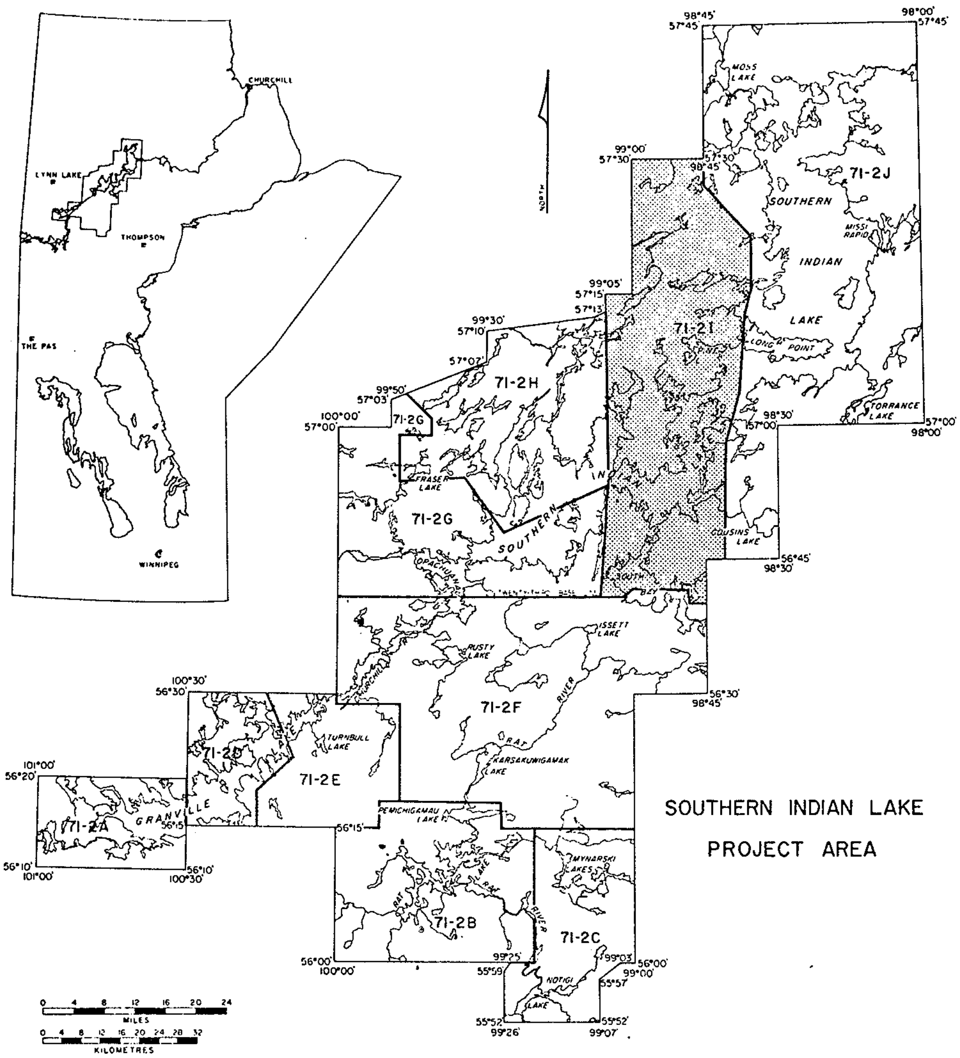

Figure 1. Location of Southern Indian Lake Project Area and area of present study (stipled).

sheet numbers 64B and 64G. The area is bounded by latitudes 56°41' and 57°30' and longitudes 98°38' and 99°10'. The only notable population concentration within the area is the settlement of South Indian Lake (population approximately 600) which is located in the south central portion of the map-area.

Previous Work

The earliest work of a geologic nature in this area was in 1908 by McInnes of the Geological Survey of Canada (1913). This early survey was part of his work

> "on an area west of Hudson Bay embracing part of the Province of Saskatchewan and part of the Northwest Territories of Canada".

No further geological work is known in the area until 1948, when Wright (1953) did preliminary work with the Geological Survey of Canada in the Uhlman Lake area. A few years later, Quinn conducted geologic surveys in the Big Sand Lake area (1957, 1960). More recently, Davison, in the course of the Geologic Survey of Canada's northern compilation program, spent the summer of 1968 in the Southern Indian Lake area.

Present Work

The present study is based on field work carried out from May 29th to September 8th,1969, June 8th to August 20th, 1970, and on laboratory investigations resulting from the above between September 1969 and March 1971. The first field season was spent mapping almost the entire area at a scale of 1/2 mile = 1 inch. The first few weeks of the second season were spent in completing the area at this scale. The rest of the time involved detailed examination and mapping (1/8 - 1/4 mile = 1 inch) of critical areas (Figure 2).

Geologic data in the area was collected along shoreline traverses on the major lakes; the shoreline work was supplemented by helicopter and pace and compass traverses in areas of probable outcrop. In addition, the helicopter was used to check for possible outcrop in the large drift-covered portions of the area to the north. Vertical aerial photographs (scale 2640 feet = 1 inch, and 5280 feet = 1 inch) were used to locate traverses and outcrop areas, and for photogeologic interpretation. Airborne magnetic survey maps, both at 1 mile = 1 inch, and 1/2 mile = 1 inch, were used for correlations in areas of scarce outcrop. Airborne input electromagnetic anomaly maps were used to delineate major structures and to subdivide the area into meaningful structural domains (Figure 10). All field data was plotted at 1/2 mile = 1 inch, except for areas of detailed study which were plotted at 1/8 mile = 1 inch. The final maps which accompany this report have been reduced to 1:50000.

Methods of Detailed Study

Petrologic Analyses

Efforts were made to collect representative and unaltered specimens of each rock type during the course of the mapping. From these samples, more than 400 thin-sections were prepared and selected sections were stained to show potassium feldspar. Optical methods of

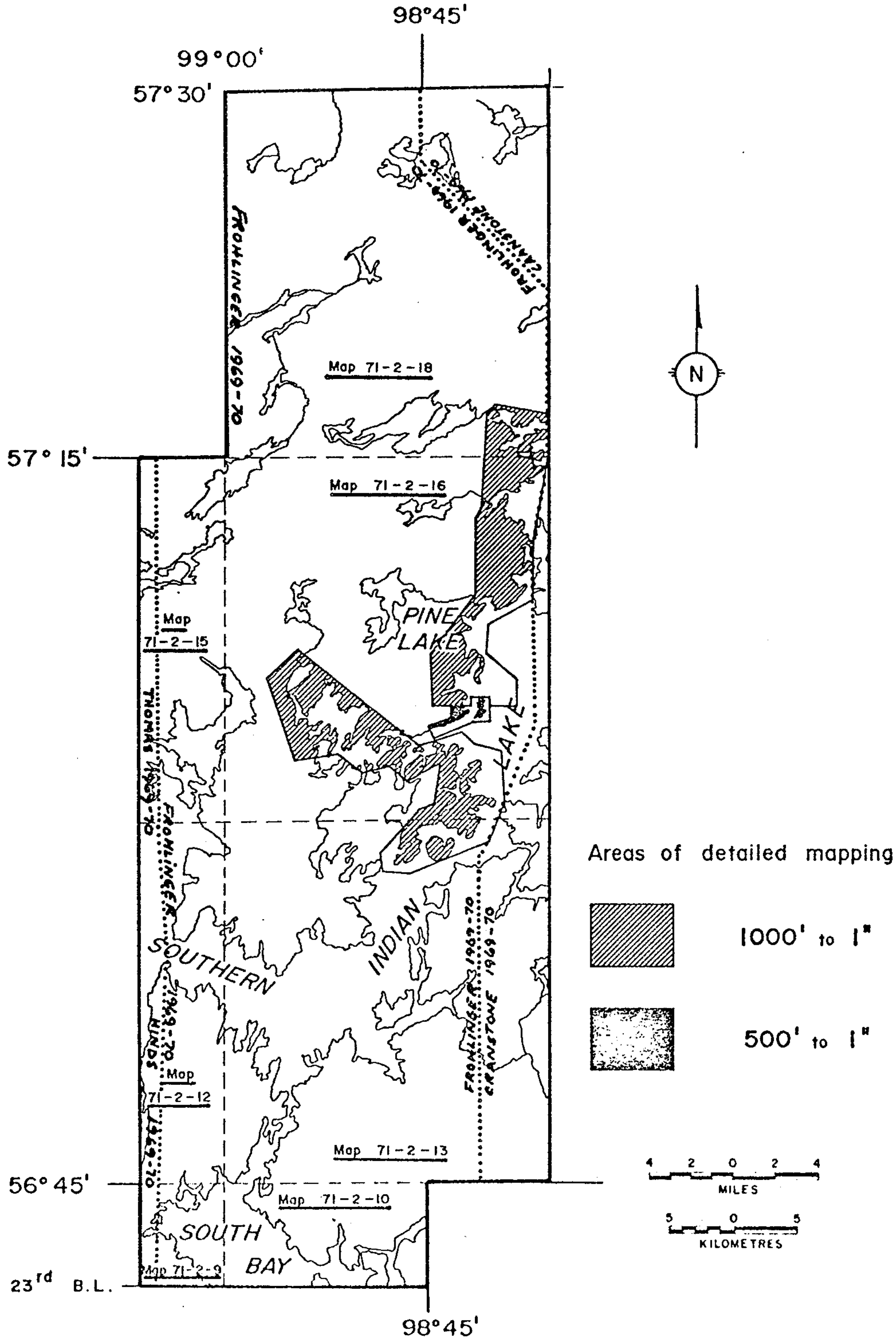

Figure 2. Index map showing boundaries of the map-area, areas of detailed mapping and the distribution of 1:50000 geologic maps covering the map-area and immediate surroundings.

mineral identification were supplemented by X-ray powder diffraction where necessary. Plagioclase compositions were measured in thin-section using the Michel Levy and the Carlsbad-albite twinning extinction angle methods. Olivine compositions were estimated from 2V measurements and are accurate within 10 per cent. For a summary of microscopic characteristics of the major rock types, see Table 5.

Modal analyses were carried out on over 200 samples. A large proportion of these, where the rocks were coarse-grained, were on staines slabs. Where the rocks were too fine-grained for the stained slab method, stained thin sections were analysed. Chemical analyses were performed mainly on ortho-amphibolites to determine original composition. The results are presented in Table 3 and Figures 6 and 7.

Structural Analyses

The map-area was divided into nine structural domains (Figure 10) selected on the basis of recognizable major structures and uniformity of lithology within each subarea. The amount of data available necessarily limited the size of these subareas. All structural measurements were plotted on a 20 cm Schmidt equal-area net using lower hemisphere projection. In areas of complex structure, numerous foliation and minor fold readings have been included from a single station, rather than averaging the values and plotting the mean. Point diagrams were contoured by the Schmidt method (Turner and Weiss, 1963).

The structural trend map (Figure 10) was constructed from orientation data collected in the field. The photo-linear trend map (Figure 10) was constructed from 1 mile to 1 inch aerial photographs. It shows photolinear trends associated with layering and foliation only. Linears correlated with jointing were selectively removed to show more clearly the above trends.

Acknowledgements

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Chapter II

GENERAL GEOLOGY

The discussion of the geology in this section is greatly generalized to acquaint the reader with the distribution and the major characteristics of the principal rock-types.

The map-area can be subdivided into three major genetic zones (Figure 3): (i) a gneissic zone; (ii) a hybrid zone; (iii) a plutonic zone.

(i) Gneissic Zone

The gneissic zone of the northern part of the area consists of greywacke derived paragneisses, migmatites and anatectic rocks. Minor diorite, granite, amphibolite and diabase dykes, sills and stocks are present. The rocks are predominantly well-layered and foliated, and most show varying degrees of folding and shearing. Two major structural trends are present; in the eastern section, an east-west vertical trend is present and in the western section, a northeast-southwest relatively shallow dipping trend is present. The two apparently butt against one another in the central portion of the area. Unfortunately, this crucial area is covered by thick overburden, thus information is scant. For the most part, aeromagnetic signatures (Figure 4) are characteristically low (absolute values less than 2600 gammas) with little relief. One notable exception is the magnetic high at Pine Lake which is ascribed to a gabbroic stock. The input electromagnetics (Figure 5) show a

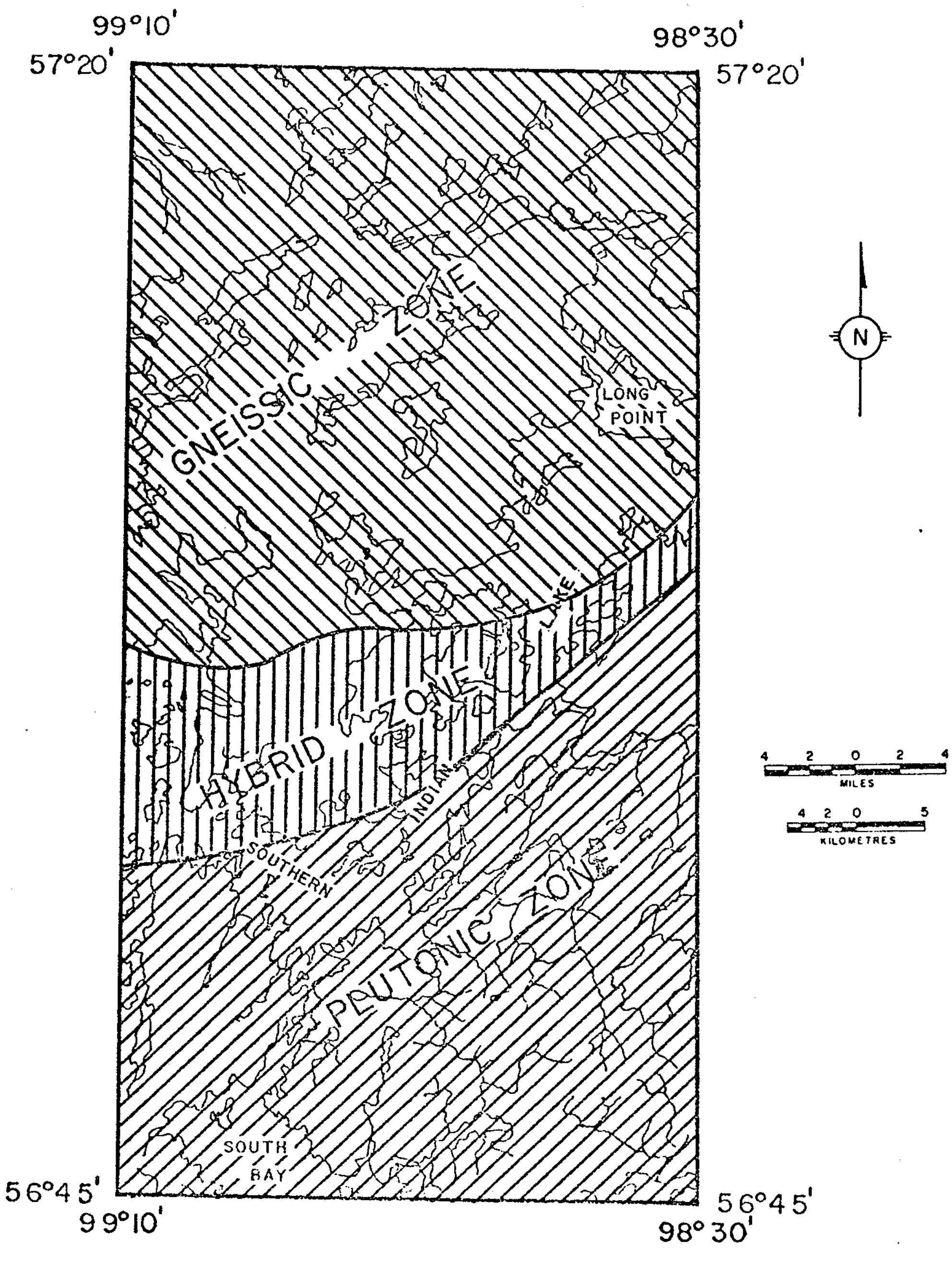

Figure 3. Genetic division of the Central Southern Indian Lake area.

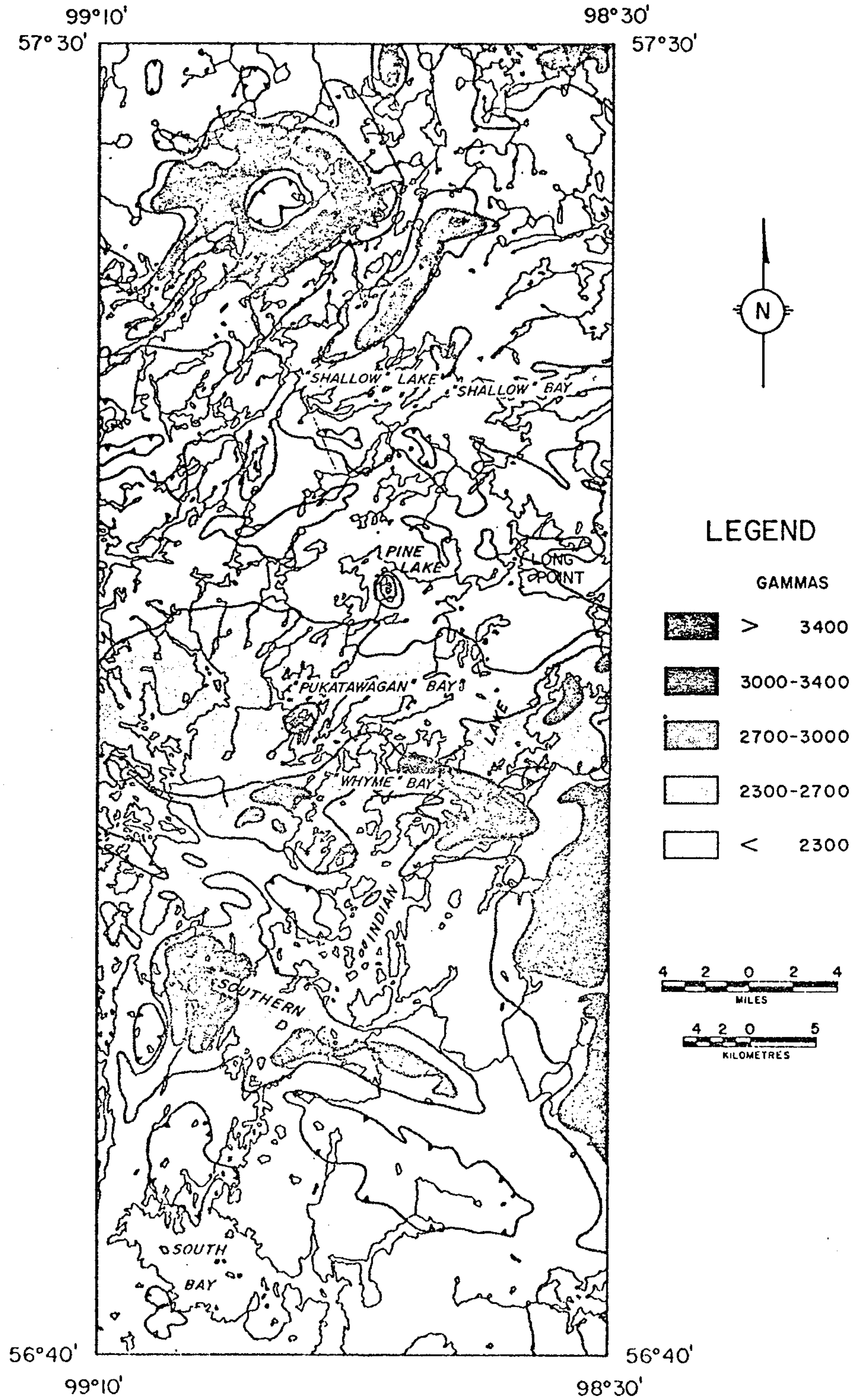

Figure 4. Aeromagnetic anomaly map.

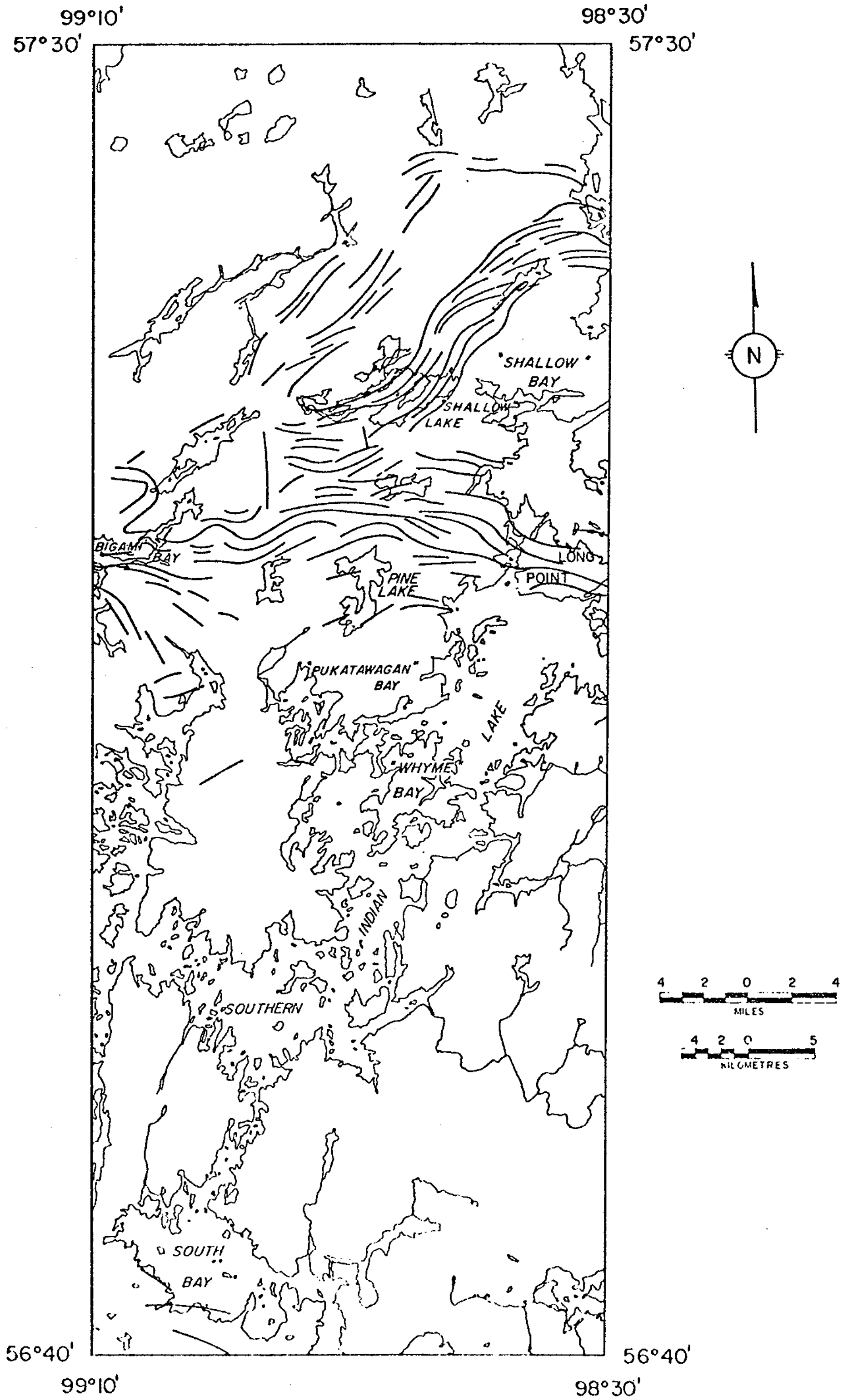

Figure 5. INPUT electromagnetic anomaly trend map.

series of long conductors which outline the major fold structures extremely well. Shorter conductors, apparently not conforming to the major structural directions, are interpreted as fracture zones which often contain pyrite, pyrrhotite and very minor chalcopyrite.

(ii) Hybrid Zone

The hybrid zone is located in the central part of the area and represents a contact phase between the plutonic granites to the south and the gneisses to the north. This zone is composed of numerous inclusions of arkosic metasedimentary rocks and gneisses, metavolcanic rocks and meta-diorite in plutonic rocks of quartz monzonitic composition. The inclusions, which range in size from less than 1 m to as much as 2 km, are interpreted as roof-pendants. The aeromagnetic signature of the hybrid zone (Figure 4) is characterized by intermediate values (2600 - 3000 gammas) with fairly high relief. Locally anomalous areas peak at about 3800 gammas; these areas may represent large magnetiferous meta-sedimentary inclusions thinly veneered by the quartz monzonite. The hybrid zone has a general northeasterly trend.

(iii) Plutonic Zone

The plutonic zone lies south of the hybrid zone. It consists of plutonic quartz monzonite batholiths and associated stocks and plugs. In the eastern part of the plutonic zone, the principal mafic constituent of the quartz monzonite is hornblende. In the western part of the mafic constituent is biotite. The hornblende quartz monzonite is interpreted as the older quartz monzonitic unit because numerous stocks of biotite-quartz monzonite are found intruded into it. Both the hornblende and biotite quartz monzonite are intruded by plugs and dykes of later finer-grained granitoid rocks. The aeromagnetic signature of this unit (Figure 4) ranges from intermediate to high with local lows. The lows are usually circular in form and are interpreted as the younger finer-grained stocks. Structure in the plutonic rocks is difficult to interpret due to the homogeneous nature of these rocks. The apparent structures are interpreted as flow foliation and doming caused by later intrusions.

Chapter III

REGIONAL LITHOLOGIC CORRELATION AND RELATIVE AGES OF ROCK UNITS

The purpose of this section is two-fold: (i) to establish the relative ages of the various rock units within the map-area; and (ii) to show the regional correlation between the lithologic sequences within the gneissic and hybrid zones of the map-area and the Wasekwan and Sickle Groups[1] of the Lynn Lake-Granville Lake area (Milligan, 1960). Units which were correlated with Wasekwan and Sickle Group rocks and then subsequently used as the foundation for the geologic column (Table 1) are here termed "anchor" units.

Geological continuity of the rocks in the area of study with those to the south, where relative ages have been determined (Steeves and Lamb, 1972; Campbell, 1972) is interrupted by quartz monzonite batholiths. The lithologic sequences recognized in the area of this study show remarkable similarities to the Wasekwan and Sickle Groups of the Lynn Lake-Granville Lake area (Table 2; Milligan, 1960). Regional correlation with these two groups depends on a suitable choice of "anchor" units within the study area. These "anchor" units were chosen not only on the basis of their similarity to Wasekwan and Sickle Group rocks, but also on the basis of readily distinguishable features in the field. Only two units, ortho-amphibolite (4(1)), and meta-arkose (7b),

1 The term Group is used in accordance with the Stratigraphic Code, section 9f, rather than Series as suggested by Milligan (1960).

Age	Group	No.	Rock	No.	High grade derivatives / related rocks
PLEISTOCENE AND RECENT			Unconsolidated sand, till and boulder deposits, clays		
GREAT UNCONFORMITY					
PRECAMBRIAN	LAMPROPHYRE AND DIABASE	23	Diabase		
		22	Lamprophyre		
	INTRUSIVE CONTACT				
	PEGMATITE AND APLITE	21b	Muscovite pegmatite		
		21a	Biotite pegmatite		
		20	Aplite		
	GRANITIC INTRUSIVE ROCKS	16	Fine-grained quartz monzonite	18	Tonalite
		15	Porphyritic biotite-quartz monzonite		
		14b	*Medium-grained hornblende-quartz monzonite*	19b	*Magnetite-biotite quartz monzonite*
		14a	Porphyritic hornblende-quartz monzonite and minor syenite	19a	*Magnetite-hornblende quartz monzonite*
		13b	*Magnetite-biotite granodiorite*	17	*Gneissic hornblende granodiorite; quartz diorite*
		13a	Granodiorite; (includes minor anatectic granodiorite)		
	INTRUSIVE CONTACT				
		12	*Quartz diorite*		
	INTRUSIVE CONTACT				
	POST-SICKLE-TYPE BASIC INTRUSIVE ROCKS	11	*Diorite; quartz diorite; hornblende granodiorite*		*HIGH GRADE DERIVATIVES*
		10	Meta-gabbro; meta-diorite	10(1)	*Ortho-amphibolite*
	INTRUSIVE CONTACT				
	SICKLE-TYPE ROCKS	9	Metavolcanic rocks II		
		8	Meta-greywacke	8(3)	Plagioclase diatexite
				8(2)	Plagioclase metatexite
				8(1)	Plagioclase paragneiss
		7b	Meta-arkose and quartzite	7(4)	Anatectic quartz monzonite
		7a	Meta-conglomerate	7(3)	Potassium feldspar diatexite
				7(2)	Potassium feldspar metatexite
				7(1)	Potassium feldspar paragneiss
	?UNCONFORMITY?				
	PRE-SICKLE-TYPE BASIC INTRUSIVE ROCKS	6	Ultramafic rocks		
		5	Meta-gabbro, meta-diorite	5(1)	Ortho-amphibolite
	INTRUSIVE CONTACT				
	WASEKWAN-TYPE ROCKS	4	Metavolcanic rocks I	4(1)	Ortho-amphibolite
		3	Calc-silicate rocks	3(1)	Para-amphibolite
		2	*Quartzite*	1(6)	Anatectic granodiorite
		1	*Meta-greywacke*	1(5)	Potassium feldspar diatexite
				1(4)	Plagioclase diatexite
				1(3)	Potassium feldspar metatexite
				1(2)	Plagioclase metatexite
				1(1)	Plagioclase paragneiss
					(↑ INCREASING MOBILIZATION)

Table 1. Table of Formations

Note: Italicized rock names correspond to those units which appear in the surrounding map areas only (Cranstone, 1972 and Thomas, 1972) and are included here only for completeness.

LYNN LAKE-GRANVILLE LAKE AREA (after Milligan, 1960)	SOUTHERN INDIAN LAKE AREA, CENTRAL PORTION	
POST-SICKLE INTRUSIVE GROUP		
Late lamprophyre dykes	Lamprophyre and diabase	(22, 23)
	INTRUSIVE CONTACT	
Several phases of granitic intrusive rocks	Granitic intrusive rocks including pegmatite and aplite	(12-21)
	INTRUSIVE CONTACT	
	*POST-SICKLE-TYPE BASIC INTRUSIVE ROCKS**	
Gneissic tonalite and Black Trout Diorite	Diorite, quartz diorite, hornblende granodiorite, meta-gabbro, meta-diorite	(10, 11)
INTRUSIVE CONTACT	*INTRUSIVE CONTACT*	
SICKLE GROUP	*SICKLE-TYPE ROCKS**	
Arkose	Metavolcanic rocks	(9)
Conglomerate	Meta-greywacke	(8)
	Meta-arkose	(7b)
	Meta-conglomerate	(7a)
UNCONFORMITY	UNCONFORMITY?	
PRE-SICKLE INTRUSIVE GROUP	*PRE-SICKLE-TYPE BASIC INTRUSIVE ROCKS**	
Biotite granite, granodiorite	Ultramafic rocks	(6)
Tonalite, minor diorite	Meta-gabbro, meta-diorite	(5)
Diorite, minor gabbro and tonalite		
Gabbro, ultramafic rocks		
INTRUSIVE CONTACT	*INTRUSIVE CONTACT*	
WASEKWAN GROUP	*WASEKWAN-TYPE ROCKS**	
Banded iron formation	Metavolcanic rocks	(4)
Volcanic flows and pyroclastic rocks	Calc-silicate rocks	(3)
Quartzite		
Greywacke, minor quartzite	Meta-greywacke	(1)
Conglomerate		

*The terms "Sickle-type" and "Wasekwan'type" are used in view of the fact that definite stratigraphic correlation with Sickle and Wasekwan Group rocks has not been established.

Table 2. Correlation of the Lynn Lake - Central Southern Indian Lake lithologies.

comply with these parameters and were used in establishing the regional correlation.

The ortho-amphibolite is readily identified in the field by its grain-size, color and fabric. The only similar unit in the area is the para - amphibolite (3(1)), which may be easily distinguished by its continuous layering and higher quartz content. Similarities to Wasekwan metavolcanic rocks of the Rusty Lake area (Steeves and Lamb, 1972) are shown by chemical analysis of representative samples of the anchor unit 4(1), (Table 3, Figures 6 and 7). The Rusty Lake metavolcanic rocks are unique in that they have high CaO:MgO ratios. The same relationship characterizes units 4 and 4(1). The former apparently suffered less intense deformation than those in the map-area and consequently correlation on the basis of fabric is impossible. The meta-arkose (7b) is distinguished in the field by its color and layering. Its appearance is similar to Sickle arkoses in the Granville Lake area (Campbell, 1972). Meta-arkoses correlated with the Sickle Group east of the map-area (Cranstone, 1972) are continuous into the meta-arkose and its metamorphic derivatives (7(1)-7(4)) at "Shallow" Bay and are very similar to those occurring at "Whyme" Bay. Thus, the ortho-amphibolite is assigned to the older Wasekwan Group and the meta-arkose to the younger Sickle Group.

The interpreted correlation discussed above is the basis for determination of the relative ages of the rest of the rocks in the map-area. The meta-greywacke and its metamorphic derivatives (1(1)-1(6)) occur as xenoliths in the metavolcanic rocks (4) and derived amphibolite