THE VOLCANOLOGY AND SEDIMENTOLOGY OF THE KAMINAK GROUP, CARR LAKE DISTRICT OF KEEWATIN, N.W.T.

A Thesis Presented

to the

Faculty of Graduate Studies

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In Partial Fulfillment

of the

Requirements for the Degree

Master of Science

by

Kent R. Barrett

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KENT R. BARRETT

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

Geological mapping of a 1200 square km segment of the Archean Kaminak greenstone belt has revealed that at least two major volcanic sources contributed to the deposition of a volcano-sedimentary succession. A mafic volcanic source to the west of the study area extruded a thickness of at least 10 km of mafic pillowed lavas. A second major volcanic source to the south of the Carr Lake area produced a thickness of greater than 7 km of intermediate to felsic volcanic fragmental rocks and flows. Volcaniclastic material was deposited predominantly by debris flows and turbidity currents. The fragmental rocks represent a volcaniclastic apron that surrounded the volcanic source with debris flow deposits which were more proximal to the source than turbidity current deposits.

Both volcanic piles were deposited largely below sea level. Field evidence suggests that almost the entire mafic volcanic pile was deposited at water depths between 100 m and 2 km. There is evidence to suggest that each volcanic pile became locally emergent at least once during their volcanic history. The volcanic piles developed under water by pulses of upward growth towards sea level accompanying and followed by pulses of isostatic subsidence. The two major volcanic sources were contemporaneous and restricted the lateral growth of one another.

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INTRODUCTION

PURPOSE AND OBJECTIVES

The Kaminak greenstone belt is an Archean succession of metavolcanic, metasedimentary and plutonic rocks within the Churchill Structural Province. The greenstone belt extends from Rankin Inlet to Ennadai Lake, N.W.T. and is overlain in some areas by outliers of Aphebian sedimentary and volcanic rocks.

The study concerns itself with a small segment of the Kaminak greenstone belt in the Carr Lake - Turquetil Lake area (hereafter referred to as the Carr Lake area).

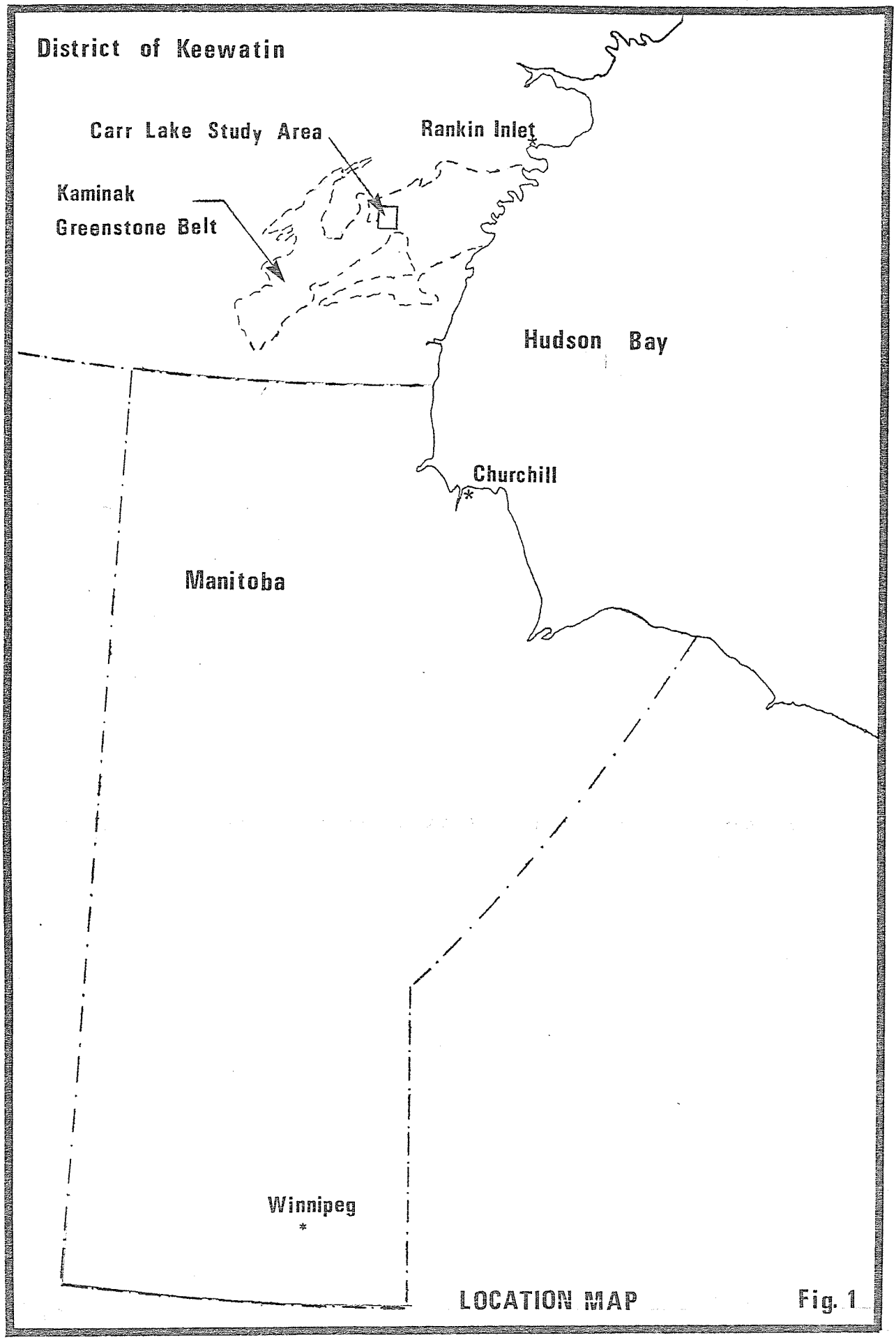
The main objectives of the study are:

1. to map the distribution of Archean metavolcanic and metasedimentary rocks of the Carr Lake area.
2. to delineate the gross structure of these rocks.
3. to outline the stratigraphic relations of volcanic and sedimentary rocks.
4. to determine the environment of deposition and provenance of the supracrustal rocks.
5. to reconstruct the volcanic history and paleogeography of the Carr Lake area during deposition of the Kaminak Group.

LOCATION AND ACCESS

The area of investigation is located in the south-central District of Keewatin, N.W.T., approximately 300 km north-northwest of Churchill, Manitoba (see Fig. 1).

The area incorporates a part of each of the following



LOCATION MAP Fig. 1

N.T.S. map sheets: 55-E/13, 55-L/4, 65-H/16, 65-I/1. The boundaries of the area of investigation are 95° 40' and 96° 15' W longitude and 61° 50' and 62° 7.5' N latitude.

The principal means of access to this region is by aircraft. Transportation within the area of investigation was by aircraft, boat and on foot.

The Carr Lake area is in the southern barren grounds, a few kilometers north of the treeline. The topography is characterized by low relief, an abundance of small lakes and a deranged drainage pattern. The few rivers that are present in the area link only the larger lakes.

Bedrock is exposed in only five percent of the area of investigation. Surficial deposits covering bedrock consist mainly of glacial tills and esker deposits of Pleistocene age. A late Pleistocene transgression in this area caused minor reworking of the glacial deposits resulting in numerous raised beaches (Lee, 1959; Ridler and Shilts, 1974a).

PREVIOUS WORK

The Kaminak greenstone belt was first delineated by reconaissance scale mapping conducted during Operation Keewatin (Wright, 1967). Later G.S.C. mapping at more reduced scale (1:250,000 and 1:253,440) resulted in geological maps for the Kaminak Lake map sheet (N.T.S. 55-L), (Davidson, 1970a); the Eskimo Point map sheet (N.T.S. 55-E), (Davidson, 1970b); and the Henik Lakes - Ferguson Lake map sheets (N.T.S. 65-H and 65-I), (Bell, 1968, 1971). Ridler (1971 a, b; 1972, 1973, 1974) and Ridler and Shilts (1974 a,b) have also made

contributions to the understanding of the regional stratigraphy, structure and metallogeny of the Archean metavolcanic and metasedimentary rocks within this belt.

COURSE OF INVESTIGATION

Field investigations for the present study were conducted during the field seasons of 1976 and 1977. Geological mapping was done at a scale of 1:31,680.

Field classification of volcanic rocks was based on mineralogy, colour, texture and hardness similar to methods described by Jensen (1975). Thin sections were studied to check field identification of rock types and to examine rock microtextures.

ACKNOWLEDGEMENTS

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GENERAL GEOLOGY

GENERAL STATEMENT

The Kaminak greenstone belt, also known as the Rankin - Ennadai belt is an inlier of Archean rocks within the rocks of the Churchill Structural Province. The metamorphosed volcanic and sedimentary rocks of this belt have been designated the Kaminak Group (Davidson, 1970a). The Kaminak greenstone belt is enclosed by younger granitoid and gneissic rocks which are pre-Hudsonian Orogeny. These granitoid and gneissic rocks are reworked Aphebian and Archean supracrustal and plutonic rocks (Davidson, 1972).

The Kaminak Group was intruded by later Archean plutons which range in composition from gabbro to granite. Archean rocks are unconformably overlain by post-Kenoran Orogeny volcanic and sedimentary rocks and have been intruded by post-Kenoran porphyritic diabase dykes. The interrelationships of the rock types present in the Carr Lake area are outlined in the Table of Formations (Table 1).

DESCRIPTION OF FORMATIONS

Kaminak Group

The oldest rocks of the Carr Lake area belong to the Kaminak Group. They consist of a highly complex sequence of volcanic and sedimentary rocks. The volcanic rocks have been subdivided according to chemical composition into mafic, intermediate and felsic volcanic rocks which have been

TABLE 1

TABLE OF FORMATIONS

AGE	GROUP	LITHOLOGY
Early Aphebian (pre-Hudsonian Orogeny)		Porphyritic Diabase Dykes
	Intrusive Contact	
		Basalt
		Conglomerate
	Unconformity	
Archean	Kenoran Orogeny	
		Plutonic Rocks
	Intrusive Contact	
	Kaminak Group	Mafic, Intermediate and Felsic Metavolcanic and Metasedimentary Rocks

designated as Rock Types 1 to 3 respectively in Fig. 2. The various clastic and chemical sedimentary rocks have been grouped together to form Rock Type 4 of Fig. 2. The rock types of the Kaminak Group are rock-stratigraphic, rather than time-stratigraphic in nature and are complexly interbedded so that no chronology is implied in their number designation.

Ridler has published 420 chemical analyses of volcanic rocks of the Kaminak Group, mainly of samples collected within or near the Carr Lake area (Ridler, 1974; and Ridler and Shilts, 1974a). His studies reveal that the volcanic rocks are sub-alkaline in character and range in composition from basalt to rhyolite.

Mafic Volcanic Rocks: Rock Type 1 is composed of basaltic pillowed and massive flows, tuffs and breccias as well as syn-volcanic dykes and sills. Most mafic volcanic rocks are aphyric. Plagioclase phenocrysts, however may constitute up to five percent of some flows. Some of these phenocrysts are up to 12 cm long. Phenocrysts of ferromagnesian minerals are rarely observed, even in thin section. Most flows are amygdaloidal. Amygdules range from 1 mm to 10 mm in diameter and the filling material is usually quartz or carbonate. Amygdules may constitute up to five percent of some flows.

Pillowed lava (rock type 1p of Fig. 2) is the most common mafic volcanic rock type. Most pillows are bun or loaf shaped (see Shrock, 1948). Their shape can commonly be used to determine facing direction and their long axes are generally aligned sub-parallel to the local strike.

Some mafic flows contain an abundance of pillows with quartz-eye structures (see Shrock, 1948). Each quartz-eye structure is an elongate cavity 5 cm to 20 cm long and 1 cm to 3 cm wide with a flat lower surface and an irregularly convex upper surface (see Plate 1). The cavity is filled with either quartz or carbonate. A single pillow may contain several quartz-eye structures stacked one above another. They generally have their long axes subparallel to the local strike. The quartz-eye structures occur near the upper surface of pillows and so are reliable indicators of stratigraphic sequence.

Some pillowed lavas are variolitic (rock type vlp). The varioles are subspherical and range in size from less than 1 mm to 4 cm in diameter. The distribution of varioles within a single pillow is similar to the distribution described by Lauren and Hebert (1977). A section of a variolitic mafic pillow reveals that the varioles are concentrated in an elliptical belt that lies between the outer rim of the pillow and the pillow core.

Massive flows (rock type 1 m) are present as irregular lenses within pillowed lava successions. Columnar jointing was observed in a massive flow (rock type 1 c) located 7 km north of the mouth of the Kogtok River (see Fig. 2 and Plate 2). The long axes of the columns are oriented perpendicular to the regional strike. This orientation is consistent with primary jointing formed shortly after the flow was extruded.

Very fine to medium grained mafic dykes and sills (rock



Plate 1. Quartz-eye structure in mafic pillowed lava (rock type 1 p). Quartz-eye structure (to the left of the hammer head) has been hollowed out by leaching. Stratigraphic "tops" is towards the top of the plate.



Plate 2. Outcrop of columnar jointed basalt (rock type lc). Columnar jointing is oriented perpendicular to the strike of the stratigraphic unit. The jointing is interpreted as having formed in a subaerially extruded mafic flow during the cooling and crystallization of the lava. The person shown in the plate is leaning against the upper surface of the flow.

type 1 d) are generally 2 m to 10 m in width. They have irregular contacts with the intruded host rocks and dyke terminations are abrupt when observed. Mafic dykes invariably intrude host rock of similar composition (i.e. mafic volcanic rocks). The mafic dykes and sills are very abundant and field evidence indicates that the dykes are synvolcanic and that many of them fed mafic flows.

Intermediate Volcanic Rocks: Rock Type 2 of Fig. 2 is composed of andesitic to dacitic fragmental rocks, flows and synvolcanic dykes. Fragmental volcanic rocks are the most prevalent rock types. These consist of tuffs, lapilli-tuffs and breccias (rock types 2t, 2l and 2b respectively); each of which reflects the modal grain size of volcanic fragments present.

The fragmental intermediate volcanic rocks are composed of angular to subrounded volcanic fragments set in a fine grained matrix (see Plate 3). Clast composition is heterolithic, ranging from rhyolite to andesite. Basaltic fragments are rare. There is generally a complete gradation in size from the matrix material to the largest clast which may exceed 1 m in diameter. Because of this gradation, all clasts less than 2 mm in diameter (i.e. all ash sized fragments) were arbitrarily designated as matrix. The more melanocratic nature of the matrix suggests that its bulk composition is more mafic than the coarse size fraction.

Intermediate flows constitute about thirty percent of Rock Type 2. Massive flows (rock type 2 m) predominate over



Plate 3. Intermediate lapilli-tuff (rock type 21). Andesite to dacite clasts are supported by a slightly more melanocratic matrix of similar composition. Note the angularity of the clasts. This is interpreted as a debris flow deposit. Stratigraphic "tops" is towards the top of the plate.

pillowed flows (rock type 2 p). All intermediate volcanic flows are very fine grained and porphyritic. Feldspar phenocrysts are almost always present. Quartz and mafic phenocrysts are much less common. Phenocrysts generally constitute between 10% and 40% of the bulk of a flow. Some intermediate pillowed flows are variolitic (rock type v2p). Amygdules are common. They may exceed 3 cm in diameter and may constitute up to 25% of the bulk of a flow.

Dykes of andesitic to dacitic composition (rock type 2 d) almost exclusively intrude volcanic rocks of intermediate composition. The dykes are fine grained and porphyritic. They range between 1 m and 5 m wide and have irregular contacts with the host rock. These dykes are synvolcanic and many of them must have served as feeders for intermediate flows.

Felsic Volcanic Rocks: Rock Type 3 of Fig. 2 is composed of rhyodacite to rhyolite flows, domes, tuffs, breccias and synvolcanic dykes. Felsic flows and domes (rock type 3 m) are aphanitic and usually porphyritic. The most common phenocrysts are quartz and feldspar, but biotite and amphibole may be present. Phenocryst content rarely exceeds 25%. Amydgules are common and they may be up to 3 cm in diameter.

Individual felsic domes are commonly several hundred meters thick but never very laterally extensive. Felsic flows east of Spi Lake and northwest of Mud Lake (see Fig. 2) approach 1 km in thickness and can be classified as true felsic domes. Associated flank breccias attest to the endogenous

nature of these domes (Parsons, 1969). Pillowed felsic flows are very rare but they have been observed northwest of Spi Lake.

Felsic tuffs (rock type 3 t) are fine grained, well sorted and thinly bedded. Graded bedding is common. Felsic breccias (rock type 3 b) are oligomictic and poorly sorted. Clast diameter may exceed 50 cm and matrix content is variable. These breccias are mainly flow breccias and crumble breccias associated with felsic flows and domes (Parsons, 1969).

Felsic dykes (rock type 3 d) are fine grained and are commonly porphyritic. They are generally 1 m to 5 m wide and have irregular contacts with the intruded rock. These dykes most commonly intrude felsic flows and fragmental rocks. The dykes are synvolcanic and many of them were probably feeders to felsic flows.

Sedimentary Rocks: Rock Type 4 of Fig. 2 is composed of a variety of clastic and chemical sedimentary rocks which include conglomerate, sandstone, slate, argillite, iron-formation, chert and dolomite.

Conglomerate (rock type 4 d) may be either matrix or clast supported. Pebbles and cobbles are angular to rounded. Matrix is predominantly sand sized. The conglomerates are rarely bedded but thin sandstone lenses may be present. Conglomerate clasts are generally of volcanic provenance but tonalitic fragments may be present (see Plate 4) and are very abundant in some localities. The matrix is composed of quartz



Plate 4. Orthoconglomerate (rock type 4d). Clasts are sub-rounded basalt and tonalite pebbles which are framework supported. The matrix is sand sized and consists predominantly of quartz and feldspar grains. The clasts are interpreted as having been transported and deposited by traction currents. Stratigraphic "tops" is towards the top of the plate.

and feldspar grains and lithic fragments.

Sandstone (rock type 4 c) includes thinly bedded lithic arenite, quartz arenite, arkose and lithic greywacke. Load structures and graded bedding may be present. Slates and argillites (rock type 4 a) are thinly bedded to laminated. They are commonly pyritic and carbonaceous.

Oxide (rock type 4 o), sulfide (rock type 4 s) and carbonate (rock type 4 f) facies of iron-formation are present in the area of investigation. Their nature and occurrence is similar to the iron-formation in the Superior Structural Province as described by Goodwin (1973).

Green, red, white and black varieties of chert are present in the Kaminak Group. Chert occurs interlaminated with argillites and with sulfide and oxide facies iron-formation. Chert is commonly interbedded with felsic to intermediate volcanic tuffs (rock types c2t and c3t respectively). Chert also occurs as laminated beds up to 20 m thick (rock type 4 h). Load structures and graded bedding may be present (see Plate 5).

One small outcrop of highly recrystallized dolomite (rock type 4 e) was observed.

Plutonic Rocks

Rocks of the Kaminak Group have been intruded by plutons which range in composition from gabbro to granite, but most commonly are tonalitic in their average composition. These plutons have been designated Rock Type 5. Most plutons are composite. Gabbroic phases have been designated Rock Type 5a.



Plate 5. Graded bedding and load structures in green laminated chert. Note the delicate nature of the sedimentary structures. This chert is interpreted as having been deposited in deeper water. Stratigraphic "tops" is towards the top of the plate.

Agmatite (rock type 5 b) is sometimes present near the margins of plutons.

Wanless and Eade (1975) reported a U-Pb zircon age of 2550 m.y. for Archean granodiorite near North Henik Lake. Since the pluton intrudes the Kaminak Group, a minimum age could be assigned to the volcanic rocks. Subsequent to this study, Wanless and Loveridge (1978) summarize published and unpublished Rb - Sr and U-Pb ages for Archean rocks in the region. An alkalic pluton that intrudes volcanic rocks of the Kaminak Group and other Archean plutons, at Kaminak Lake, yields a Rb - Sr whole rock age of 2787± 56 m.y.

Conglomerate

A conglomerate (rock type Ps) unconformably overlies Archean rocks 4 km west of Carr Lake. Field evidence indicates that the conglomerate postdates Archean volcanic and plutonic rocks, but is older than Aphebian volcanic rocks in the Carr Lake area. The conglomerate underlies the Spi Lake basalt which is interpreted as Early Aphebian in age (Beavon, 1976).

The conglomerate is composed of frame supported, sub-rounded tonalitic and metavolcanic pebbles and cobbles with a quartz-rich sandy matrix. Coarse quartz-rich sandstone lenses are sometimes present within the conglomerate. The local relative abundances of lithic fragments appear to reflect the nature of the underlying Archean basement. The southernmost exposures of conglomerate in the area of study are rich in felsic volcanic clasts which were probably derived from an Archean rhyolitic source in Spi Lake area. Further north;

where the conglomerate overlies Archean plutonic rocks; the pebbles and cobbles are largely tonalitic.

Basalt

The Aphebian conglomerate unit (rock type Ps) is overlain by massive unfoliated mafic volcanic flows (rock type Pb), which have been termed the Spi Lake basalt by Beavon (1976). These flows are fine grained to aphanitic and commonly have large (1 cm to 10 cm long) plagioclase phencrysts. Amygdules and interflow sediment are sometimes present and poorly developed pillowed structures have been reported (Beavon, 1976).

Porphyritic Diabase Dykes

Fresh unfoliated mafic dykes (rock type Pd) are very common in the Carr Lake area. They are commonly referred to as the Kaminak dyke swarm (Christie et al, 1975), and have been dated (K/Ar) at 2330± 200 m.y. (Davidson, 1970a). The dykes are fine to medium grained and commonly contain tubular plagioclase phenocrysts. Phenocrysts range from less than 1 cm to 15 cm in length. The dykes are very similar petrographically to the Aphebian mafic flows (rock type Pb) and both contain large tabular plagioclase phenocrysts. They are considered to be of similar age.

Dykes are 1 m to 25 m wide. Davidson (1970a) has noted that they commonly trend slightly east of north. Many dykes are oriented obliquely to this trend.

STRUCTURAL GEOLOGY

The geology map of the Carr Lake area (Fig. 2) was used as the basis for the interpretation of the structural geology. As well as illustrating the areal distribution of the various rock types found in the Carr Lake area, it shows the various structural elements produced by the deformation of these rocks. It shows the small scale structural features such as foliation, bedding plane and lineation orientations and direction of sequence. Figure 2 also shows the large scale structural features such as the axial traces of synclines and anticlines. This map also shows the locations of the three cross sections A-A', B-B' and C-C' of Fig. 3. These cross sections were helpful in positioning the fold axial traces of Fig. 2.

FOLDING

Two deformational events that have affected the Precambrian rocks of the Carr Lake area have been recognized. The earlier event, designated "D_1", deformed the volcanic and sedimentary strata of the Kaminak Group. The later deformational event, designated "D_2", folded the Aphebian supracrustal rocks of the Carr Lake area but had only minor effect on the structure of the earlier Archean rocks.

$\underline{D_1}$ - The earliest and strongest deformation event produced the isoclinal folding of the rocks of the Kaminak Group. Bedding planes in these strata seldom dip less than

75° and they are commonly overturned. This deformational event has produced a very pronounced subvertical penetrative foliation that is almost always sub-parallel to the bedding plane.

The axial traces of the D_1 folds are shown in Fig. 2. The axial traces of the synclines tend to wrap around the margins of the four major plutons. The plutons form the cores of anticlinal or domal areas. The cross sections show that between these domes, the rocks of the Kaminak Group are isoclinally folded into broad synclines. This dome and basin style of deformation is very common in the Kaminak greenstone belt (see Ridler and Shilts, 1974a; Fig. 3). All the major D_1 folds plunge into a central depression located immediately south of Spi Lake. This is very similar to the deformation style of Archean sedimentary rocks in the Savant Lake area of northern Ontario as described by Shegalski (1975). The D_1 deformation appears to have been directly related to the emplacement of the plutons, so the age of these plutons (2550 m.y.) can be used as an approximate date for this deformational event.

D_2 - Aphebian sedimentary and volcanic strata (rock types Ps and Pb respectively) post date D_1, but have been folded by a younger deformational event termed D_2.

The D_2 deformation is interpreted to have folded the Aphebian supracrustal rocks into a syncline. The same event produced downwarping of the Archean basement and folding of

the unconformity surface between Aphebian and Archean basement rocks. This relationship is illustrated by cross section B-B' of Fig. 3.

Evidence for this is:

1) The contact between the Aphebian supracrustal rocks and underlying Archean rocks is an angular unconformity.
2) The Aphebian conglomerate (rock type Ps) possesses a north-south trending subvertical foliation which is oblique to the northwest-southeast trending fabric of the underlying Archean rocks.
3) The axial trace of folded Aphebian strata is parallel to N-S foliation of the Aphebian conglomerate and is oblique to the axial traces of folded Archean strata.

Understanding of the exact structural relationships between Archean and Aphebian rocks in the study area is hindered by lack of outcrop.

In some areas volcanic rocks of the Kaminak Group possess a weak north-south trending subvertical foliation in addition to the prominant D_1 foliation (see Plate 6). Field relations demonstrate that it is later than the D_1 foliation and that it is sub-parallel to the foliation present in the Aphebian conglomerate (rock type Ps) north of Spi Lake. This supports the hypothesis that the Archean basement rocks were involved to some degree in the D_2 deformation event but that the

effects were minor.

Wanless and Eade (1975) have reported Rb-Sr whole-rock ages in the region which establish limits for the time of D_2 deformation. Proterozoic (Hurwitz Group) volcanic rocks give an age of 1872± 35 m.y. while a quartz monzonite pluton interpreted as syntectonic, and intrusive into the Archean plutons, gives an isochron age of 1834± 22 m.y. Finally, the post-tectonic Nuelton Lake granite gives an age of 1760± 16 m.y., thus bracketing the duration of the Hudsonian Orogeny in this part of the Churchill structural province.

FAULTING

Numerous faults are present in the Carr Lake area. They usually involve only minor displacements. Orientation and age of faulting are probably diverse (Ridler and Shilts, 1974a). Poor exposure and lack of good stratigraphic markers impede the study of faulting. The maximum apparent displacement observed was along a fault present in the northwest corner of the study area (see Fig. 2). The contact between a variolitic flow and a porphyritic flow has been displaced 2 km horizontally by a northwest-southeast trending fault.



Plate 6. Two oblique foliations in an intermediate lapilli-tuff (rock type 21). The later diagonal trending foliation cross cuts an earlier foliation (trending perpendicular to the top of the plate) which is associated with D_1 deformation event.

METAMORPHISM

Davidson (1970a) has shown that the rocks of the Kaminak Group in the Carr Lake area have undergone two periods of metamorphism. The earlier event produced greenschist to amphibolite facies metamorphic grades in the volcanic and sedimentary rocks of the Kaminak Group. Metamorphic grade in these rocks increases towards the margins of Archean plutons (Davidson, 1970a). This metamorphic event coincides with the intrusion of Archean plutons referred to above and also coincides with the D_1 deformation event.

A later metamorphic event has affected all Precambrian rocks of the Carr Lake area. Davidson (1970a) studied the metamorphic mineral assemblages present in Aphebian dykes (rock type Pd) in the Carr Lake area. He concluded that the metamorphic grade related to the second thermal event increases in a northwesterly direction. South of Spi Lake; including most of the study area; the mafic dykes are essentially unmetamorphosed. Northwest of Spi Lake the metamorphic grade rises quickly, such that it is approaching greenschist facies at the northern fringe of the study area (see Davidson, 1970a, Fig. 6).

This second metamorphic event probably corresponds to the Hudsonian Orogeny which has affected the Churchill Structural Province. The relationship between the second metamorphic event and the D_2 deformational event is unclear.

DEPOSITIONAL FACIES OF THE KAMINAK GROUP

INTRODUCTION

This section presents an interpretation of the depositional facies of the Kaminak Group. Each of the lithological types described previously has been studied to determine the mode of deposition, the position of deposition and the environment of deposition to whatever degree it is revealed by the rocks themselves. These aspects combined with the basic lithology of the rock types permit the discrimination of depositional facies.

Table 2 summarizes the attributes of the seven facies which have been identified. Identification of the mode, position and environment of deposition, where possible, is based primarily on textural and mineralogical criteria as well as field relationships. Each of the seven facies is distinctive and different than the other facies. The Kaminak Group depositional facies map (Fig. 4) shows the areal distribution of these facies in the Carr Lake area.

DESCRIPTION OF DEPOSITIONAL FACIES

Facies I - Subaqueous Mafic Flows

This facies of mafic subaqueous flows is composed predominantly of basaltic pillowed lavas and includes all mafic volcanic rocks (rock type 1) of Fig. 2. The pillowed structures indicate that these lavas have been quenched in a subaqueous environment. The thickness of rocks of this facies

TABLE 2
DEPOSITIONAL FACIES OF THE KAMINAK GROUP

FACIES	LITHOLOGY	MODE OF DEPOSITION	POSITION OF DEPOSITION	ENVIRONMENT OF DEPOSITION
Facies I Subaqueous Mafic Flows	Mafic lavas	Effusive subaqueous flows	Relationship of flows to source vent is unresolved	100 m to 2000 m water depth
Facies II Proximal Facies Of Intermediate Volcanic Rocks	Coarse grained intermediate volcanic fragmental rocks and flows	Debris flows	Proximal to the volcanic source	Unknown
Facies III Distal Facies Of Intermediate Volcanic Rocks	Fine grained intermediate volcanic fragmental rocks and flows	Turbidity currents	Distal from volcanic source	Deposited in water below storm wave base
Facies IV Proximal Facies Of Felsic Volcanic Rocks	Rhyolite breccias and flows	Viscous lava flows and associated flow breccias	Very proximal to the volcanic source	Unknown
Facies V Distal Facies Of Felsic Volcanic Rocks	Rhyolite tuffs	Airfall or water settled tuffs	Distal from volcanic source	Subaqueous (?)
Facies VI Shallow Water Sedimentary Facies	Sandstone, dolomite orthoconglomerate	Traction currents	Shallow water depths	Fluvial or shore/near shore deposits
Facies VII Deeper Water Sedimentary Facies	Chert, iron-formation slate, argillite, greywacke	By turbidity currents or by release from suspension	Deeper water depths	Below storm wave base

is up to 7 km, which indicates that they have been extruded into a deep body of water or a deepening basin.

Almost all the flows that constitute Facies I are amygdaloidal. Vesicles will not form in lavas extruded at water depths exceeding 2 km because the hydrostatic pressure will impede vesiculation (Moore, 1965, 1970; Jones, 1969). The presence of vesicles is evidence that the environment of deposition of these flows was at water depths of less than 2 km.

There is a dearth of fragmental rocks within the subaqueous mafic flow facies. At water depths of less than 100 m, low hydrostatic pressures associated with the shallow depth promote increased pyroclastic activity. More importantly, hydro-explosive volcanism, a phreatic process (Parsons, 1969); is an extremely important process at water depths of less than 100 m (Cotton, 1969; Jones, 1969). In summary the data suggest that most of the rocks of the subaqueous mafic flow facies were erupted at water depths exceeding 100 m, but less than 2 km into a deepening basin.

One outcrop of columnar basalt (rock type 1c) was observed within the confines of the rocks of this facies (see Plate 3). Field evidence suggests that this is a flow rather than an intrusion. The columnar character is the only evidence of subaerial volcanic activity associated with Facies I.

The well formed shapes of the pillowed structures in the mafic flows suggests that the mafic lava outpourings occurred on low angled slopes. Unfortunately these rocks tell us little about their proximity to the source vent.

Facies II - Proximal Facies of Intermediate Volcanic Rocks

The distribution of the proximal facies of intermediate volcanic rocks is shown in Fig. 4. The rocks that have been included into this facies are intermediate fragmental volcanic rocks and flows. This facies is interpreted as having been deposited relatively closer to the source areas of volcaniclastic material than the distal facies of intermediate volcanic rocks (Facies III).

Fragmental rocks of Facies II; tuffs, lapilli-tuffs, and breccias; consist of intermediate to felsic volcanic clasts enclosed in a finer grained matrix of similar composition (see Plate 3). The matrix content (all fragments less than 2 mm in diameter) is highly variable (20 to 90%), but it generally constitutes at least 50% of the rock. Clasts are usually supported by the matrix. Clast orientation is random except for the tendency of some larger clasts to have their long axes aligned sub-parallel to bedding. The latter property may be a product of depositional processes or tectonic rotation or both.

The extreme lack of sorting, matrix supported nature and angularity of the clasts and random orientation of these clasts within the matrix suggests that the mixture of fine and coarse grained material of this facies was deposited by debris flows below wave base (Walker, 1975; Padgett et al, 1977; Jones, 1967). Traction currents strong enough to transport the larger sized fragments would winnow away the finer matrix material.

A debris flow or slurry flow (Carter, 1975) is a mixture of mud, water and possibly larger clasts deposited by movement down a slope (Middleton and Hampton, 1973; Carter, 1975). Water acts as a lubricant and reduces the cohesive strength of the clastic material. During transport, the dispersive pressure of the flow is generated by ordered shear velocity and changes as dispersed grains approach one another (Carter, 1975). Hence the fragments are not held entirely rigid by the enclosing matrix but their motions are greatly restricted. The size of clast that a debris flow can support is a function of the matrix strength (Enos, 1977). Matrix strength increases with increasing clay content. Debris flows can occur in both subaerial and subaqueous environments (Padgett et al, 1977).

Debris flows consist of either pyroclastic or epiclastic material. Pyroclastic material includes both primary vent ejecta and material that has been eroded and reworked from unconsolidated pyroclastic ejecta (Fiske, 1969). Epiclastic material is defined as volcaniclastic material that has been derived by the erosion of consolidated volcanic material (ibid.), but not highly reworked.

Most of the debris flows that contribute to Facies II result in rock types that are heterolithic in terms of clast composition, suggesting a source area consisting of several rock types. This heterolithic character is most consistent with an epiclastic origin rather than a pyroclastic origin. A single vent would erupt products of similar composition over

a short period of time (Franklin, 1976).

An abundance of pumice fragments was observed within debris flow deposits east of Dog Lake (61° 55' N. 96° 7.5' W). Pumice occurs as rounded blocks of highly vesicular rhyolite, ranging in size from 1 cm to 40 cm in diameter. Pumice fragments account for 50% of some rock exposures. The pumice fragments are enclosed in a finer grained matrix of felsic and intermediate volcanic rocks fragments. The pumaceous deposits are at least 300 m thick.

It has been pointed out that the presence of pumice in a debris flow indicates a pyroclastic origin (Fiske, 1969); the reason being that the delicate structure of pumice is unlikely to be preserved during the erosive activity necessary to produce epiclastic fragmental rocks. The pumaceous deposits at Dog Lake are therefore interpreted as products of a pyroclastic debris flow.

Although most of the volcaniclastic rocks that comprise the proximal facies of intermediate volcanic rocks were deposited as debris flows, some rock types were deposited by other processes. Some breccias have matrix contents that are too low (less than 35%) to have supported the larger clasts in a debris flow mode of transport (see Plate 7). These are interpreted as being scree deposits that were deposited by avalanches and landslides on the flank of the volcanic edifice. These deposits may be either pyroclastic or epiclastic and subaerial or subaqueous.

Although these possible avalanche and landslide deposits



Plate 7. Clast supported intermediate volcanic breccia (rock type 2b). Subangular andesite to dacite breccia and lapilli sized clasts are self supporting. The matrix is andesitic and its content is approximately ten percent. This rock type is an example of the proximal facies of intermediate volcanic rocks (Facies II) and is interpreted as a scree deposit. Stratigraphic "tops" is towards the top of the plate.

do not appear to have been voluminous in the Carr Lake area, their presence may be significant. The high degree of internal friction that develops in such transport processes limits their potential distance of travel. The presence of such deposits may indicate that they were deposited near a steeply sloping volcanic terrain.

Intermediate volcanic flows are more abundant in Facies II than in the distal facies of intermediate volcanic rocks (Facies III) but otherwise, they are not very useful in estimating the proximity of the volcanic products to the source vent.

Facies III - Distal Facies of Intermediate Volcanic Rocks

The distal facies of intermediate volcanic rocks consists of intermediate tuffs, lapilli-tuffs, breccias and flows. The distribution of Facies III in the Carr Lake area is shown in Fig. 4. Fragmental rocks of Facies III are heterolithic and are generally thin bedded. The upper and lower contacts of individual beds are sharp (see Plate 8). Finer and coarser grained bedded units commonly alternate. Beds are commonly graded. Maximum clast size rarely exceeds 10 cm. Matrix content almost always exceeds 50%.

The sharp bedding contacts and the continuous character of the beds suggests sedimentation was uninterrupted by the reworking actions of traction currents. Consequently the beds were probably deposited below wave base (i.e. in deep water). The presence of thin bedding and graded bedding in



Plate 8. Interbedded andesitic tuffs and lapilli-tuffs. The tuffs and lapilli-tuffs are graded. In the centre of the plate lapilli fragments plastically deform an underlying tuff bed. Large rhyolite clast in the lower part of the plate is 30 cm in diameter. This is an example of the distal facies of intermediate volcanic rocks (Facies III). Arrow in upper right corner of the plate indicates stratigraphic sequence.

these deposits suggest deposition by turbidity currents.

Turbidity currents are gravity driven, dilute mixtures of granular solids plus water with bulk densities not much greater than water (Hampton, 1972). It is believed that, during transport, debris flows generate turbidity currents (ibid.). Coarser grained facies of turbidity current deposits (also known as fluxoturbidites) may be deposited during the transition from debris flow to turbidite modes of transport (Walker and Mutti, 1973). Hence turbidity current deposits commonly are the more distal, laterally equivalent facies of debris flow deposits. Turbidity currents generated in this way can, over a short period of time, deposit thick volumes of detritus (see Lovell, 1969); especially off the flanks of volcanic islands. The turbidity current deposits of Facies III are interpreted as being epiclastic, based on the heterolithic nature of the volcaniclastic material.

Intermediate volcanic flows in the distal facies of intermediate volcanic rocks are not as abundant as in Facies II rocks. Flows are not very useful in determining the proximity of the enclosing suite of rocks to their volcanic source area.

Facies IV - Proximal Facies of Felsic Volcanic Rocks

The proximal facies of felsic volcanic rocks consists of felsic flows and domes (rock types 3m and 3p) and coarse felsic breccias (rock type 3b). The distribution of this facies is outlined on the depositional facies map (Fig. 4). The high

viscosity of felsic magmas greatly restricts the ability of rhyolite lavas to flow great distances (Macdonald, 1972; p.67). Consequently, felsic flows and their associated breccias usually are found close to the source vent. The limited nature of the accumulations of this facies, as seen in Fig. 4, suggests that the felsic volcanic vents did not produce voluminous outpourings of rhyolite lavas and therefore they are only of local significance.

Facies V - Distal Facies of Felsic Volcanic Rocks

Rocks of the distal facies of felsic volcanic rocks included felsic tuffs, lapilli-tuffs, and fine breccias (rock types 3t, 3l and 3b respectively). These deposits are commonly finely laminated, graded and may be interbedded with chert. They are pyroclastic deposits; either airborne or waterlain; which, because of their nature, are interpreted as having been deposited further from their source than the felsic flows and breccias of Facies IV.

Facies VI - Shallow Water Facies of Sedimentary Rocks

Rocks belonging to the shallow water facies of sedimentary rocks are present in two regions within the Carr Lake study area at the southeast end of Dog Lake (61° 55' N, 96° 7.5' W) and along the Kogtok River, 3 km north of its mouth (62° 0' N, 95° 59' W) as shown in Fig. 4. The distinction between volcanically derived clastic sedimentary rocks and epiclastic fragmental volcanic rocks is arbitrary. Clastic

sedimentary rocks are considered to be more highly reworked than epiclastic volcanic rocks and this is the main criteria used to distinguish these two rock types.

The sedimentary rocks of Facies VI at the southeast end of Dog Lake consist of a lens of rhyolite pebble and cobble orthoconglomerate underlain by mafic pillowed lavas of Facies I and overlain by intermediate volcanic tuffs, lapilli-tuffs and breccias of Facies II. The conglomerate lens is approximately 300 m thick and has a strike length of approximately 4 km. The pebbles and cobbles in the conglomerate are almost entirely massive, non vesicular, subangular to rounded rhyolite fragments that are between 2 cm and 30 cm in diameter (see Plate 9). A few andesite pebbles are present. Matrix comprises less than 15% of the rock. It consists mainly of quartzose sand sized material.

The high degree of rounding and sorting and the bimodal nature of grain size (i.e. pebbles and cobbles vs. matrix) suggest that the conglomerate was winnowed, transported and subsequently deposited by traction currents (see Walker, 1975). The conglomerate is therefore a shallow water sediment, deposited in less than 100 m of water (ibid.). The oligomictic nature of the pebbles and cobbles suggests that the distance of transport was short (preventing extensive mixing of these deposits with material shed from other sources) or that the material was derived exclusively from a felsic volcanic source.

Shallow water facies sedimentary rocks are also located along the Kogtok River, 3 km north of its mouth (see Fig. 4).



Plate 9. Rhyolite cobble and pebble orthoconglomerate (rock type 4d). The conglomerate is well sorted and the clasts are subrounded to rounded. The conglomerate is interpreted as having been transported and deposited by traction currents. These rocks are an example of the shallow water facies of sedimentary rocks (Facies VI). Stratigraphic "tops" is towards the top of the plate.

These deposits consist of conglomerate, sandstone, slate and dolomite. They overlie distal facies felsic volcanic rocks (Facies V) and rocks of the subaqueous mafic flow facies (Facies I) and are overlain by rocks of Facies I.

The conglomerate of the shallow water sedimentary facies is polymictic, clast supported and well sorted. Tonalite and basalt pebbles and cobbles predominate (see Plate 4). Matrix material is sand sized and constitutes less than 20% of the rock. Mature and immature sandstones are also present in this area. Included in the former are quartz arenites composed entirely of quartz grains cemented by dolomite. Immature sandstones included greywacke and arkose.

The well sorted and clast supported nature of the conglomerate suggests that it has been transported and subsequently deposited by traction currents like the previously described conglomerate at Dog Lake. The well sorted nature of the mature sandstones; especially the quartz arenite; suggest that they also were transported and subsequently deposited by traction currents (i.e. in shallow water).

The depositional environment of the immature sandstones and slate is more problematical. The influence of traction currents in their deposition is uncertain. They do not yield enough sedimentological data to determine their depositional environment but are included in the shallow water sedimentary facies because of their close association with the orthoconglomerate and mature sandstones of Facies VI. Due to lack of preserved sedimentary structures, the origin of the dolomite is



Plate 10. Greywacke (rock type 4c). These deposits consist of poorly sorted sand and silt sized grains of predominantly volcanic derivation. The deposits are thinly bedded to laminated and graded bedding is common. These rocks are interpreted as having been deposited in deeper water by turbidity currents and are included in the deeper water facies of sedimentary rocks (Facies VII). Sedimentary "tops" is towards the top of the plate.

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equally uncertain. It is included in the shallow water sedimentary facies for the same reason as the inclusion of the slates and immature sandstones.

Facies VII - Deeper Water Facies of Sedimentary Rocks

The deeper water facies of sedimentary rocks is composed of greywacke, slate, argillite, paraconglomerate, chert and oxide iron-formation. Rocks of this facies occur in outcrops near and along the Kogtok River, at the mouth of the Maguse River and at Mud Lake (see Fig. 4).

Greywacke of the deeper water facies of sedimentary rocks is fine grained, poorly sorted and thinly bedded; graded bedding and load structures are common (see Plate 10). Slate and argillite are thinly bedded and carbonaceous. Load structures are common.

The conglomerates are poorly sorted and consist of lithic pebbles and cobbles (predominantly volcanic clasts but some tonalitic clasts may be present) supported by a fine sandy matrix (see Plate 11). The matrix content of the conglomerate is generally 20 to 50%. The conglomerates are massively bedded. Channel scours are present but uncommon. Greywacke beds are sometimes intercalated with conglomerate.

Chert is thinly bedded to laminated; graded bedding and load structures may be present (see Plate 5). Oxide iron-formation consists of magnetite beds that are commonly intercalated with green chert or jasper beds.

The fine grained, poorly sorted nature of the greywacke,

slate and argillite suggest that they were deposited outside of the winnowing influence of traction currents (i.e. in deep water). The thinly bedded and graded bedded nature of the greywackes suggest that they were deposited by turbidity currents. The poorly sorted and matrix supported nature of the conglomerates suggests that they were deposited out of the influence of the winnowing action of traction currents, possibly in deeper water.

The chert and oxide iron-formations are chemically precipitated rock types. The presence of graded bedding in some cherts suggest that they have undergone at least some transport by turbidity currents (see Price, 1977). The fine grained, delicately laminated nature of these deposits suggest that they have not been disturbed by the influence of traction currents. This implies that they were deposited in deep water.



Plate 11. Paraconglomerate (rock type 4d). The conglomerate is poorly sorted and consists of subangular rhyolite pebbles and cobbles supported by a predominantly volcanically derived silty and sandy matrix. These rocks are interpreted as being deeper water facies sedimentary deposits (Facies VII).

STRATIGRAPHY OF THE KAMINAK GROUP

INTRODUCTION

The previous sections have presented data describing the character of the various rock types within the Kaminak Group and have interpreted their depositional facies in terms of depositional location, depositional mechanism and depositional environment. Still unresolved is the question of how these rock types and the depositional facies they represent were related, one to another, during the period of deposition.

The first step in solving this problem was to remove the effects of folding by rotating the geological cross sections in Fig. 3 to form an unfolded restoration of the stratigraphy of the rock types and later the depositional facies of Kaminak Group. The restored cross sections were then used to portray, in three dimensions, the stratigraphic relationships between the rock types and their depositional environments (see Fig. 5). This procedure does not account for any tectonic thickening or thinning which may have taken place during folding. Consequently, the stratigraphic relationships shown in the fence diagram (Fig. 5) may incorporate the effects of tectonic distortion. However, at this time there is no way to assess these effects. Consequently it will have to remain an unresolved problem.

The greatest thickness of volcanic and sedimentary rocks

as expressed by the fence diagram is 10.5 km. This thickness must be considered as a minimum value of the total thickness of Archean volcanic and sedimentary rocks that were deposited at this site.

DESCRIPTIVE STRATIGRAPHY OF THE KAMINAK GROUP

A thick accumulation of subaqueous mafic flows is present in the northwest corner of the area portrayed by the fence diagram (panel B-D' of Fig. 5). Here the mafic volcanic pile has a minimum thickness of 10 km. In the upper-middle part of the mafic volcanic succession, as illustrated by panel D-D', irregular pods of proximal facies intermediate volcanic rocks, distal facies felsic volcanic rocks and shallow and deeper water facies sedimentary rocks are present (Facies II, V, VI and VII respectively).

The thick pile of subaqueous mafic flows disappears to the south and east by wedging out and interfingering with rocks of the proximal and distal facies of intermediate volcanic rocks as is depicted in panels A-B, D-D', D'-C and B-B' of the fence diagram (Fig. 5).

Panel A-A' illustrates that the thickest accumulation of proximal facies intermediate volcanic rocks (Facies II) is present in the southwest part of the fence diagram. Beds or lenses of Facies I, V and VI are present within this thick sequence of Facies II rocks. The minimum aggregate thickness of these rocks in panel A-A' is 5 km. The fence diagram shows that the proximal facies of intermediate volcanic rocks

disappears to the north and east. To the east it undergoes a facies change to laterally equivalent distal facies intermediate volcanic rocks (Facies III) as shown by panel A'-C. Smaller pods of Facies II rocks are also present northwest of its thickest accumulation (see panel C-C', B'-C' and D-D' of Fig. 4).

The thickness of distal facies intermediate volcanic rocks is greatest in the eastern part of the fence diagram. They are also present underlying and overlying much of the thick accumulation of subaqueous mafic flows in the western part of the fence diagram (see panel D-D').

Felsic volcanic and sedimentary rocks (Facies IV, V, VI and VII) are present as small discrete lenses within the rocks of the three major facies (Facies I, II and III). Proximal facies felsic volcanic rocks are present in panels B'-C' and C-C' of Fig. 5. The most notable feature of these deposits is their large height/width ratios. Distal facies felsic volcanic rocks occur in a more laterally continuous bedlike form. Rocks of this facies are shown in panels B-B', D-D' and A-A'. Small pods of shallow water facies sedimentary rocks are present within the thick buildup of subaqueous mafic flows that is present in the western part of the fence diagram (see panel D-D') and at the contact between proximal facies intermediate volcanic rocks and subaqueous mafic flows illustrated in panel A-A'. Several small pods of deeper water facies sedimentary rocks are illustrated in the fence diagram. In panel D-D' Facies VII rocks are present as lateral facies

equivalents to shallow water facies sedimentary rocks. A lens of deeper water facies sedimentary rocks in panels C-C', D'-C and A-C' has a maximum thickness of 1 km. The fence diagram illustrates the very complex nature of the stratigraphy of the Kaminak Group. Within the Carr Lake area voluminous amounts of two major and compositionally distinct volcanic products; mafic and intermediate volcanic rocks; were deposited. These rocks were deposited into a heterogeneous depositional environment. The facies relationships of volcanic products to their source are complex. It is difficult to envisage how a single volcanic source could have been the progenator of such a complexly stratified suite of volcanic and sedimentary rocks as are found here. Conversely the complexities of the stratigraphy become easier to comprehend if two or more volcanic sources areas at different distances from the depositional site are considered.

INTERPRETATION OF ARCHEAN VOLCANISM AND SEDIMENTATION

The distribution of the various volcanic and sedimentary facies of the Kaminak Group as shown in the fence diagram (Fig. 5) allows inferences to be made about their mode of deposition. The hypothesis presented here is that there were at least two major sources of volcanic and sedimentary products in the Carr Lake area during deposition of the Kaminak Group. One volcanic center supplied predominantly basaltic rocks (Facies I) while the other volcanic center was intermediate to felsic in composition (Facies II, III, IV and V). The complexities of the variations in depositional facies can be interpreted as relating to variations in the relationship between the volcanic source and the water level (i.e. submergent or emergent volcanism). Sedimentary rocks of the Kaminak Group (Facies VI and VII) are largely chemical sediments and reworked volcanic rocks. They play a largely accessory role in the deposition of the Kaminak Group but are commonly useful indicators of relative water depth.

MAFIC VOLCANISM

The fence diagram shows a thick mafic volcanic pile (Facies I) in the western part of the Carr Lake area. The thick pile undergoes a facies change to the south and east into laterally equivalent rocks of Facies II and III, which are derived from a different source. The principal source of

the mafic volcanic rocks was probably to the west of the study area.

The mafic volcanic pile consists of a thick continuous buildup of flows. This suggests that the lava outpourings were relatively continuous so that there were few significant pauses in volcanism to allow the accumulation of a significant thickness of interflow pelagic sediment. Field evidence suggests that the lavas were poured out onto relatively gentle slopes. This is consistent with the nonviscous nature of mafic flows (see Macdonald, 1972; pp. 61-64).

Geological mapping in the study area did not yield evidence for a main feeder zone for the mafic lavas or of a magma chamber from which the lavas were derived. It is possible that the synvolcanic dykes observed in the area fed many small vents on the flanks of the mafic volcanic buildup. Such a process would have produced an irregular volcanic edifice with moderate local relief and a shallow regional slope. The form of such an accumulation would be similar to modern day shield volcanoes such as those of the Hawaiian Islands (see Macdonald, 1972; pp. 271-279).

Panel D-D' of Fig. 5 shows the thick accumulation of Facies I rocks wedging out to the south. Near the top of the wedge of mafic volcanic rocks are enclosed lenses of rocks of Facies II, V, VI and VII. These rocks are overlain by mafic flows of Facies I. The stratigraphic succession, as portrayed in panel D-D' suggests that the mafic volcanic rocks were deposited in three successive stages: an initial submergent

stage, an emergent stage and a final submergent stage.

Initial Submergent Mafic Volcanic Stage

The first stage of mafic volcanism involved the deposition of at least 6 km of vesicular mafic pillowed flows. The pillowed and vesicular nature of these rocks suggests that this facies must have been deposited at water depths of less than 2 km but greater than 100 m. Consequently considerable subsidence must have occurred during the deposition of these lavas.

Emergent Mafic Volcanic Stage

In panel D-D' of Fig. 4, the thick buildup of subaqueous mafic volcanic flows is overlain by shallow and deeper water facies sedimentary rocks, proximal facies intermediate volcanic rocks and distal facies felsic volcanic rocks. The shallow water facies sedimentary rocks include quartz arenite, dolomite and tonalite - basalt cobble orthoconglomerate. Associated with shallow water facies sedimentary rocks is a columnar basaltic flow which is interpreted as having been extruded into a subaerial environment. Panel D-D' of Fig. 5 shows that the shallow water facies sedimentary rocks undergo a facies change to the north and south into deeper water facies sedimentary rocks.

The presence of these shallow water facies sedimentary rocks within the volcanic succession indicates that at the time of their deposition the volcanic pile had risen above

sea level in neighbouring areas. Basaltic cobbles in the orthoconglomerate indicate emergence and some erosion of the mafic volcanic pile. The occurrence of quartzarenite indicates that a significant source of detrital quartz was available (probably the felsic and intermediate volcanic rocks of panel D-D' of Fig. 5) and that stable tectonic conditions probably had developed within this segment of the volcanic pile. Stable tectonic conditions rarely prevail on volcanic islands because of volcanic activity and isostatic subsidence. The emergent mafic volcanic stage may represent a hiatus in volcanism because during such a hiatus erosion may have occurred, sediment may have accumulated and a minor influx of felsic and intermediate volcanic products could have taken place.

The absence of mafic breccias associated with the emergence of the mafic volcanic pile is perplexing. Mafic volcanism in shallow water usually generates abundant breccias and pyroclastic rocks (Cotton, 1969; Jones, 1969). However, none were observed in the Carr Lake area.

Final Submergent Mafic Volcanic Stage

Rocks of the emergent mafic volcanic stage are overlain by 1 km of pillowed and massive mafic lavas (see panel D-D' of Fig. 5). These rocks indicate that the mafic volcanic pile has subsided below water level in this area. These lavas indicate a renewal in the eruption of voluminous mafic flows in this area after the interpreted hiatus or retardation in mafic volcanism during the emergent mafic volcanic stage.

The pillowed lavas of this stage were overlain by distal facies intermediate volcanic rocks (Facies III).

INTERMEDIATE TO FELSIC VOLCANISM

To the south and east of the mafic volcanic pile in Fig. 5, Facies I mafic volcanic rocks interfinger with laterally equivalent rocks of Facies II and III. The rocks of Facies II and III are intermediate to felsic fragmental rocks plus flows and synvolcanic dykes of similar composition.

The sudden and complete transition from mafic volcanic to intermediate and felsic volcanic rocks as depicted in panels A-B, B-B', D-D' and D'-C suggests that there were separate and independent sources of mafic and intermediate - felsic volcanic rocks. The interfingering character of the transition between rocks of Facies I and rocks of Facies II and III demonstrates that the two volcanic sequences were contemporaneous and that each restricted the lateral growth of the other.

The rocks of Facies II and III are interpreted as debris flow and turbidity current deposits that formed an apron of volcaniclastic material around the main centre of intermediate to felsic volcanism. Debris flows of the proximal facies intermediate volcanic rocks would have been deposited closer to the volcanic source area than turbidity current deposits. Facies II deposits are best developed in the south part of the Carr Lake area (see panel A-A' of Fig. 5). To the northwest, Facies II rocks interfinger with laterally equivalent distal facies intermediate volcanic rocks (see panels D-D' and

A'-C of Fig. 5). This facies relationship suggests that the main source of intermediate to felsic volcanic material was to the south of the Carr Lake area (south of panel A-A').

The heterogeneity of clast composition of the debris flow and turbidity current deposits of Facies II and III, respectively, suggest that several local and compositionally varied volcanic sources contributed material to the volcaniclastic deposits. The presence of many synvolcanic dykes throughout the intermediate volcanic pile also suggests that many different eruptive centres could have supplied volcanic material to this sequence. The presence of lava flows, pyroclastic deposits and synvolcanic dykes within the rocks of Facies II and III implies that intermediate to felsic volcanism was active during deposition of these rocks (i.e. they are not the products of the erosion of an extinct volcano). The great thickness of debris flow and avalanche material (Facies II) on the flank of the intermediate to felsic volcanic edifice suggests that this edifice must have had a steep primary slope that was prone to oversteepening in order to generate such deposits.

Development of the Intermediate - Felsic Volcanic Buildup

The development of the intermediate - felsic volcanic buildup can be interpreted from the fence diagram. Panel A-A' of Fig. 5 provides a convenient section to study the development of this buildup. At the base of panel A-A', 1 km of distal facies intermediate volcanic rocks (Facies III) overlies a tongue of subaqueous facies mafic volcanic rocks.

These Facies III rocks are overlain by a 3 km thick sequence of proximal facies intermediate volcanic rocks (Facies II). This upward transition from distal to proximal facies of intermediate volcanic rocks can be interpreted to mean that the source of intermediate - felsic volcanic material had migrated toward the Carr Lake area or the entire intermediate - felsic volcanic buildup had grown thicker and consequently spread out laterally.

The Facies II deposits in panel A-A' are overlain by a 300 m thick lens of shallow water facies sedimentary rocks (Facies VI; Dog Lake occurrence). These deposits indicate that this portion of the intermediate - felsic volcanic buildup was on the verge of becoming emergent during deposition of the Facies VI rocks and the volcanic edifice was totally emergent to the south.

These rocks are overlain by 500 m of mafic pillowed lavas (Facies I) indicating that this area has undergone a period of subsidence and southward encroachment of the mafic volcanic pile has occurred. The mafic pillowed lavas are overlain by 1 km of proximal facies intermediate volcanic rocks and a 500 m lens of distal facies felsic volcanic rocks (Facies II and V respectively).

The thick sequence of proximal facies intermediate volcanic rocks of panel A-A' grades northward and eastward into distal facies intermediate volcanic rocks. Distal facies intermediate volcanic rocks are interpreted as being mainly distal deposits derived from the intermediate volcanic pile

to the south and deposited by turbidity currents. Undoubtedly other more distant intermediate to felsic volcanic centres may also have contributed detritus to the thick accumulation of Facies III deposits located in the eastern corner of the fence diagram.

Isolated pods of proximal and distal facies felsic volcanic rocks occur throughout the Carr Lake area and are particularly conspicuous in the northeast corner of Fig. 5. These pods are probably too distant from the summit of the main intermediate - felsic volcanic buildup to be considered flank eruptions. The small lenses of proximal facies felsic volcanic rocks are mainly rhyolite endogenous domes which are separate but minor felsic volcanic centres. The lenses of distal facies felsic volcanic rocks are largely tuffaceous deposits from a phantom felsic vent.

Small lenses of deeper water facies sedimentary rocks (Facies VII) are also present. These deposits consist of reworked volcanic detritus and chemical sedimentary rocks deposited below wave base.

CONCLUSIONS

1. The volcanic and sedimentary rocks of the Kaminak Group in the Carr Lake area were deposited from at least two different major volcanic sources: a mafic volcanic source and an intermediate to felsic volcanic source. The thicknesses of the resulting volcanic piles were controlled by the degree to which isostatic subsidence kept pace with the outpourings of volcanic products.

2. A 10 km thickness of mafic pillowed lavas is preserved in the western part of the Carr Lake area. Field evidence suggests that the bulk of this volcanic succession was deposited at water depths between 100 m and 2 km. The mafic volcanic pile was produced by cycles of upward growth followed by subsidence. There is some evidence that the mafic volcanic edifice locally emerged above sea level near the end of one cycle of upward growth.

During the period when basaltic lavas were erupted, the mafic volcanic pile was probably irregularly shaped with gently dipping slopes. There were probably numerous vents on the edifice, fed by small dykes.

3. The intermediate to felsic volcanic eruptive source deposited a great thickness (7 km) of andesitic to rhyolitic fragmental volcanic rocks and flows. The fragmental volcanic rocks were mainly deposited by debris flows and turbidity currents which represent a volcaniclastic apron that

developed around the volcanic source. Debris flow material was deposited closer to the volcanic source than the turbidity current deposits. These relations suggest that the source of intermediate to felsic volcaniclastic material was to the south of the Carr Lake area.

4. The intermediate to felsic volcanic pile also shows evidence of cycles of upward growth, evidence of local emergence of the volcanic edifice above sea level and subsidence below sea level.

5. The mafic volcanic pile and the felsic to intermediate volcanic pile were being deposited contemporaneously and each restricted the lateral expansion of the other, producing an interfingering of the volcanic products.

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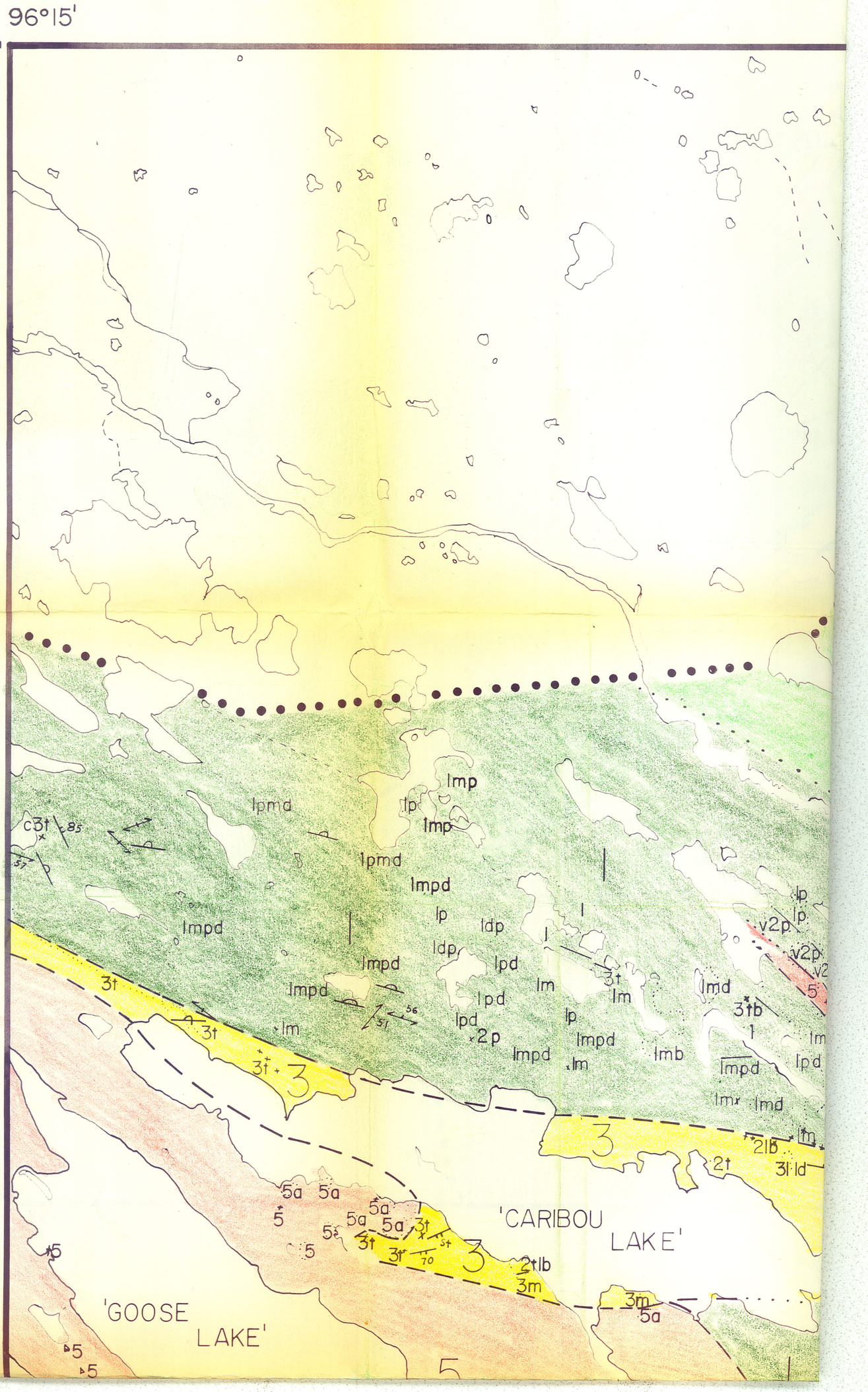
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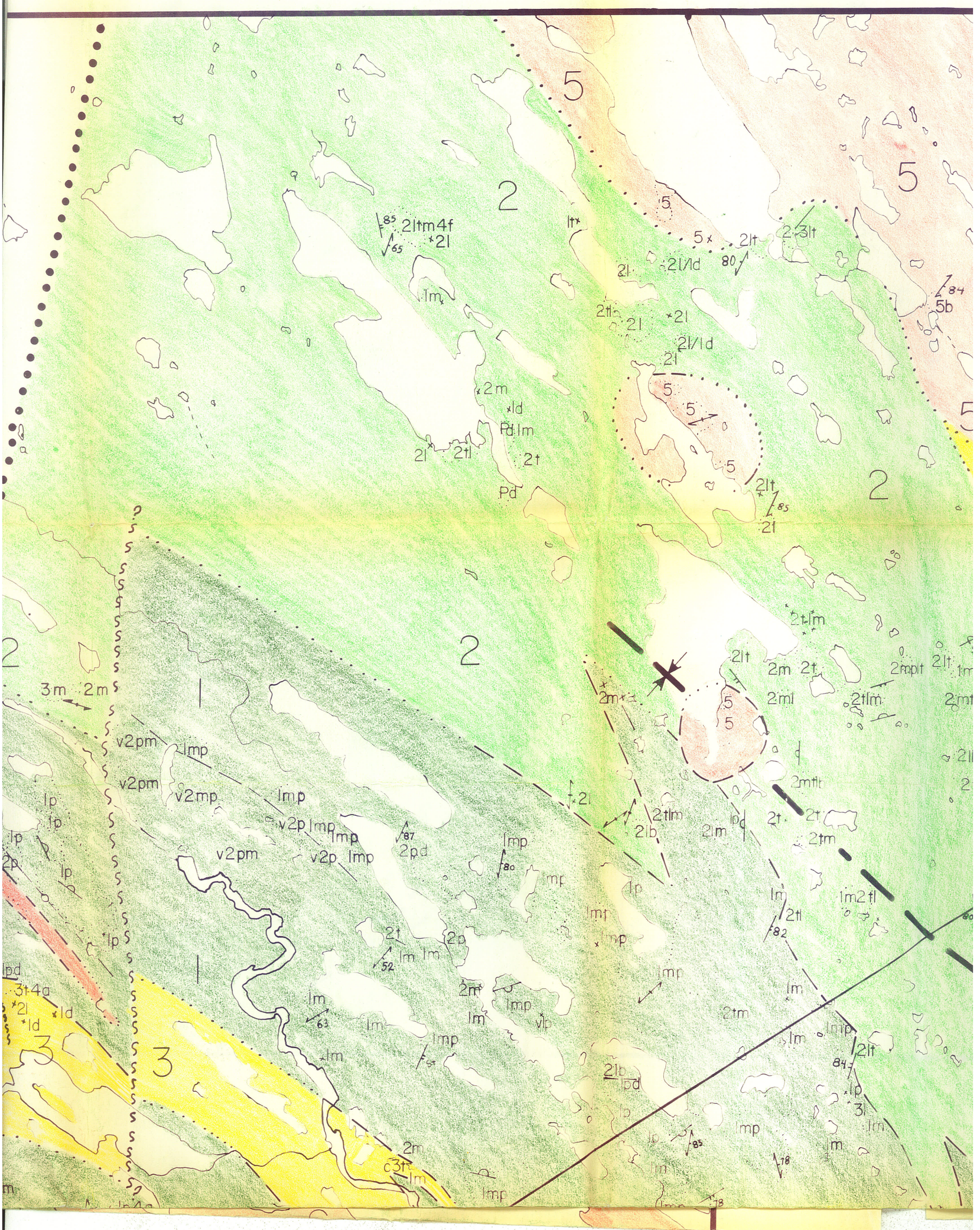
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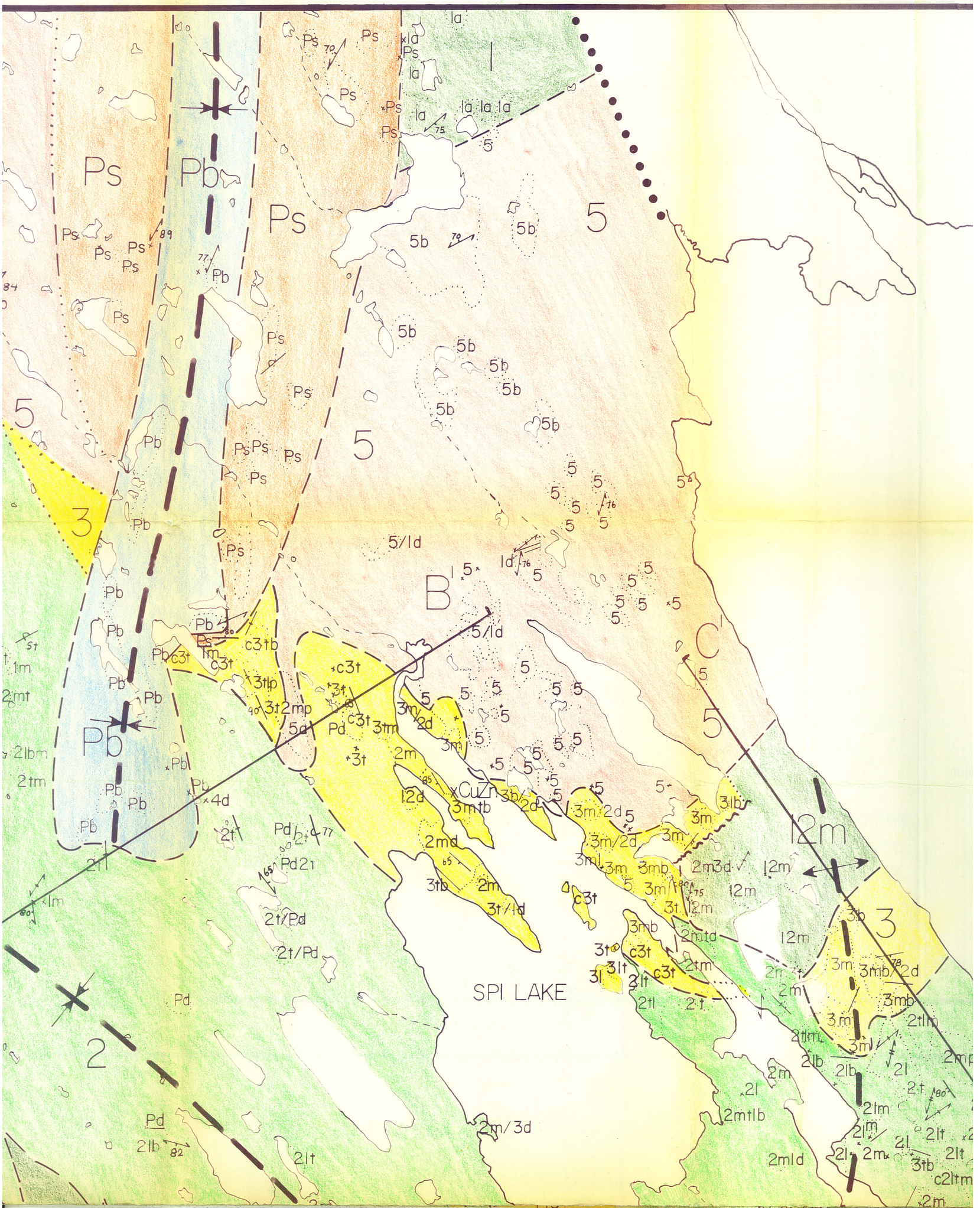
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GEOLOGY


96°15'
62° 7.5'
lmp
lpmd
lp
lmp
lpmd
lmpd
lp
ldp
lmpd
ldp
lpd
lmpd
lm
lpd
lpd
2p
lmpd
lp
lmpd
lm
lmb
lmd
lmd
lm
lpd
lmd
lm
2tb
2t
3t
3t
3t
3
3
3
3
5a
5a
5
5a
5a
5a
3t
5
3t
3t
2tb
3m
3m
5a
5
5
5
'CARIBOU LAKE'
'GOOSE LAKE'


96°00'
5
2
5
5
2
2
2
1
1
3
3
2lt m4f
2l
2m
ld
Pd lm
2t
Pd
2l
2tl
2l/ld
2lt
2t lm
2m
2mpl
2mtl
2tlm
2tm
2lb
lpd
2t
2p
lm
lmp
v2pm
v2mp
v2p lmp
lp
3m
2m
3t4a
ld
3t
vlp
2tm
lm2tl
2mpl
5b

PARTS OF AREAS N.T.S.-55E-13,



55E-13, 55L-4, 65H-16, 65I-1

95°40'

62° 7.5'

CARR LAKE

NO OUTCROP

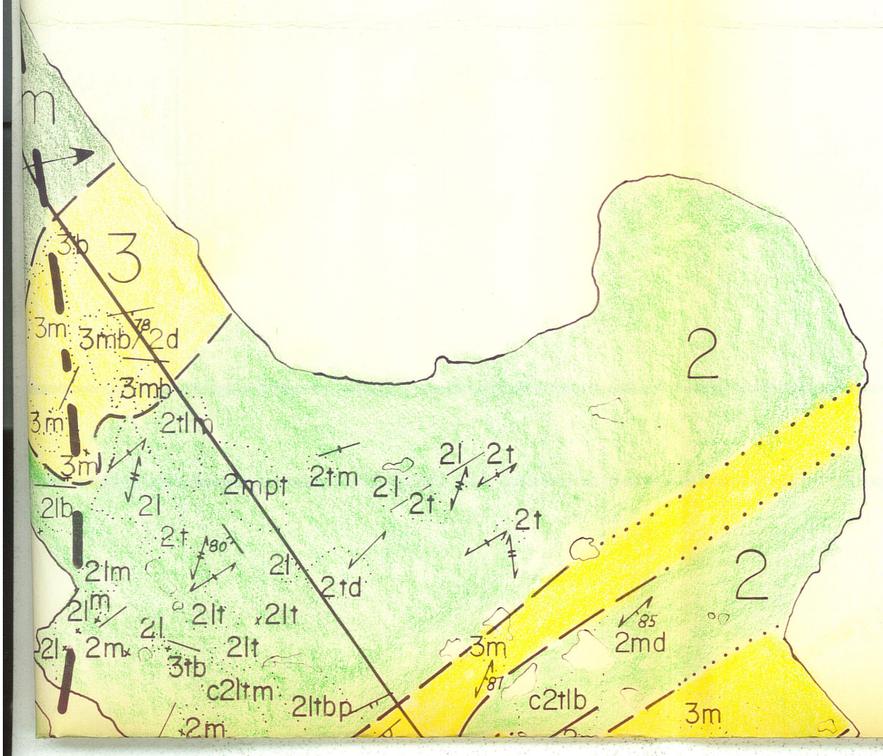
55E-13, 55L-4, 65H-16, 65I-1

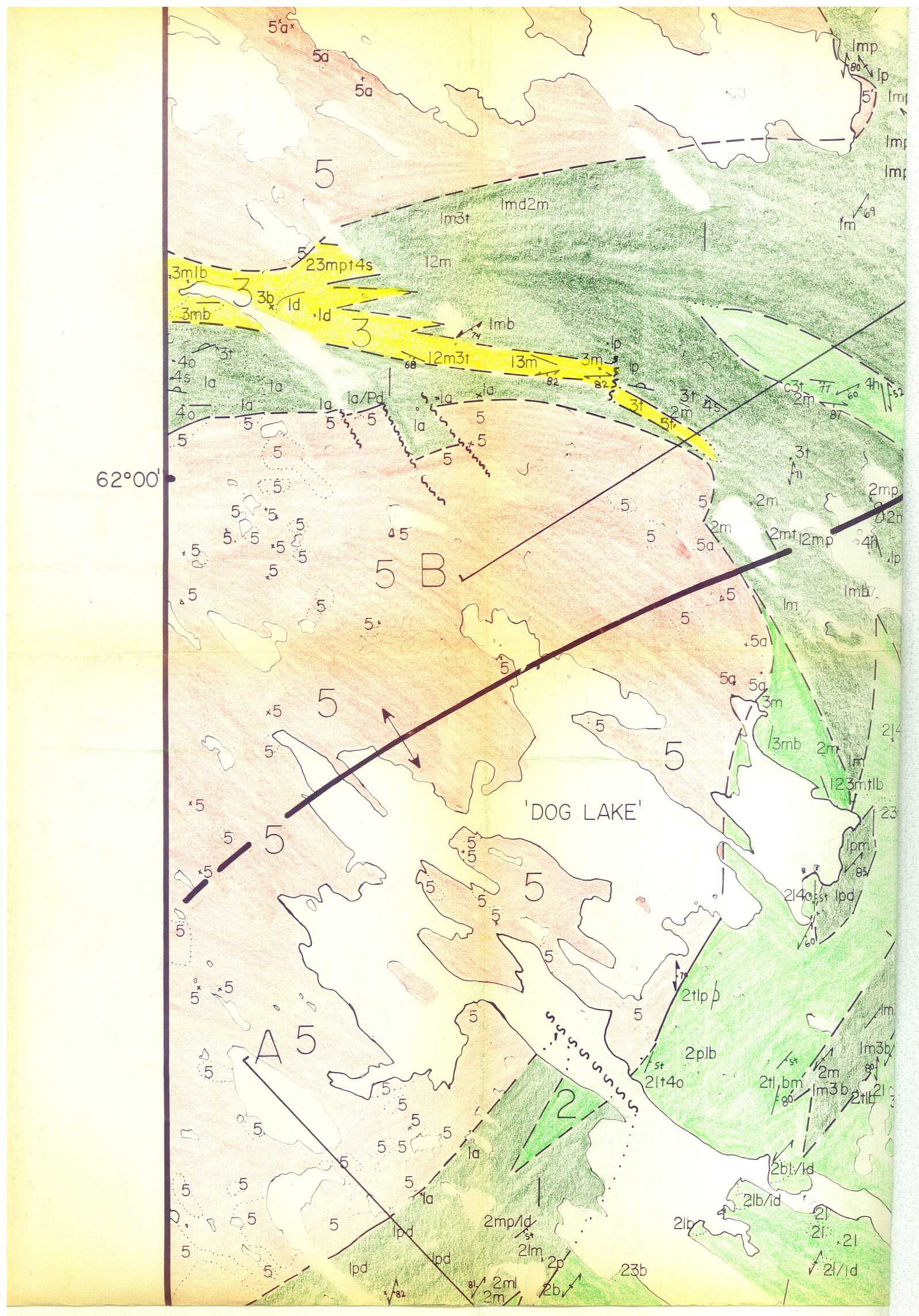
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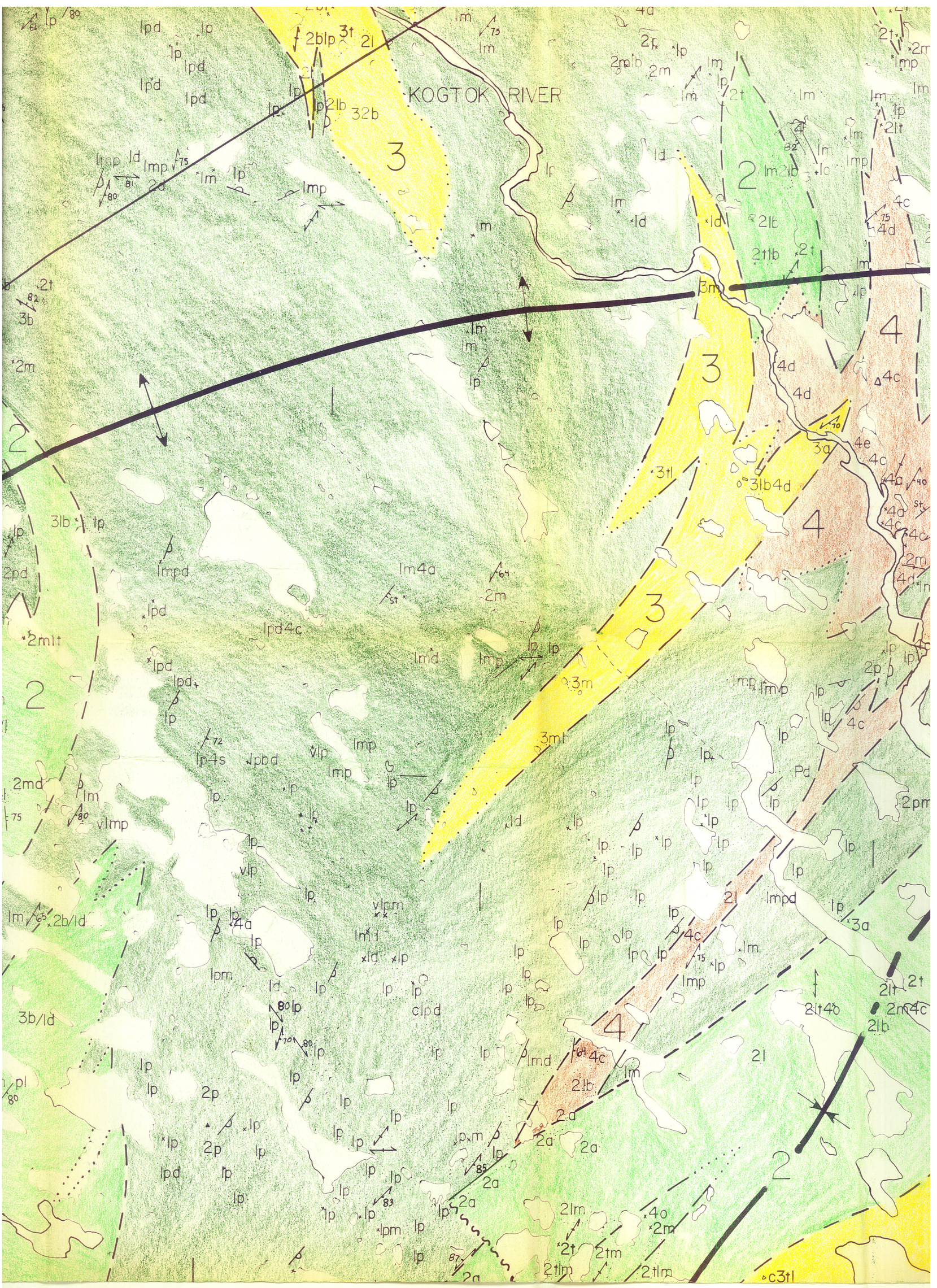
62°7.5'

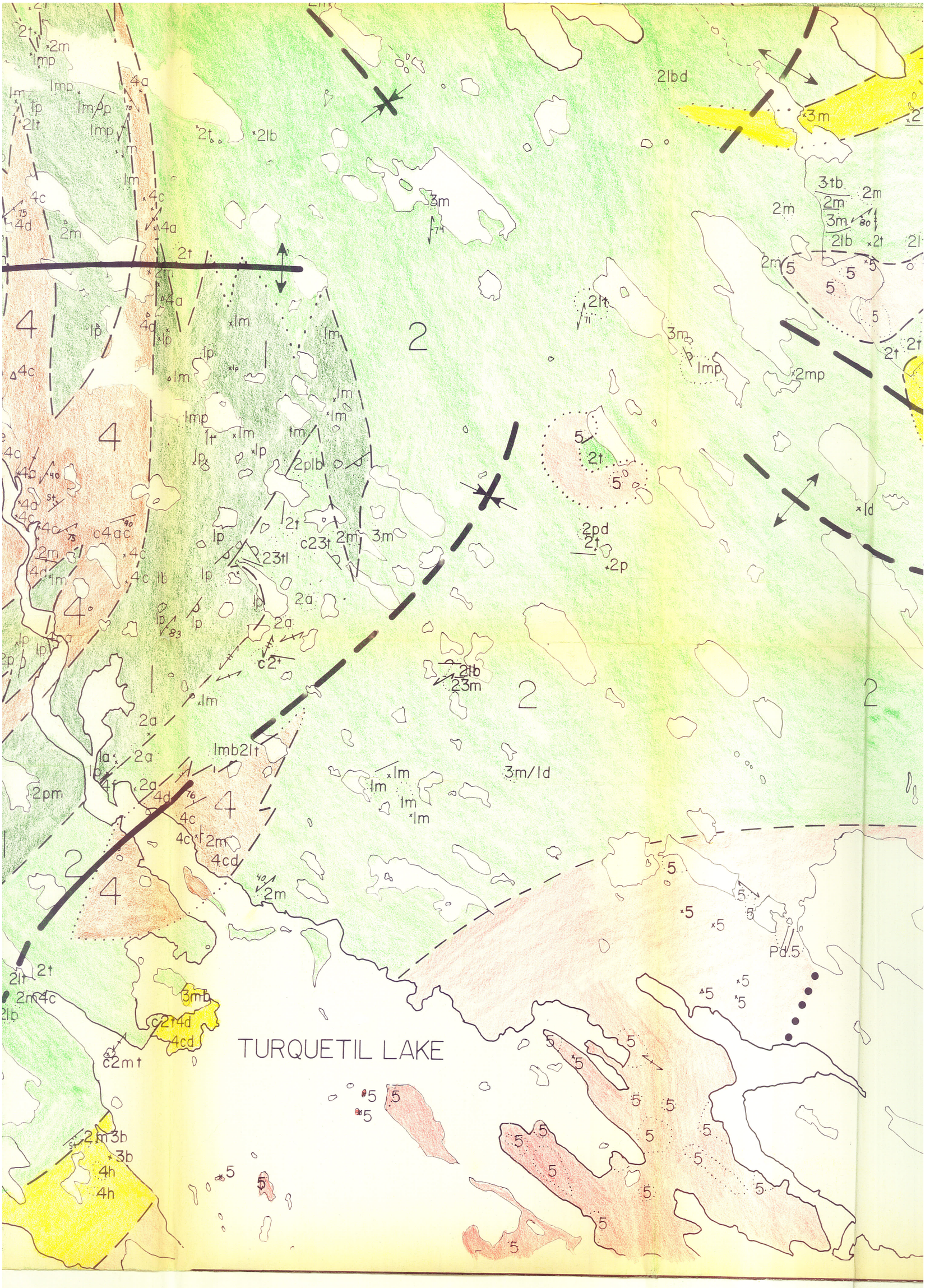
CARR LAKE

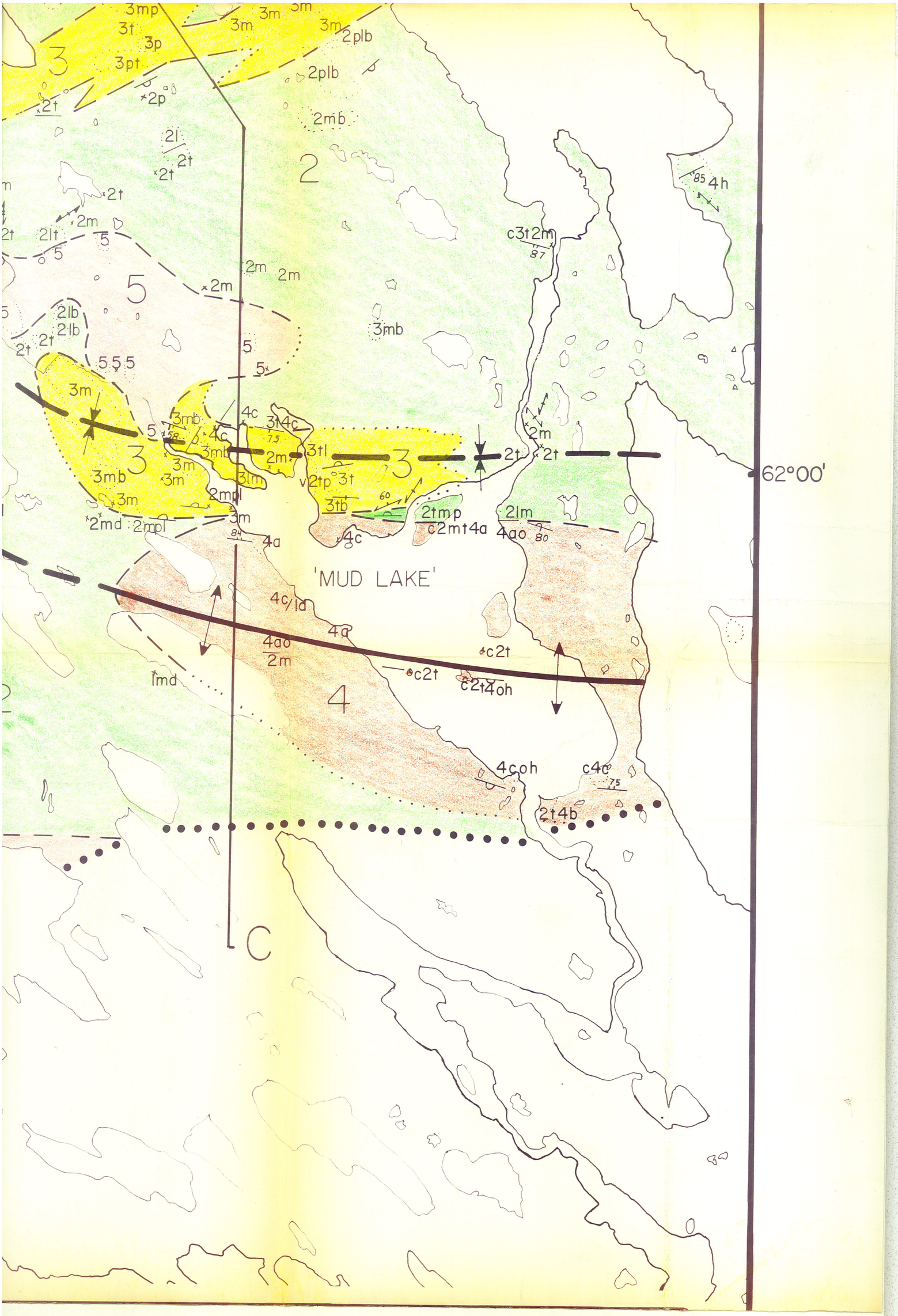
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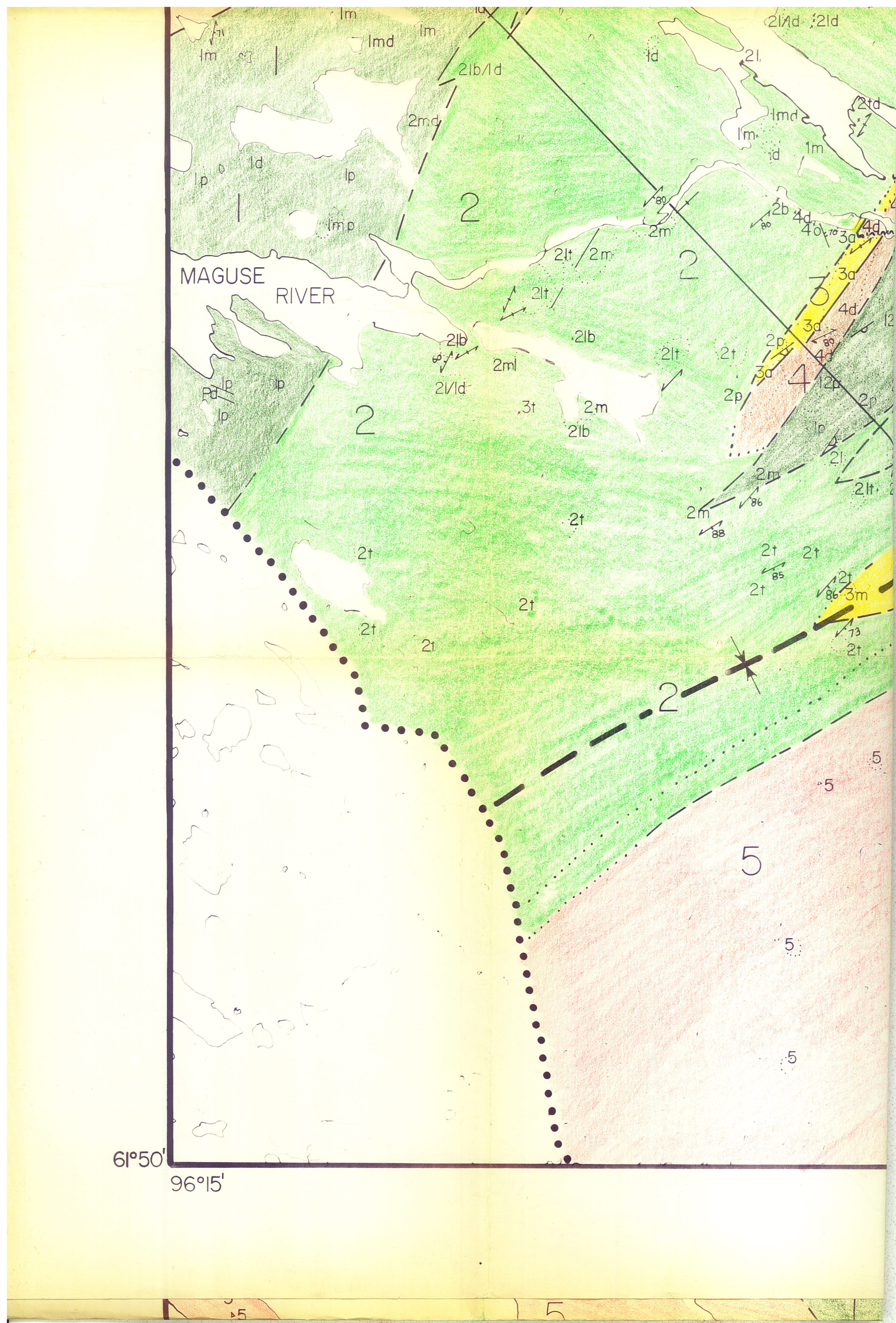


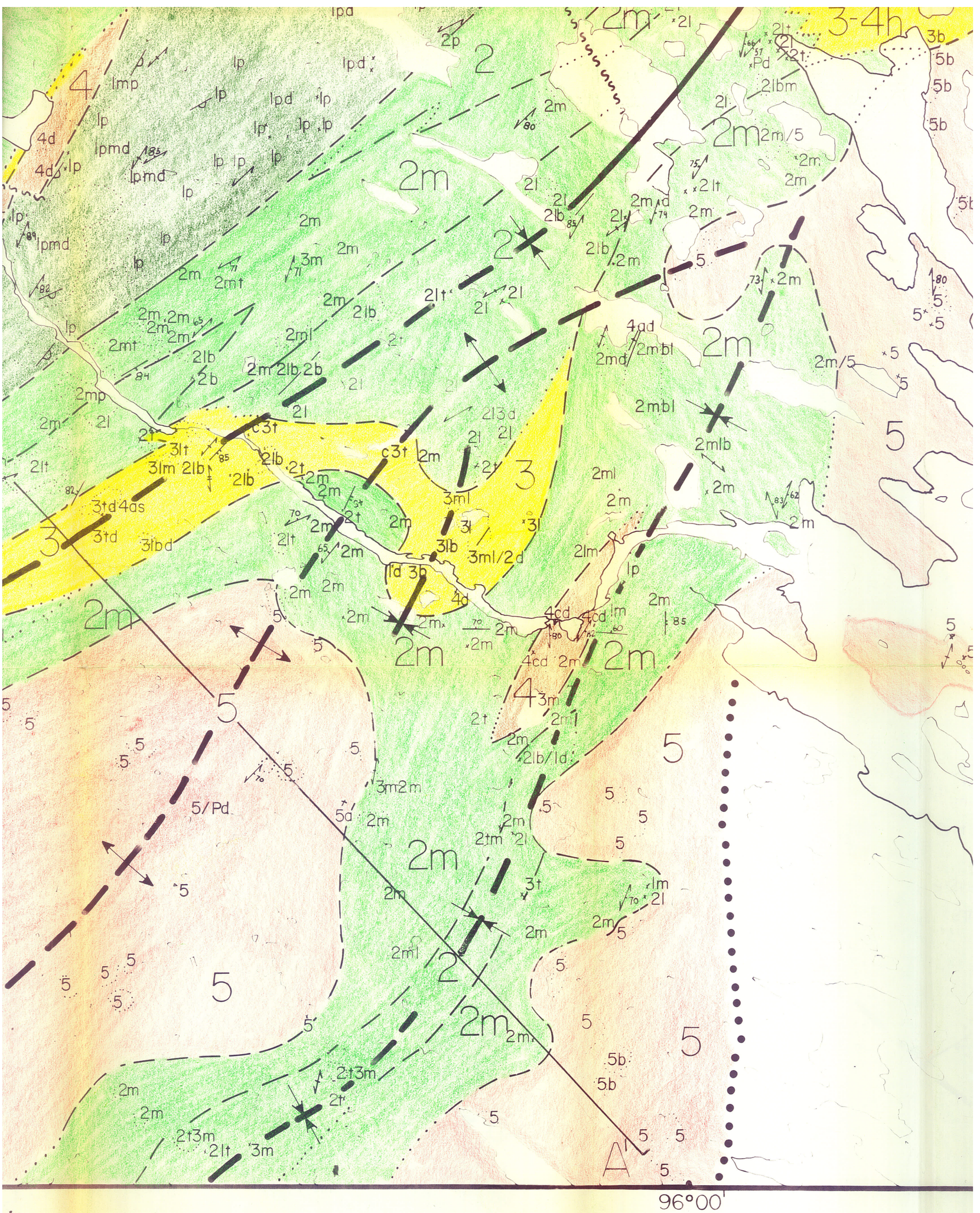

62°00'
'DOG LAKE'
5B
A5
5
3
2
1
5a
lmp
lp
lm3t
lmd2m
lm
23mpt4s
12m
3mlb
3b
ld
3mb
lmb
12m3t
13m
3m
3t
4s
4o
la
la/Pd
lpd
2m
3t
4h
c3t
2mp
2mt
12mp
lmb
3m
3mb
123mtlb
lpm
214o
2tlp
2plb
2t14o
2tlbm
lm3b
2tlb
2bl/ld
2lb/ld
2lb
2l
2l/ld
2mp/ld
2lm
2p
23b
2ml
2b


KOGTOK RIVER
1
2
3
4
lp
lpd
lmp
lm
ld
2t
2m
2l
3t
3m
3b
3a
4d
4c
4a
4b
2p
2a
2b/ld
3b/ld
2t4b
2m4c
2t2b
3b4d


TURQUETIL LAKE


'MUD LAKE'
62°00'
3mp
3t
3p
3pt
3m
2plb
2p
2t
2mb
2l
2m
4h
c3t2m
3mb
2lb
5
4c
3t4c
3t
2tmp
c2mt4a
4ao
2lm
4a
4c/ld
2ao
c2t
c2t4oh
4coh
c4c
2t4b
2md
2mpl
3lm
v2tp
3tb
C


MAGUSE
RIVER
61°50'
96°15'


A
96°00

LEGEND: CARR LAKE-TURQU

ROCK TYPES

APHEBIAN

Pd	MAFIC DYKES
Pb	BASALT FLOWS
Ps	CONGLOMERATE-plus minor sandstone

ARCHEAN

5	TONALITIC INTRUSIVES-5a, gabbroic phase; 5b, agmatite.

KAMINAK GROUP

Rock Stratigraphic Units

4	SEDIMENTARY ROCKS-4a argillite and slate, c sandstone and greywacke, d conglomerate, e dolomite f carbonate iron formation, h bedded chert, o oxide iron formation, s sulfide iron formation
3	FELSIC VOLCANIC ROCKS-a meta-rhyolite, b breccia, d dyke, l lapilli tuffs, massive flows, p pillowed flows, t tuffs, c3t cherty tuffs.
2	INTERMEDIATE VOLCANIC ROCKS- 2a meta-andesite-dacite, b breccias, l lapilli tuffs m massive flows, p pillowed flows, t tuffs, v2m, p-variolitic flows. Flows tend to be very porphyritic.
1	MAFIC VOLCANIC ROCKS-1a meta-basalt, b breccia, c columnar jointed flows, d dyke, m massive flows, p pillowed flows, l lapilli tuffs, t tuffs, v1p variolitic pillowed flows. Nonporphyritic andesite flows occur throughout this unit.

Fig. 2

mile

2m

TURQUETIL LAKE GEOLOGY

GEOLOGICAL SYMBOLS

Outcrop

Frost heaved boulder

Geological contact (defined, approximate, assumed)

Limit of geological mapping

Bedding, tops known (inclined, vertical, overturned, dip unknown)

Bedding, tops unknown (inclined, vertial, dip unknown)

Foliation (inclined, vertical, dip unknown)

Second generation foliation (inclined, vertical)

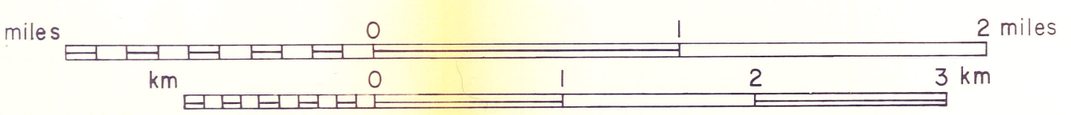
Fault

Fold axis (anticline, syncline., approximate, assumed)

Spi Lake mineral deposit

XCu-Zn

Scale - 1: 31,680

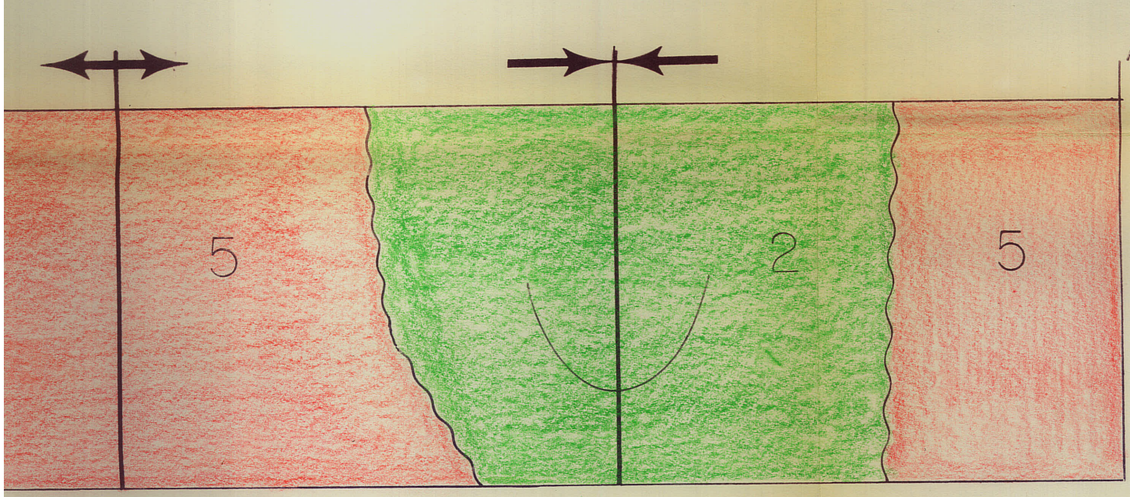


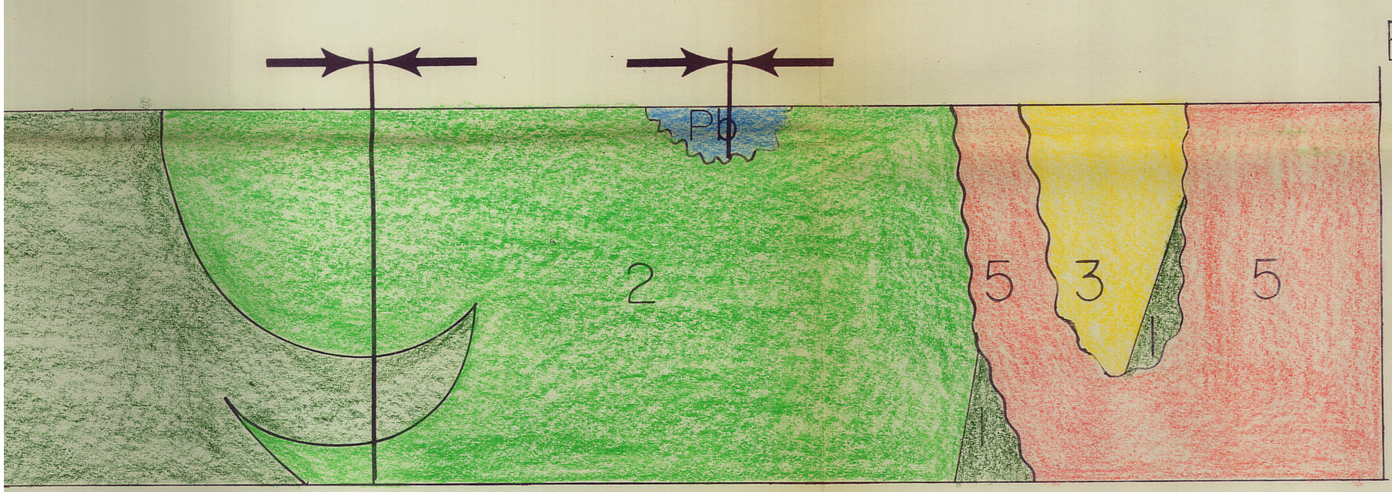
Geology by K.R. Barrett, P.J. Laporte, S.R. Leggett, and G.D. Schwab

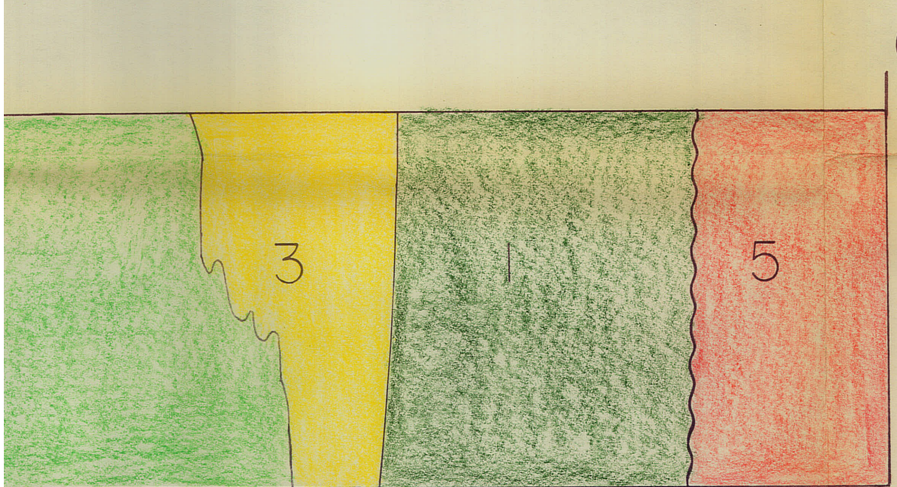
Geological Compilation by K.R. Barrett (1978)

61°50'

95°40'

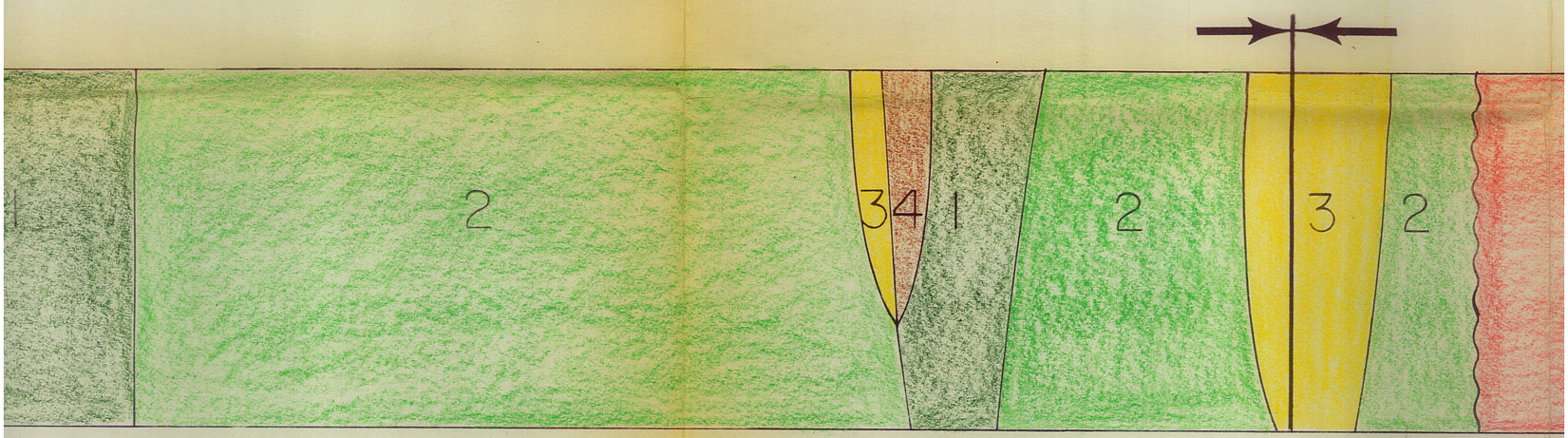


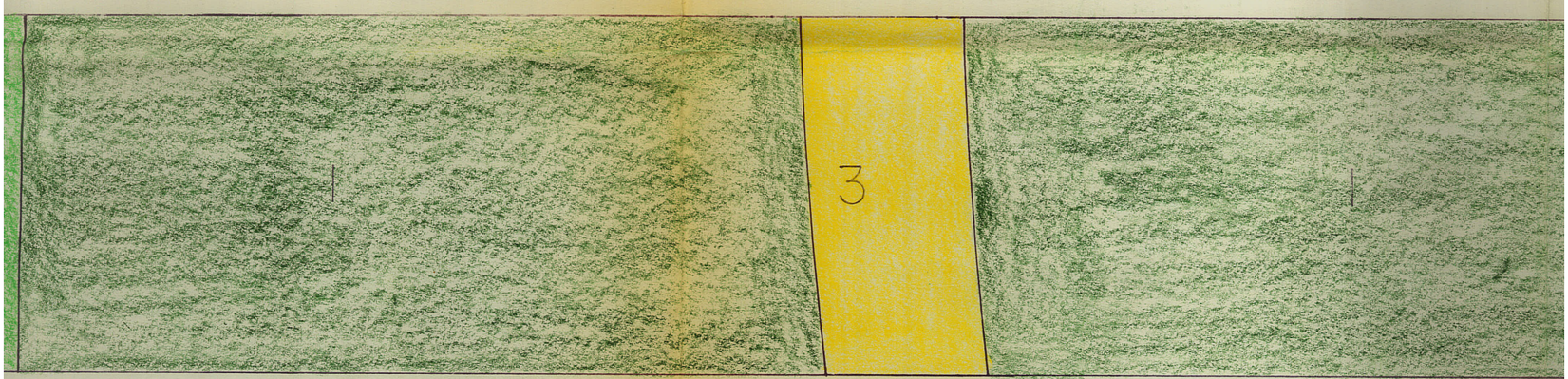


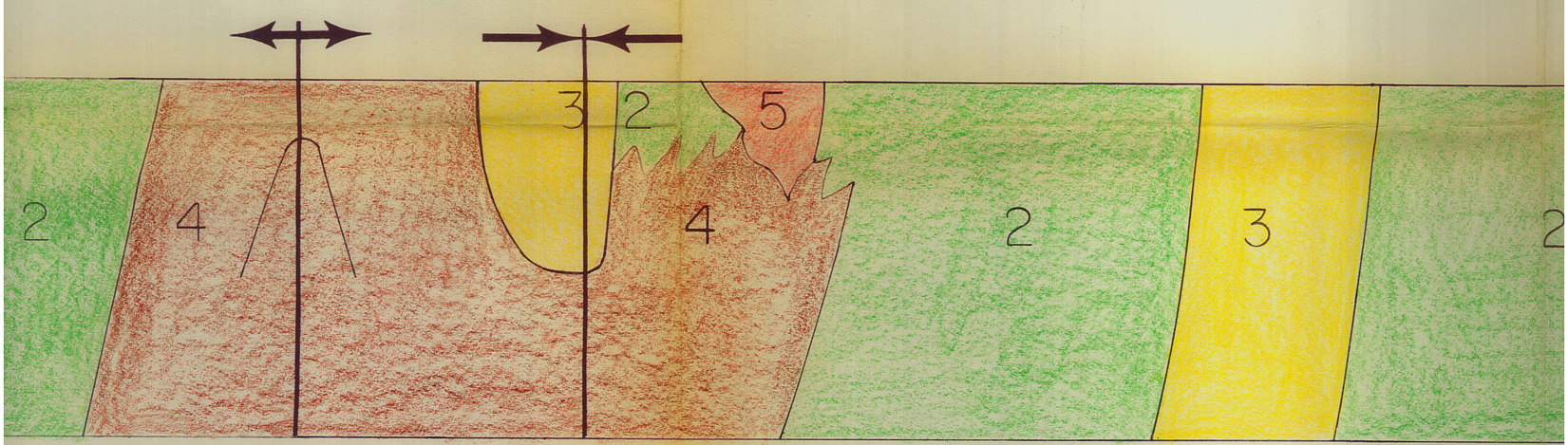


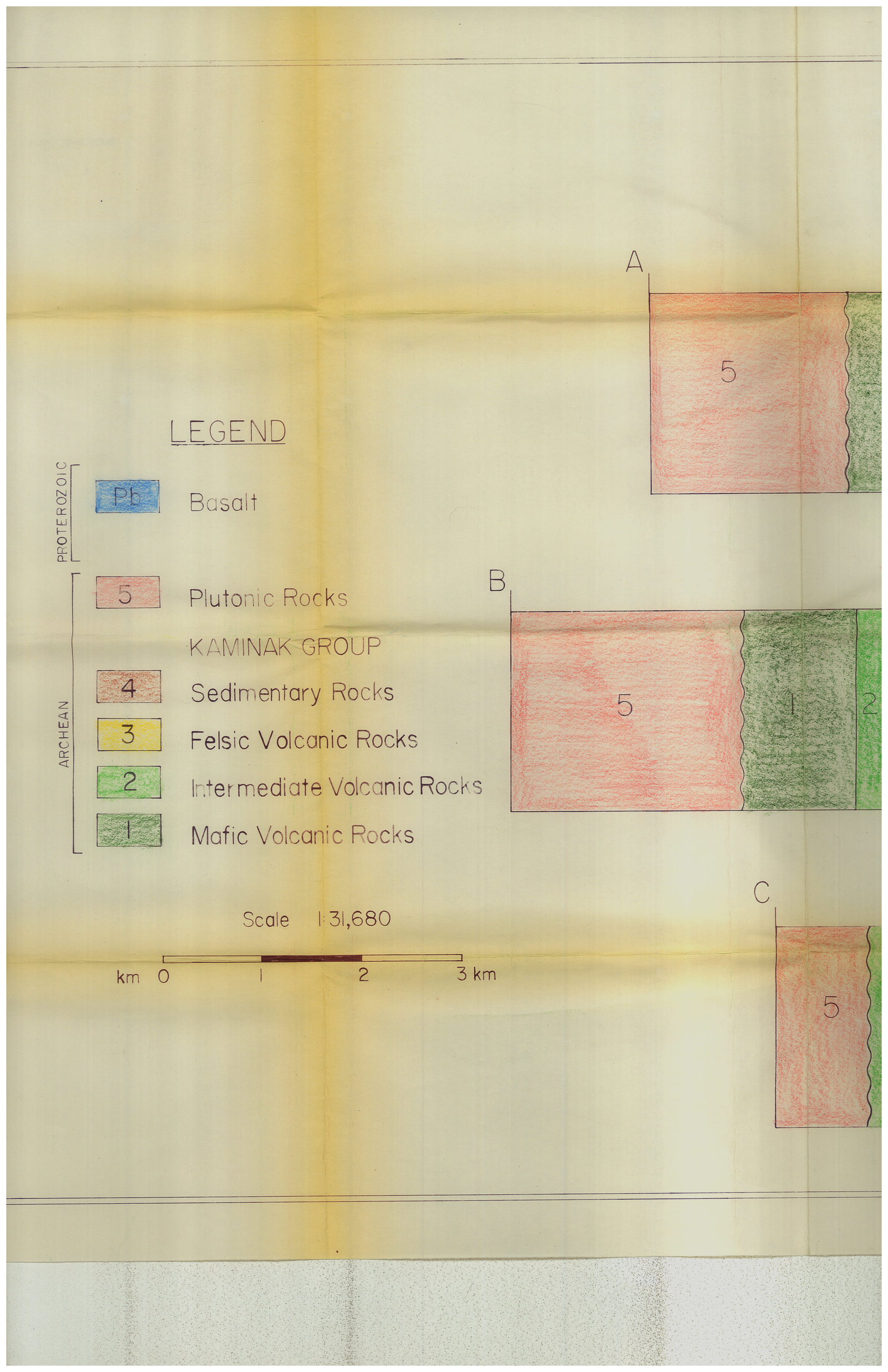
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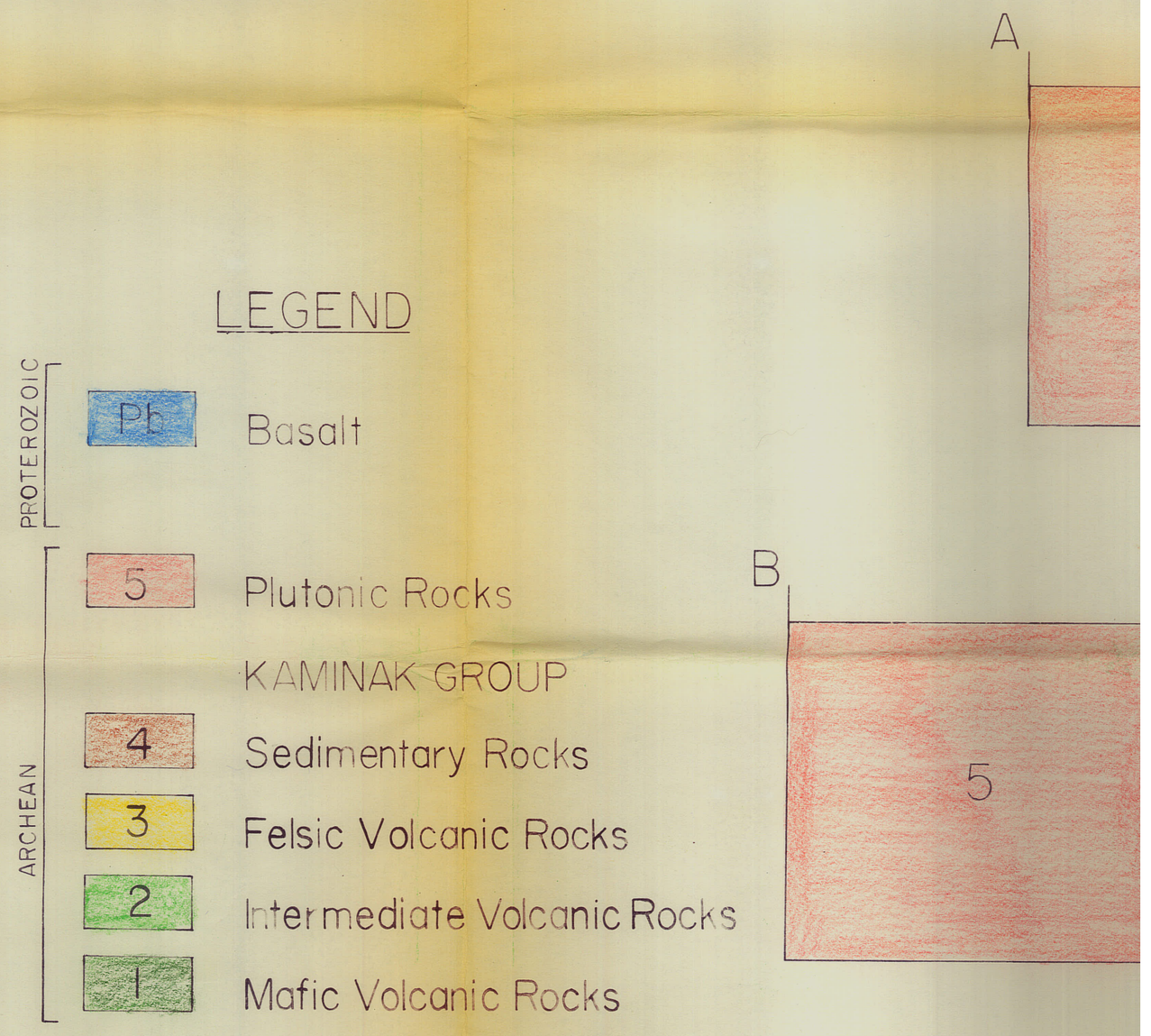
CROSS SECTIONS








LEGEND
PROTEROZOIC
Pb
Basalt
ARCHEAN
5
Plutonic Rocks
KAMINAK GROUP
4
Sedimentary Rocks
3
Felsic Volcanic Rocks
2
Intermediate Volcanic Rocks
1
Mafic Volcanic Rocks
Scale 1:31,680
km 0 1 2 3 km
A
5
B
5
1
2
C
5



LEGEND

PROTEROZOIC

Pb — Basalt

ARCHEAN

5 — Plutonic Rocks

KAMINAK GROUP

4 — Sedimentary Rocks

3 — Felsic Volcanic Rocks

2 — Intermediate Volcanic Rocks

1 — Mafic Volcanic Rocks

Scale 1:31,680

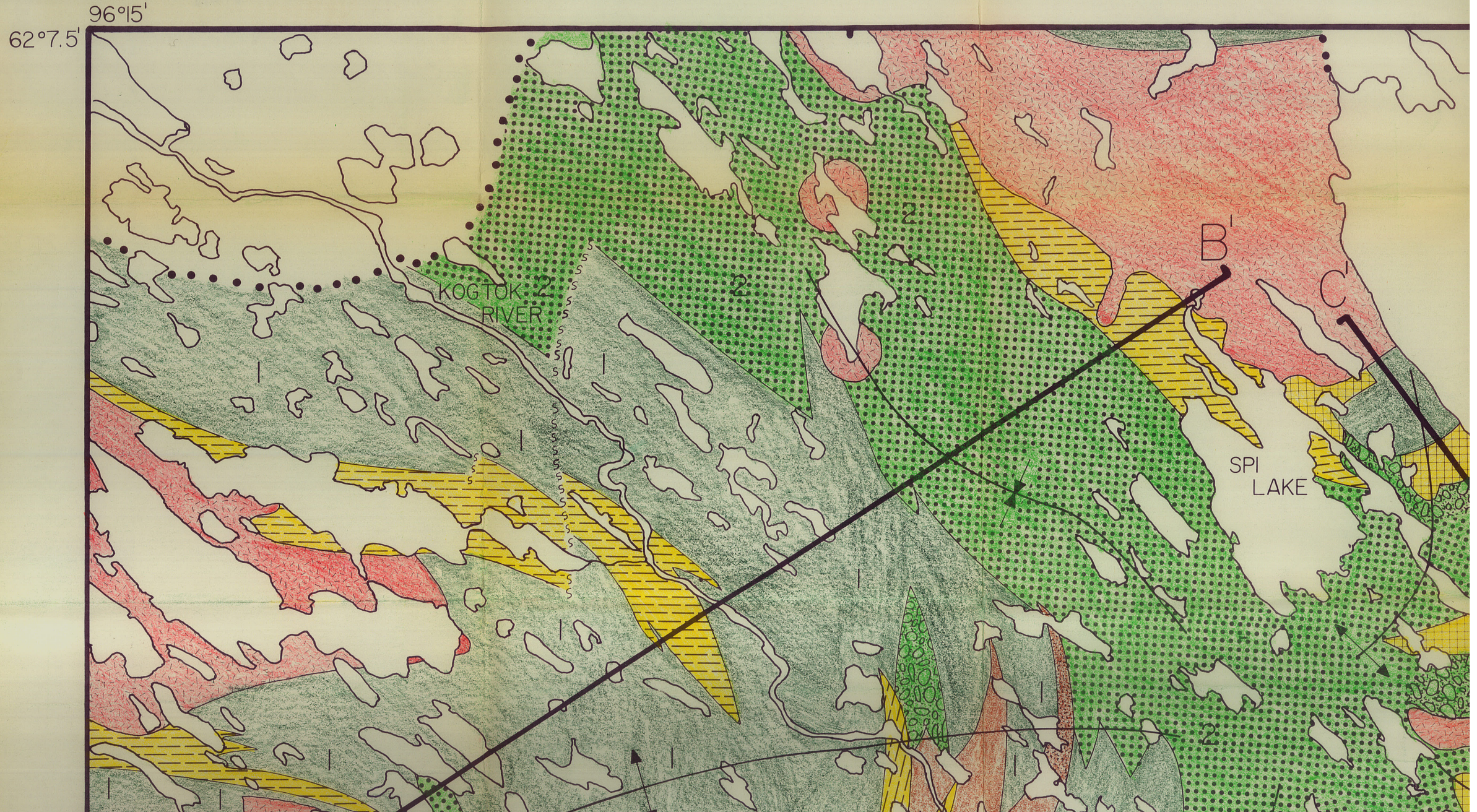
km 0 1 2 3 km

Fig. 3

DEPOSITIONAL FACIES OF THE KAMINAK GROUP

CARR LAKE · N.W.T.

N.T.S. 55E



B

A

MAGUSE
RIVER

TURQUETIL
LAKE

A

A'

TURQUETIL
LAKE

MAGUSE
RIVER

61°50'

96°15'

13,L-4,65 H-16,I-I

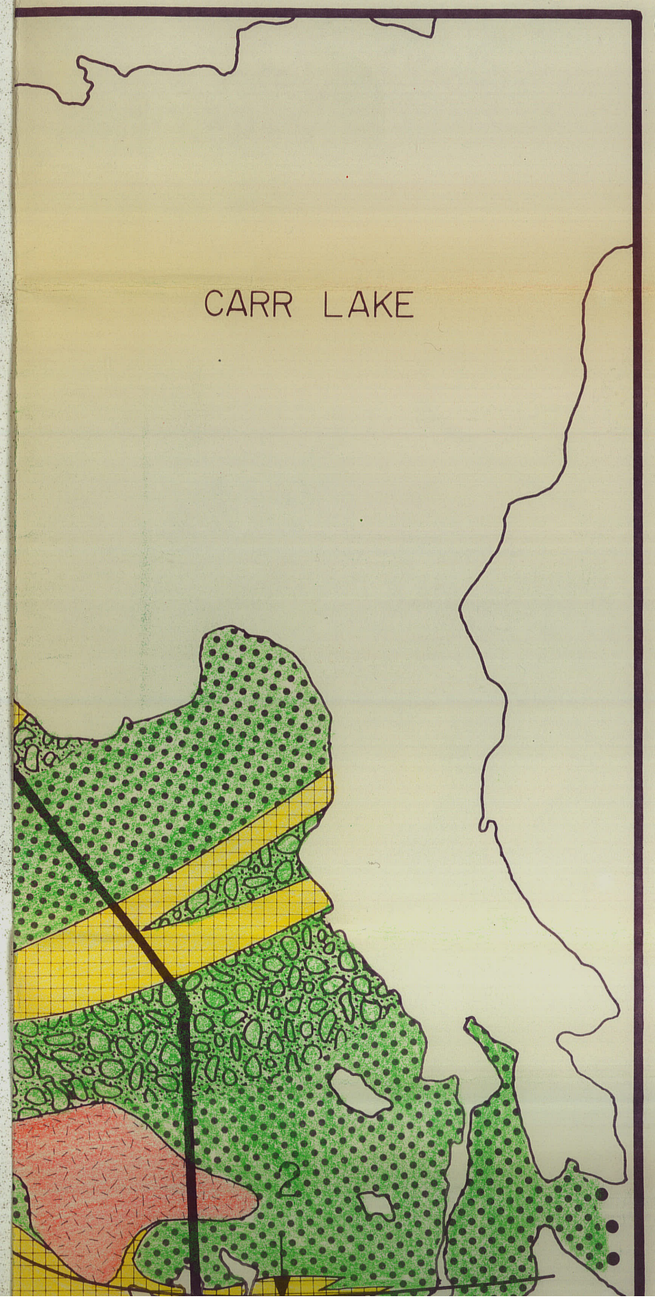
95°40'

13,L-4,65H-16,1-1

95° 40'

62° 7.5'

CARR LAKE



LEGEND

Plutonic Rocks

Depositional Facies of the Kaminak Group

Facies VII (Deeper Water Facies of Sedimentary Rocks)

Facies VI (Shallow Water Facies of Sedimentary Rocks)

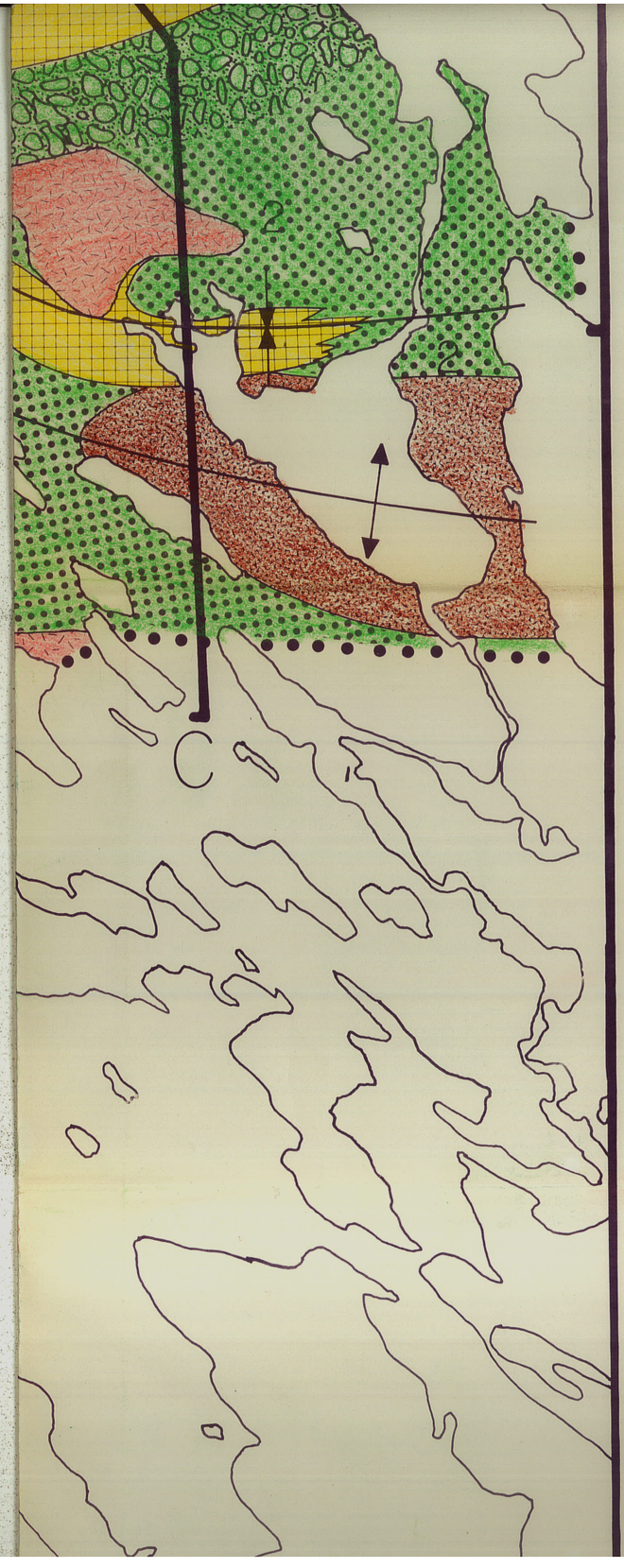
Facies V (Distal Facies of Felsic Volcanic Rocks)

Facies IV (Proximal Facies of Felsic Volcanic Rocks)

Facies III (Distal Facies of Intermediate Volcanic Rocks)

Facies II (Proximal Facies of Intermediate Volcanic Rocks)

Facies I (Subaqueous Facies of Mafic Volcanic Rocks)



Facies III (Distal Facies of Intermediate Volcanic Rocks)

Facies II (Proximal Facies of Intermediate Volcanic Rocks)

Facies I (Subaqueous Facies of Mafic Volcanic Rocks)

(Proterozoic rocks have been omitted from this map)

Fig. 4

SCALE 1:63,360

km 0 1 2 3 4 km

C

95°40'

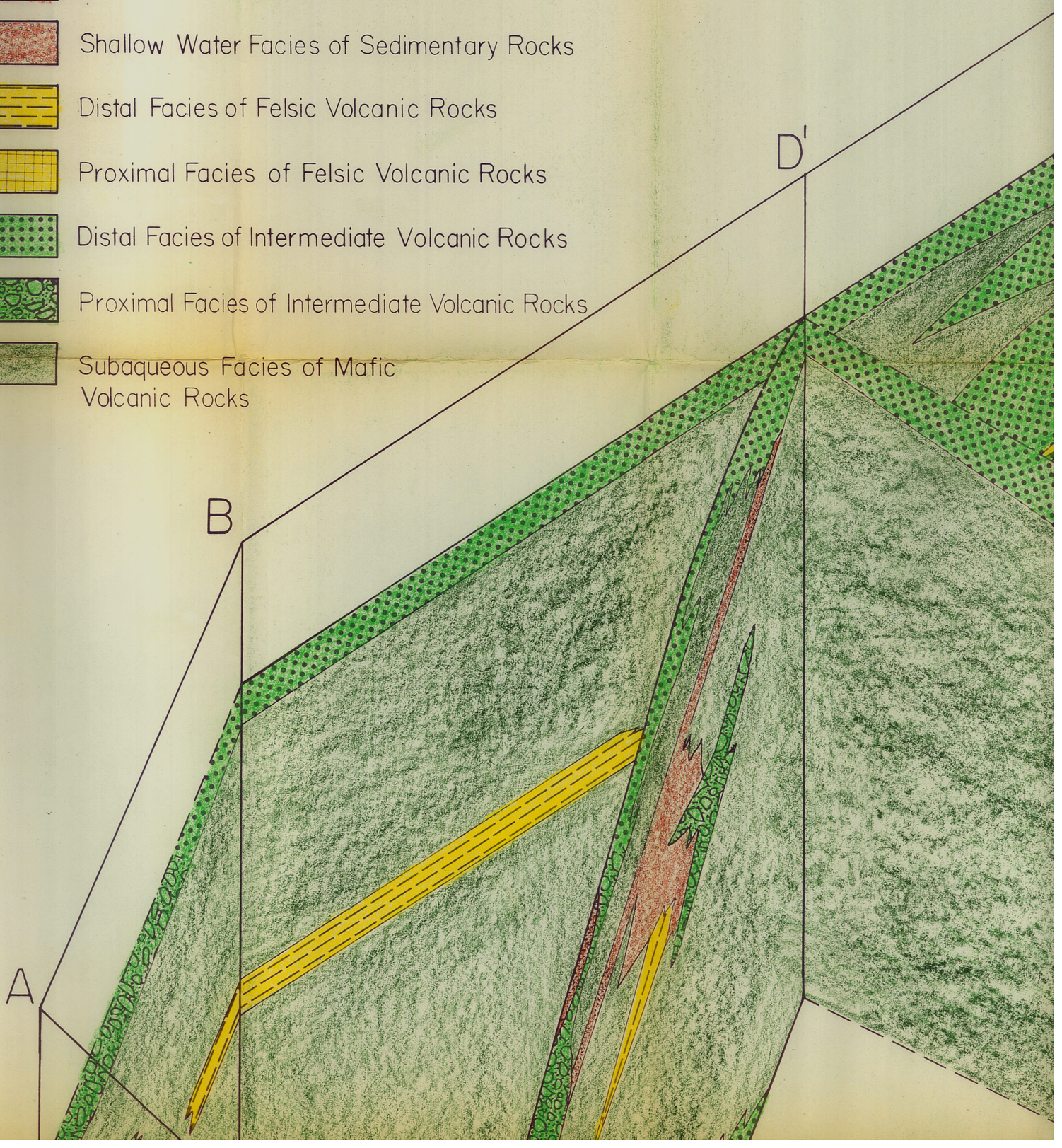
61°50'

FENCE DIAGRAM OF THE PREFOLDED THE KAMINAK GROUP, CARR LAKE N.W.T.

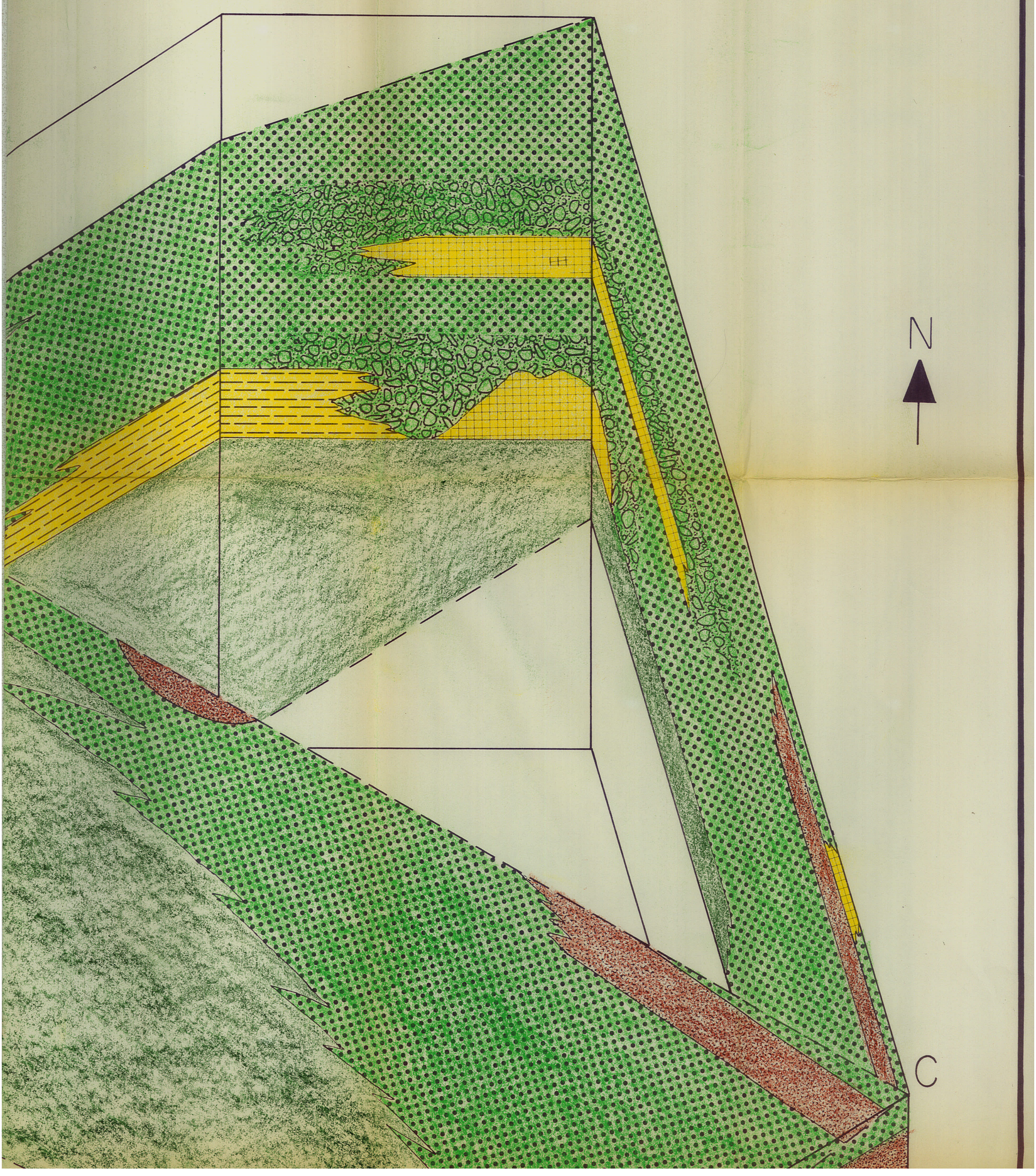
LEGEND

KAMINAK GROUP

- Deeper Water Facies of Sedimentary Rocks
- Shallow Water Facies of Sedimentary Rocks
- Distal Facies of Felsic Volcanic Rocks
- Proximal Facies of Felsic Volcanic Rocks
- Distal Facies of Intermediate Volcanic Rocks
- Proximal Facies of Intermediate Volcanic Rocks
- Subaqueous Facies of Mafic Volcanic Rocks



DEPOSITIONAL FACIES OF



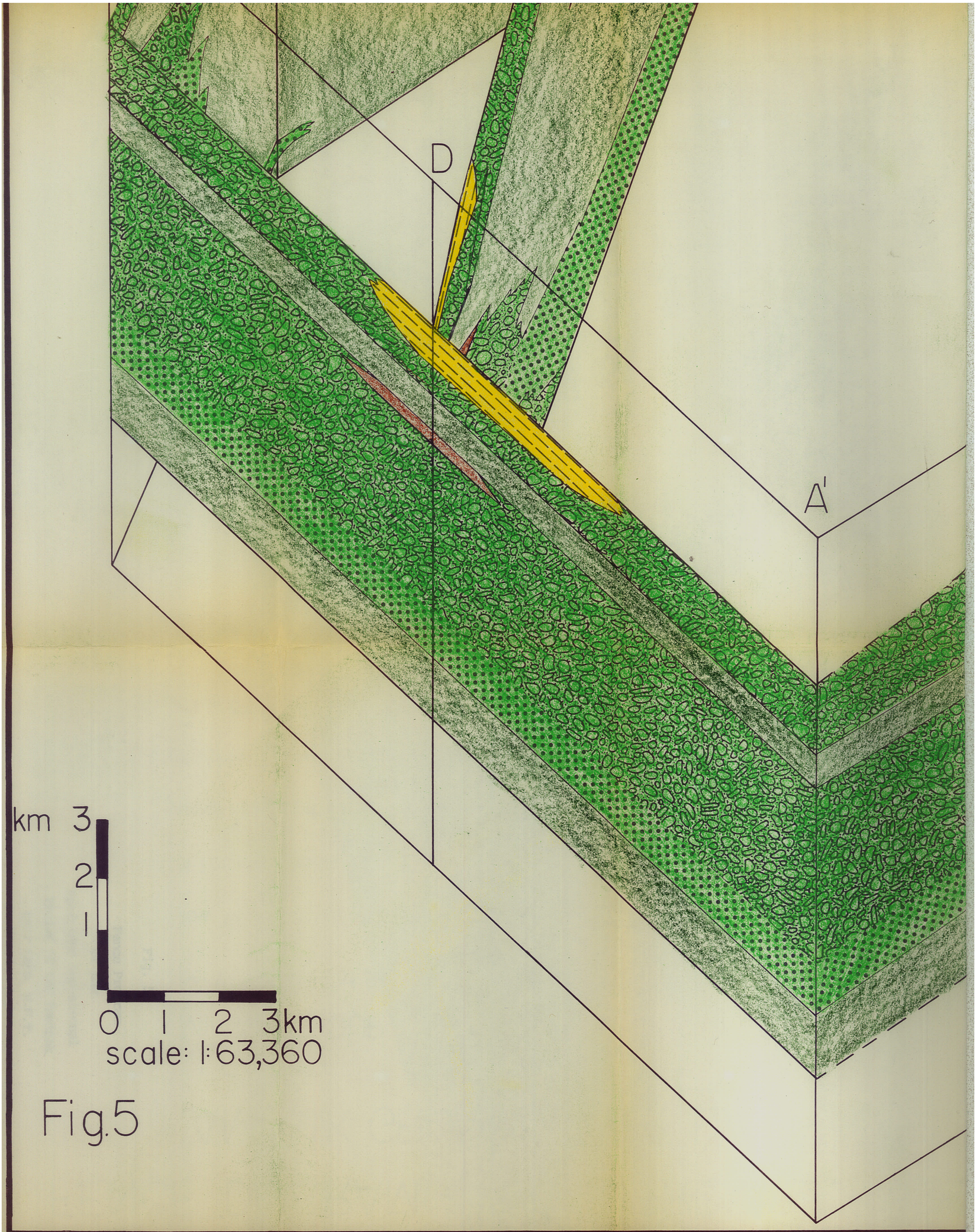


Fig.5

