STRATIGRAPHY, STRUCTURE, AND METAMORPHIC PETROLOGY OF THE ARCHEAN GREENSTONE BELT AT BIRD RIVER, MANITOBA

A Dissertation
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the Faculty of Graduate Studies
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of Doctor of Philosophy

by

David Lawrence Trueman

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ABSTRACT

The development of the earth's crust in the Bird River area of southeastern Manitoba involved volcanism, erosion, sedimentation, folding, and metamorphism which terminated during the Kenoran event of the Canadian Shield. The rocks, so formed and known as the Bird River greenstone belt, are present in the study area as a wedge of greenschist and amphibolite facies metamorphites situated between gneissic rocks to the north known as the Manigotagan gneiss belt, and intrusive and gneissic rocks to the south termed the Winnipeg River batholithic belt.

Mapping on outcrop scale, petrographic, structural, and chemical analysis of the rocks of the Bird River area conducted over a period of six years have allowed a six-fold subdivision of rocks of the greenstone belt. This includes a lowermost formation of volcaniclastic and epiclastic rocks, a succession of tholeiitic metabasalts, a succession of metarhyolite flow, clastic, and epiclastic rocks, a succession of fine to coarse volcaniclastic and epiclastic rocks intercalated with tholeiitic and calc-alkaline flows, an unconformable succession of arenaceous and metaconglomeratic rocks derived from the underlying formations, and an unconformable succession of metamorphosed greywacke - mudstone turbidites.

The metavolcanic and related metasedimentary rocks of these formations have been intruded by synvolcanic counterparts, and all of the rocks of the stratigraphic section were subsequently intruded during metamorphism by diapiric batholiths. Late intrusive rocks, post-dating major metamorphism, include batholiths of quartz monzonite and stocks and dykes of pegmatite kindred.

Major and minor fold structures within the area are products of multiple periods of tectonism. The oldest folding event recognized was a flexural event directed on axial surfaces now trending easterly and was accompanied by metamorphic grades of at least upper greenschist facies. The second, or younger, folding event of the area was a passive event directed on easterly trending axial surfaces, and appears to have been accompanied by the diapiric emplacement of the batholiths. Metamorphic assemblages developed in attendance with the second folding event equilibrated in a range from greenschist to granulite facies and are diagnostic of a high temperature - low pressure environment.

The youngest metamorphic event recognized in the area was essentially retrogressive and accompanied by the development of easterly trending faults which served to telescope the stratigraphic succession of the belt, and served as loci for subsequent granite and pegmatite intrusion.

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INTRODUCTION

The volcanic and sedimentary rocks of the Archean Bird River greenstone belt have long been known as important hosts for nickel-copper, chromite, lithium, beryllium, cesium, and tantalum-tin deposits. The present work was undertaken (a) to gain an understanding of the volcanic-sedimentary stratigraphy of this greenstone belt, (b) to determine the tectonic and metamorphic history of the belt, and (c) to determine the history of its intrusive rocks.

LOCATION, ACCESS, AND TOPOGRAPHY

The Bird River greenstone belt is situated in the Superior (Archean) geologic province of the Canadian Shield in southeastern Manitoba (Fig. 1a).

The approximate geographic center of the Bird River greenstone belt is located about 200 km northeast of Winnipeg (Fig 1b) and the area in general is accessible by Provincial Roads 313, 314, and 315 east from the town of Lac du Bonnet. Access to southern parts of the belt is best gained by road to Umfreville Lake.

Internal access in the greenstone belt can be achieved by canoe, boat, or aircraft. Ground travel is greatly facilitated by several hundreds of miles of logging roads which are for the most part winter roads, and wind about much of the rock outcrop providing useful mapping control.

The topography and physiography of the area is typical of much of the Canadian Shield, and consists of low (< 25m) rock outcrop mantled by swamp, or tree-covered ground. Much of the area has been subjected to "clear- cutting" logging operations

PREVIOUS GEOLOGICAL WORK AND ECONOMIC DEVELOPMENT

The first geologic investigation in the Bird River area was conducted by Tyrell (1900). Moore (1913) correlated the rocks of the Bird River area with those of the Rice Lake Group of the Bisset area to the north.

The discovery of base metal (Ni-Cu) sulphides in the Cat Creek-Maskwa River area prompted initial studies of the Bird River Sill by Colony (1920; 1921) and McCann (1921). Regional mapping of the Bird River greenstone belt was subsequently conducted by Cooke (1922) and Wright (1926; 1932) and during this period prospectors discovered chromite in gabbroic rocks of the area. In 1942 the discovery of chromite deposits in the Bird River Sill resulted in extensive investigations by Bateman (1942; 1943; 1945)

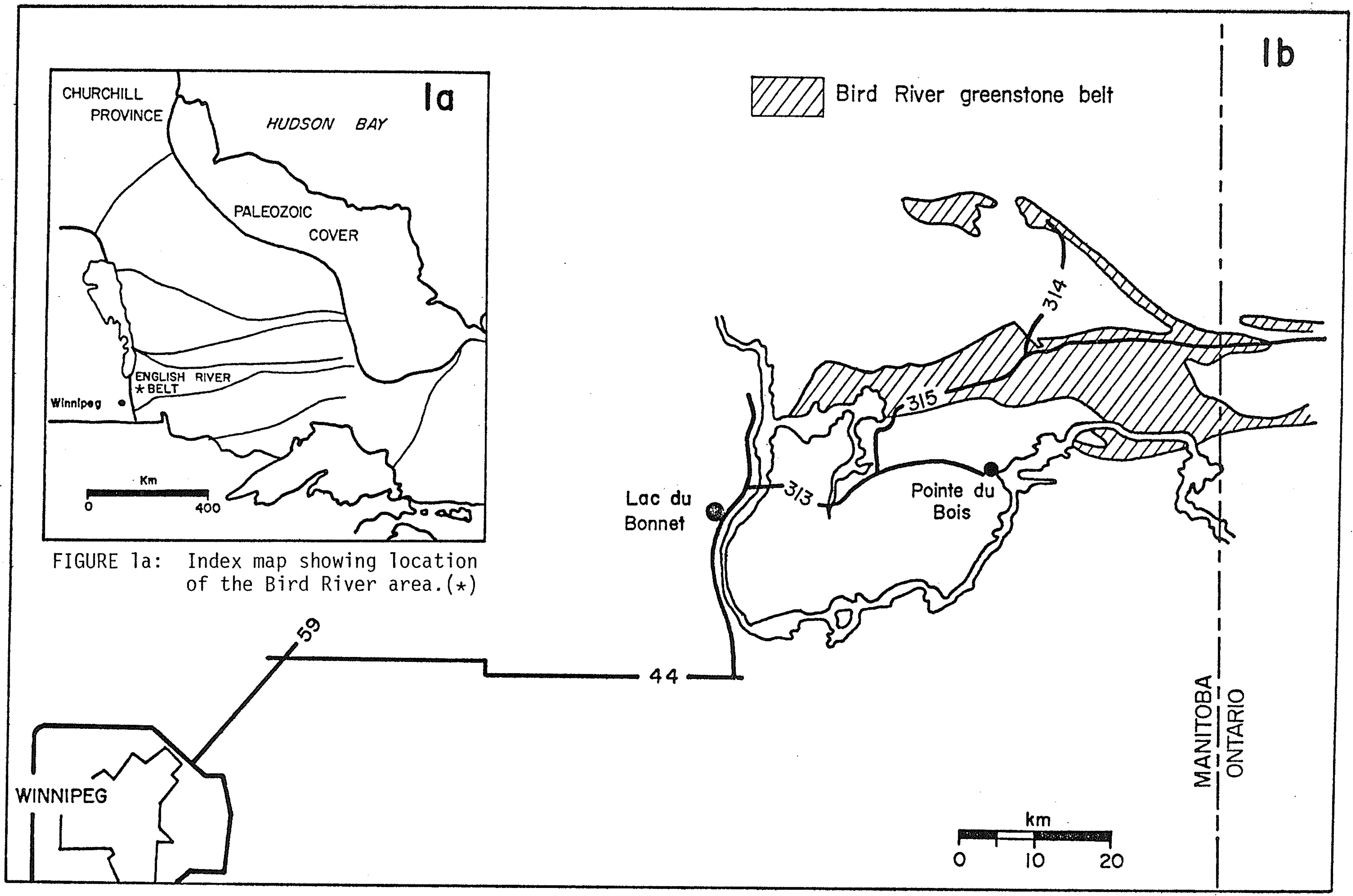

FIGURE 1a: Index map showing location of the Bird River area.(*)

FIGURE 1b: Location map showing the Bird River greenstone belt.

and Brownell (1942) and further regional mapping was undertaken by Springer (1949; 1950) and Davies (1952; 1955; 1956; 1957).

The eastern continuation of the Bird River greenstone belt in Ontario has been described by Burwash (1925), Derry (1931), Carlson (1958), and Breaks et al. (1978).

Studies of various aspects of the geology of the Bird River greenstone belt include descriptions of the Bird River Sill by Osborne (1949), Trueman (1970; 1971; in preparation), and Trueman and Macek (1971). Descriptions of chromite deposits of the Bird River Sill are given by Bateman (1943), Brownell (1942), Springer (1950), Davies (1952; 1955), Davies et al.(1962), Gait (1964), and Trueman (1971; in preparation).

Description of base metal sulphide deposits of the area are given by Colony (1920; 1921), McCann (1921), Childerhouse (1928), Wright (1926; 1932), Taylor (1950), Springer (1950), Davies (1952; 1955), Chown (1956), Carlson (1958), Davies et al. (1962), Karup-Møller and Brummer (1971), Ritchie (1972), Scoates (1973), and Juhas (1973).

Description of lithium - cesium - beryllium - tantalum - tin bearing pegmatites of the area are given by Wright (1932), Springer (1950), Davies (1956; 1957), Hutchinson (1959), Davies et al. (1962), Wright (1963), Černý and Turnock (1971), Bannatyne (1972), and Simpson (1976). Study of several of these pegmatite deposits is currently ongoing (Černý et al. 1979), and the Tanco pegmatite (formerly Montgary pegmatite) has been described in detailed and ongoing studies by Crouse and Černý (1972), and Crouse et al. (1979).

Petrologic studies within the greenstone belt have been conducted by Butrenchuk (1970), McRitchie (1971), Bond (1972), and Posehn (1976). Structural studies have been conducted locally in the area by Trueman (1971), and Lamb (1973). Isotope and chronology studies of the rocks have been conducted by Penner (1970), Penner and Clark (1971), and Farquharson (1976).

R. Springer (University of Brandon) is currently engaged in mineralogical study of the Bird River area chromites, and Trueman (1977) demonstrated the existence of a meteorite impact structure on Poplar Bay of Lac du Bonnet.

One mine is currently producing in the area; the Tanco Mine at Bernic Lake which is in production of tantalum concentrates. In past, Ni-Cu production was undertaken by Canadian Consolidated Faraday at Werner Lake in Ontario and at the Dumbarton Mine in a joint venture with Falconbridge Nickel Mines and Maskwa Nickel Mines Ltd.

Cobalt was extracted for a short period near Werner Lake by Falconbridge Nickel Mines Ltd., and considerable exploratory work has also been conducted in the area by Norpax Nickel Mines, Bird River Mines and Manoka Mines Ltd.

Lithium production was undertaken near Cat Lake by Lithium Corporation of Canada in 1955, and elsewhere in the greenstone belt various rock types are being quarried by Red River Quarries Ltd.

PRESENT WORK AND ACKNOWLEDGEMENTS

Fieldwork forming the basis of this study was conducted seasonally in 1974 and 1975, and geologic mapping encompassed portions of four 15 minute map sheets. Initial results of this work were published by the Manitoba Mineral Resources Division (Trueman, 1975 a;b), and have been summarized elsewhere (Trueman, 1975; Trueman and Turnock, 1976; and Trueman et al., 1975).

Base maps for this study were assembled from National Topographic Series maps, aerial photographs and air-photo mosaics at scales of 1" = 1/2 and 1" = 1/4 mile. Other unpublished maps and air-photo mosaics were acquired from various unpublished airborne geophysical surveys of the area, and ongoing Manitoba government reforestation studies.

Data were collected for the present study from 1,286 outcrop occurences. In excess of 250 thin sections from previous, the present, and ongoing studies were examined, as were 132 whole rock chemical analyses of which 46 are newly reported below. Additional data were also acquired from unpublished airborne electromagnetic, magnetic, and radiometric surveys, and ground electromagnetic, magnetic, gravity, and geochemical surveys conducted by the writer. The latter, viz. gravity and geochemical surveys have provided, with correlative geologic study, in excess of 12,000 additional observations.

Support for this study was derived through the Department of Earth Sciences of the University of Manitoba, and the Manitoba Mineral Resources Division. Equipment and logistic support was also gained through individual National Research Council operating grants to Department of Earth Sciences staff members, and through the Manitoba Mineral Resources Division.

Laboratory and analytical support for this study was made available by both the Manitoba Mineral Resources Division, and the Department of Earth Sciences of the University of Manitoba.

Personal support for the investigator was derived through grants to the Department of Earth Sciences, a University of Manitoba Fellowship, and a National Research Council Science Scholarship.

Without the further support of many individuals this work would not have been possible. Accordingly the writer would like to acknowledge all facets of assistance provided by A.C. Turnock, W.C. Brisbin, H.D.B. Wilson, L.D. Ayres, and P. Černý of the University of Manitoba, C.F. Lamb, W.D. McRitchie, R.F.J. Scoates, D.A. Janes, and W. Weber of the Manitoba Mineral Resources Division, the technical support staff of both of the above institutions, the staff of Tantalum Mining Corporation, the staff of Dumbarton Mines Limited, Canadian Consolidated Faraday, Manitoba Quarries Limited, A.O. Zeemel of Gunnar Mines Limited, J. Donner of Bird River Mines Limited, and W. and J. Stoeterau and C.J.A. Coates of Falconbridge Nickel MInes Limited.

REGIONAL SETTING AND GENERAL GEOLOGY OF THE BIRD RIVER GREENSTONE BELT

The Archean (Penner and Clark, 1971) Bird River greenstone belt lies in the exposed western extremeties of a broad, linear crustal feature termed the English River gneissic belt (Wilson, 1971; Fig. 1a). This feature, first identified by its regional aeromagnetic signature, was found to be dominated by rocks of para-, and orthogneissic affiliation. In Figure 2a, the aeromagnetic signature of a portion of the belt is shown with that of the corresponding regional geology (after Beakhouse, 1977) in Figure 2b.

Coincident with the aeromagnetic signature and surface geology of the English River gneissic belt is, in much of the area, a thinning of the lower crust which is a result of downwarping of the intermediate discontinuity (Hall, 1971). A map showing the thickness of the lower crust is presented in Figure 3.

A further attribute of the English River gneissic belt is a coincident, linear, gravity high which corresponds in general to the distribution of the gneissic rocks (Fig. 4) and their eastward extension. Analysis of these data with the aformentioned seismic work detailing the Mohorovicic and Conrad discontinuities has allowed the interpretation of the gneiss belt as being in "seismic - isostatic" equilibrium (Brown, 1969; Hall, 1971).

Beakhouse (1977) in his synthesis of the English River gneiss belt recognized a fundamental subdivision of the area (Fig. 2b) into a northern belt (Manigotogan - Ear Falls gneiss belt) dominated by metasedimentary rocks, and a southern belt dominated by intrusive rocks (Winnipeg River batholithic belt). Of these, and within the study area, the Manigotagan gneiss belt is seen to be flanked on the north by the Rice Lake greenstone belt, and on the south by the Bird River greenstone belt. Studies by Weber (1971) haveindicated that sedimentation from the Rice Lake greenstone belt occured in the Manigotagan gneiss belt, and in a subsequent study Trueman et al. (1976) demonstrated a correlation of the metasedimentary gneisses with metasedimentary rocks of the Bird River greenstone belt.

Recently, Ermanovics et al. (1979) have postulated on the basis of their own and other work (Breaks and Bond, 1977) that some of the rocks of the Pine Falls complex and the Winnipeg River batholithic belt represent older rocks, and hence may be interpreted as basement to the now metamorphosed

FIGURE 2a: Compilation of Federal-Provincial Aeromagnetic coverage over, and adjacent to the study area (Study area in pink).

Contour Interval 100 γ

Scale 1:2,000,000

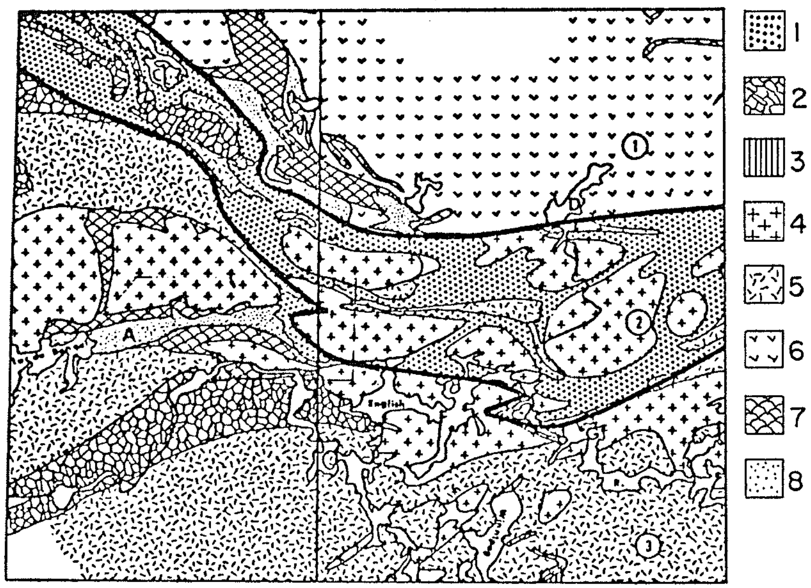

FIGURE 2b: Geological compilation of (1) Red Lake Block
(2) Manigotogan Gneiss Belt
(3) Winnipeg River Batholithic Belt
(after Beakhouse, 1977)

KEY
A: Bird River Greenstone Belt
1: Metasedimentary Gneiss
2: Early Gneissic Suite
3: Diorite Suite
4: Trondhjemite - Granodiorite Suite
5: Granodiorite - Granite Suite
6: Granitoid Rocks
7: Metavolcanic Rocks
8: Metasedimentary Rocks

Scale 1:2,000,00 (Study area in pink).

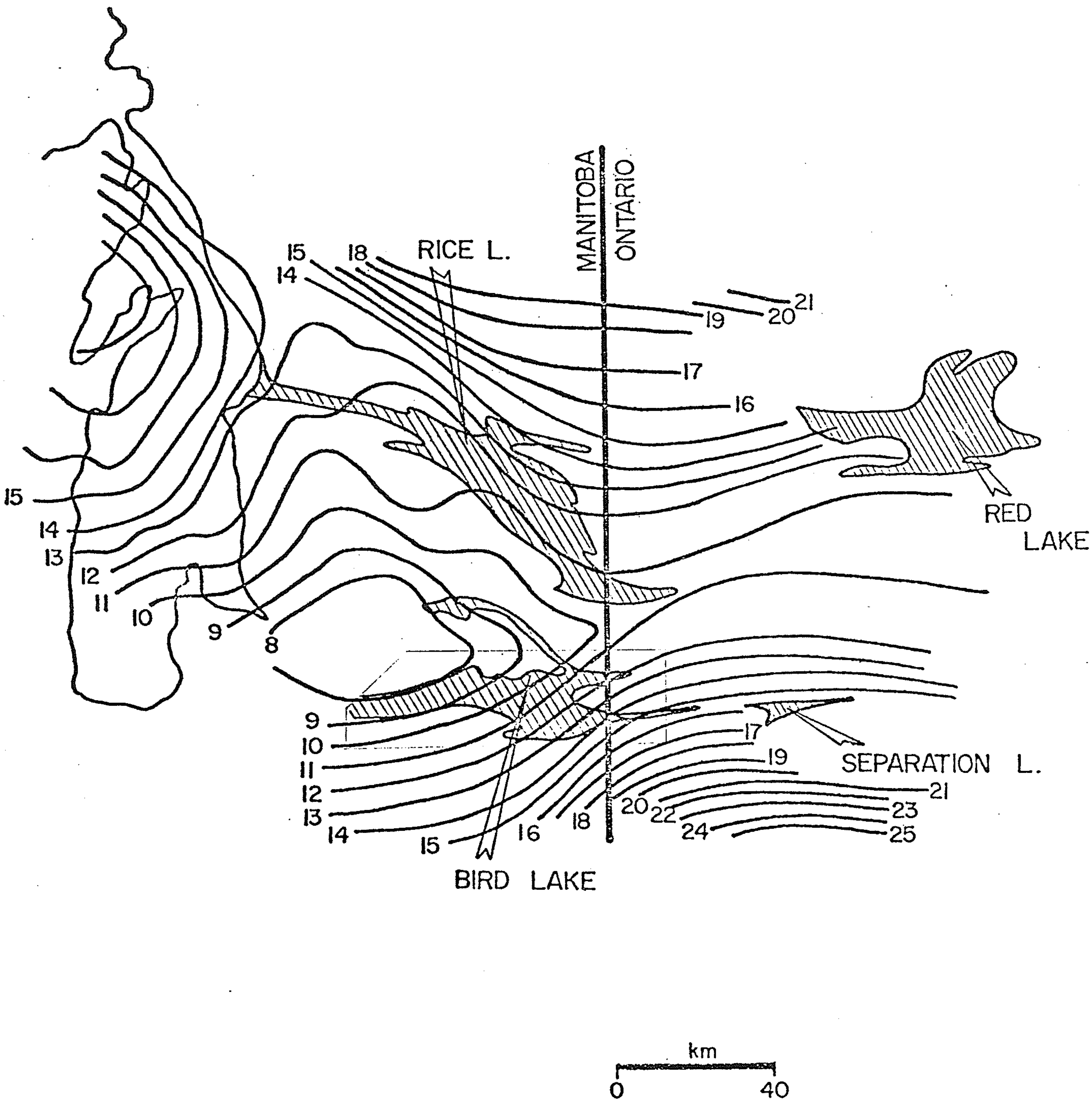

FIGURE 3: Isopach map of the basaltic crust underlying the study area (pink), and adjacent greenstone belts. Contour interval 1 km.

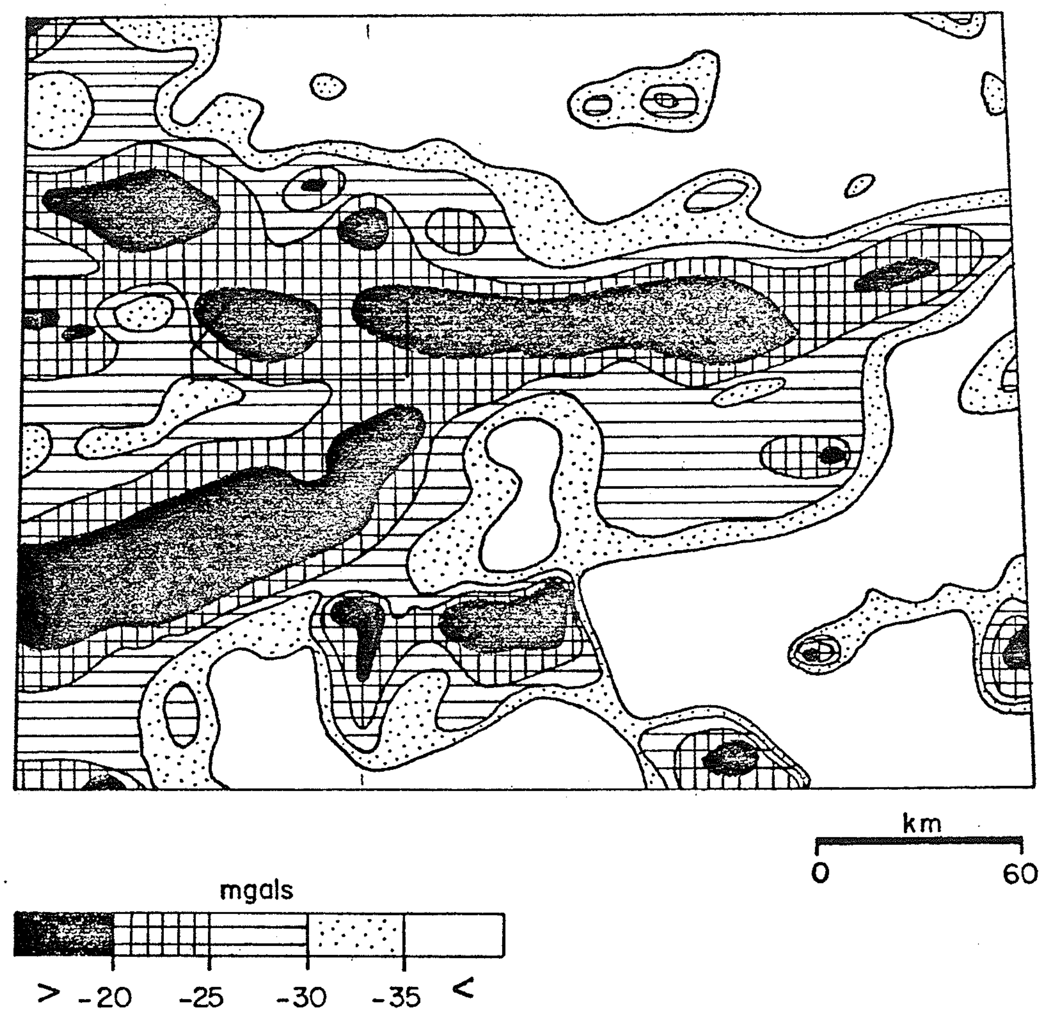

FIGURE 4: Bougeur gravity map, over and adjacent to the study area (pink). (After Beakhouse, 1977).

volcanic and sedimentary rocks of the Bird River area.

The Bird River greenstone belt comprises metavolcanic and metasedimentary rocks which were first termed a part of the Rice Lake Group by Moore (1913).

In the Bird River area, detailed outcrop mapping and analysis of the rock types has allowed a subdivision of the layered rocks of the Rice Lake Group into six formations which are shown in Figure 5. Their respective ages, and gross lithologies, based on the data which follows, are summarized in Table 1.

Intrusive rocks of the Bird River area can be subdivided on the basis of field relationships, compositions, and internal structures into synvolcanic, syntectonic, and late - tectonic categories. The distributions of these rock types are shown in Figure 6 and the temporal sequence of their emplacement is also shown in Table 1.

The presence or absence of metamorphic assemblages or structures in both layered and intrusive rocks of the Bird River area has allowed the sequencing of metamorphism and deformation of these rocks, as shown in Table 1.

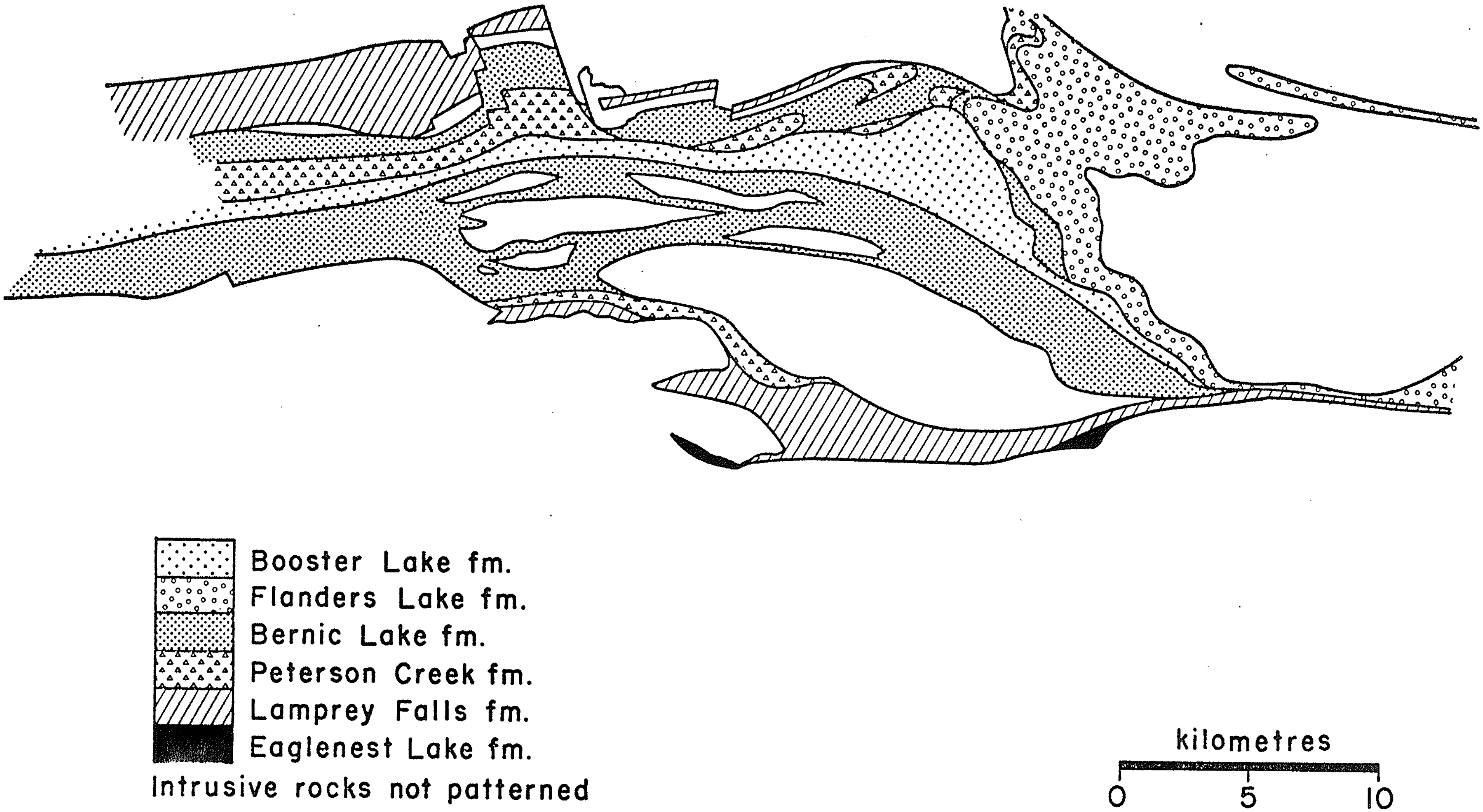

FIGURE 5 : Stratigraphic subdivision of the metavolcanic and metasedimentary rocks of the Bird River area.

TABLE I. TABLE OF FORMATIONS IN THE BIRD RIVER AREA, MANITOBA.

ARCHEAN

RICE LAKE GROUP

FORMATION	DOMINANT LITHOLOGY	INTRUSIVE ROCKS	METAMORPHISM	DEFORMATION	STRUCTURE
		Pegmatite, aplite, pegmatitic granite			
			M_4	D_4	F_4
		Lac du Bonnet quartz monzonite			
			M_3	D_3	F_3
		Maskwa, Marijane Lake batholiths	M_2	D_2	$f_2 s_2$
Booster Lake	metamorphosed greywacke-mudstone				
		UNCONFORMITY			
Flanders Lake	lithic meta-arenite metaconglomerate		M_1	D_1	$f_1 s_1$
		UNCONFORMITY			
Bernic Lake	clastic derivatives metarhyolite metadacite meta-andesite metabasalt	Metamorphosed: gabbro diorite quartz-feldspar porphyries grandodiorite			
		UNCONFORMITY			
Peterson Creek	metarhyolite, clastic equivalents				
Lamprey Falls	metabasalt	Bird River Sill metagabbro			
Eaglenest Lake	metamorphosed volcanic wacke				

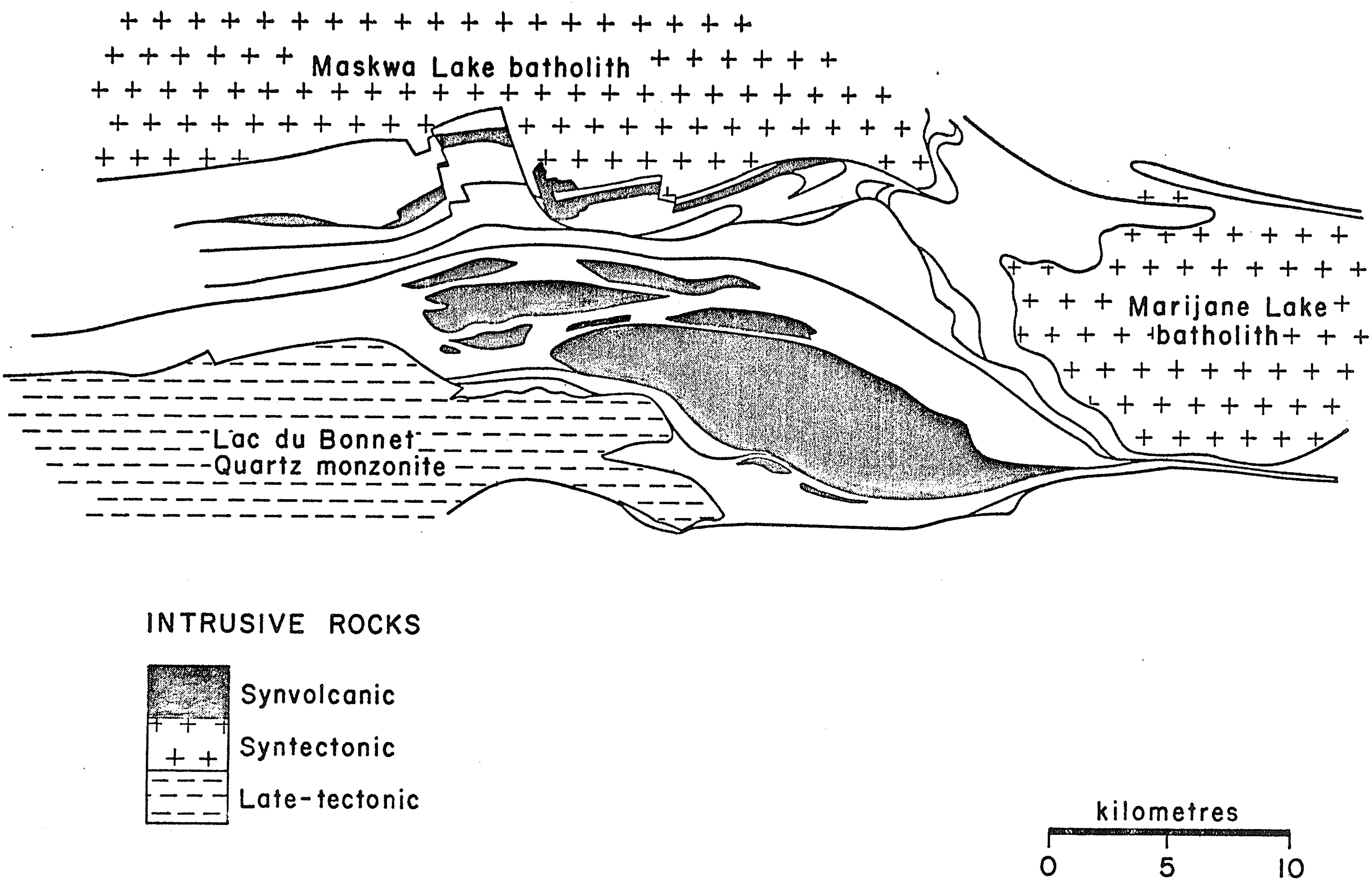

FIGURE 6: Classification and distribution of intrusive rocks of the Bird River area.

THE EAGLENEST LAKE FORMATION

DESCRIPTION OF ROCK TYPES (unit 1 on Map A)

The rocks of the Eaglenest Formation (Fig. 7) crop out extensively on the shores and islands of Eaglenest Lake which forms a part of the Winnipeg River (see also accompanying Map A). These rocks are intruded along their south contact by rocks of the Winnipeg River batholithic belt (Beakhouse, 1977) and form a part of the agmatitic and *schollen* zone of Janes (1976). To the north the Eaglenest Lake Formation lies in fault contact with metabasalts of the Lamprey Falls Formation.

Rock types of the Eaglenest Lake Formation include metamorphosed volcanic and pebbly wackes, and volcanic sandstones. Less abundant are biotite schists and amphibolites which occur between *lit* of dioritic intrusive rocks in the south contact zone. Banded iron formation occurs in proximity to the northern fault boundary of the Formation.

The rocks of the Eaglenest Lake Formation are typically dark grey to buff weathering, are fine to coarse grained, and moderately to strongly schistose. The volcanic wackes and pebbly variants are poorly bedded, lack sorting, and consist chiefly of quartz, albite, chlorite, actinolite, biotite, zoisite, and helycitic and euhedral garnet. Matrix-supported pebble-size lithic fragments consist variously of metabasalt, fine to medium grained gabbros, and more felsic volcanic sandstone clasts, all of which are strongly deformed and flattened parallel to the schistosity.

Volcanic sandstones interbedded with the wackes are grey to buff weathering, fine grained, show a degree of sorting and consist essentially or quartz and feldspar detritus, minor biotite, chlorite, and sericite.

Biotite schists and amphibolites are gradational with the above rocks, and appear only to have suffered a more extensive recrystallization with emplacement of intrusive *lit* from the batholithic complex to the south. Boudinage of beds is common, and ultimately these rocks pass into a dismembered zone of agmatite with porphyroblastic tonalitic and dioritic material.

The iron formation forms an appr ximately 6 m thick unit near the north boundary of the Eaglenest Formation and consists essentially of pyrrhotite,

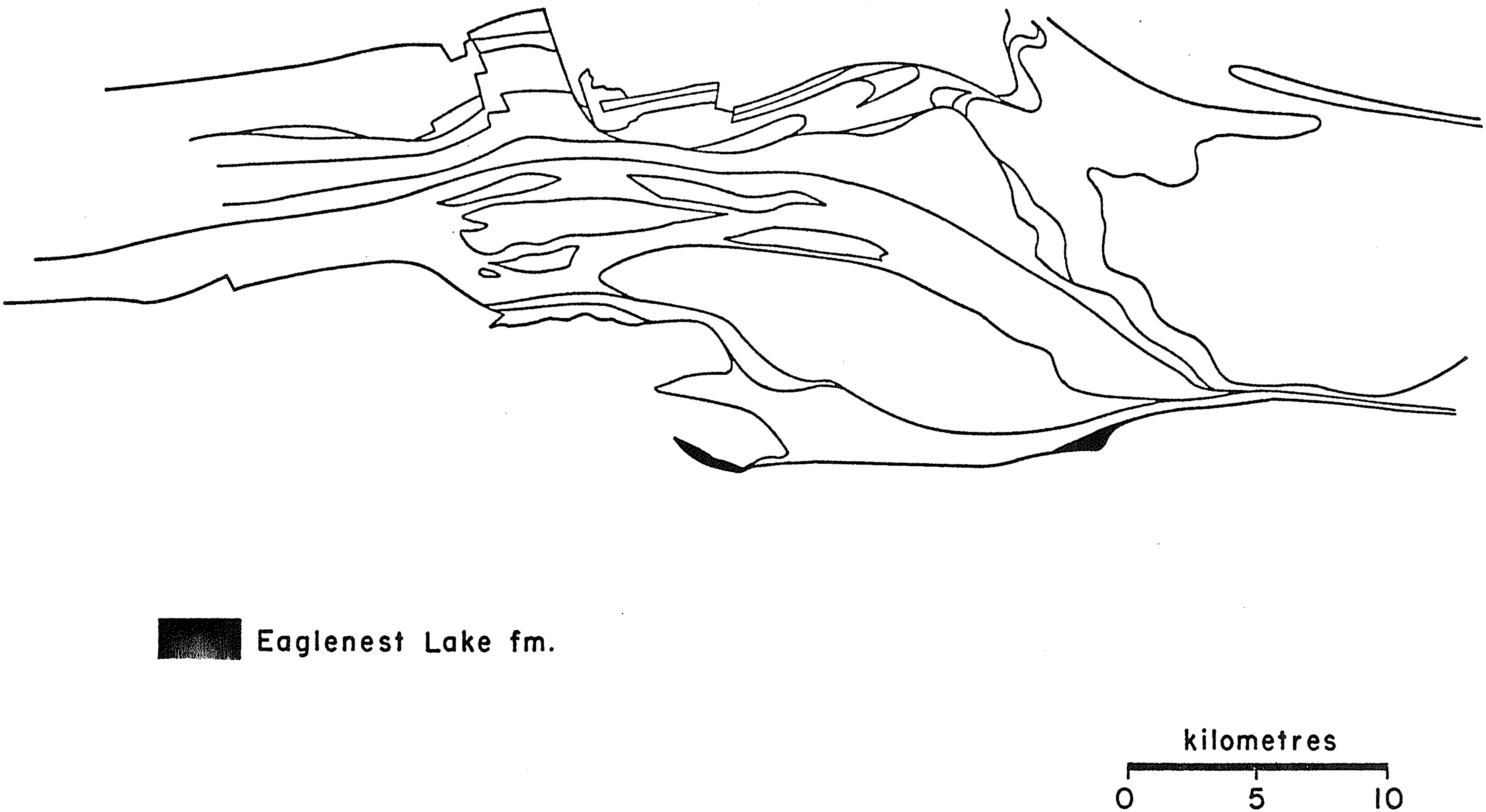

FIGURE 7: Location map of the Eaglenest Lake Formation.

magnetite, pyrite, and interlayered chert laminae. In outcrop the iron formation is highly weathered, forming rubbly gossans from which traces of chalcopyrite have been reported by Davies (1957).

The rocks of the Eaglenest Lake Formation were derived from a volcanic source area, but are of uncertain relative age. These rocks are bound to the south by an intrusive contact, and to the north by a fault. It is possible, however, to interpret these rocks in two ways; the Formation possibly occupies its true position in the stratigraphic succession and represents detritus from an edifice not recognized elsewhere in the area; or, conversely, the Eaglenest Lake Formation is a possible faulted segment (allocthon), removed from another part of the succession. In this regard it is noted that the Formation exhibits strong lithologic similarity with clastic rocks of the Bernic Lake Formation (descriptions of which are presented below).

THE LAMPREY FALLS FORMATION

DESCRIPTION OF ROCK TYPES (2)

The Lamprey Falls Formation (Fig. 8) crops out extensively on the Winnipeg River area and north of the Bird River (see also accompanying Map A). In these locales the Lamprey Falls formation consists essentially of mafic metavolcanic and related hypabyssal intrusive rocks, which attain a maximum thickness of 3 km. and thin laterally to the east and west.

Rock types of the Lamprey Falls Formation include metamorphosed pillow basalts, tuffs, hyaloclastites, aquagene breccias, megacrystic basalts, porphyritic and amygdaloidal metabasalts, and iron formation. Related intrusive rocks include numerous hypabyssal metagabbro sills, descriptions of which are presented in a subsequent description of the intrusive rocks.

Pillowed metabasalt (Fig. 9) is the dominant rock type of the Lamprey Falls Formation. This rock is typically dark grey-black to green weathering, fine to medium grained, massive to weakly schistose, and is characterized by well preserved pillow selvages which allow reliable top determinations. Elsewhere, a more strongly developed schistosity yields a moderate stretching of pillows.

South of the Winnipeg River, pillowed matabasalt is more commonly marked by the occurrence of small (<.5 cm) quartz and quartz - carbonate filled amygdales, and to a lesser extent by the occurrence of small (<2 mm) plagioclase (anorthite) phenocrysts.

Megacrystic metabasalts occur in isolated horizons, one approximately 100 metres north of the north contact of the Bird River Sill, and one northwest of Greer Lake (see accompanying Map A). These metabasalts are marked by an abundance of coarse, single crystal and glomeroporphyritic aggregates of calcic plagioclase (An79 - An85) which range in size from 1 to 10 cm (Fig. 10). The matrix of these megacrysts is black to green weathering, fine to medium grained, and massive, and generally retains dismembered pillow selvages which are in part perforated by the megacrysts.

Mafic tuffs are disposed as thin (<3 m) intercalations in metabasalt and have little (<100 m) lateral persistence. These rocks are generally greenish weathering, medium grained, and moderately to strongly schistose. Lapilli size (Fisher, 1966) fragments are commonly present but never comprise in excess of 10 percent of the rock.

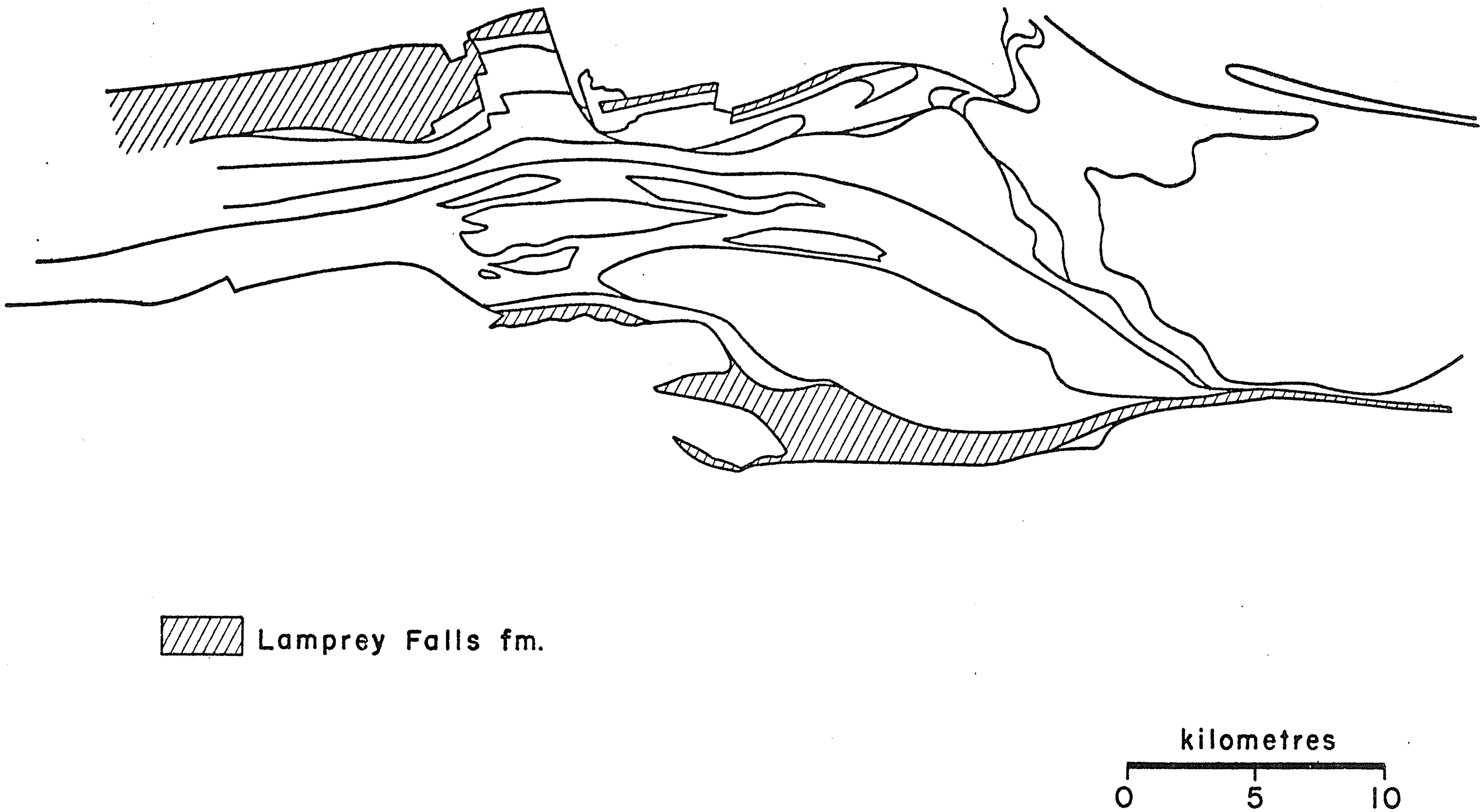

FIGURE 8: Location map of the Lamprey Falls Formation.

FIGURE 9: Pillowed metabasalt in the Lamprey Falls Formation north of the Page Property (see accompanying Map C).

FIGURE 10: Megacrystic metabasalt in the Lamprey Falls Formation north of the Chrome Property (see accompanying Map C).

A mixed zone of hyaloclastite and pillowed metabasalt crops out north of the Bird River (see accompanying Map A). This rock comprises irregularly shaped pillow - like fragments of metabasalt, in a voluminous matrix of fine to coarse shards of clastic quench material (Fig.11). Similar hyaloclastites and aquagene breccias occur at the top of the Lamprey Falls Formation close to its contact with the Peterson Creek Formation along the Winnipeg River (see accompanying Map A).

In thin section all of the above rock types consist of plagioclase (albite - labradorite), tremolite- actinolite, chlorite, biotite, zoisite, leucoxene - ilmenite, locally garnet, quartz, and carbonate. Texturally, these rocks vary from lepidoblastic chlorite - rich to massive or nematoblastic amphibole - rich.

Iron formation occurs intercalated with the mafic metavolcanic rocks of the Lamprey Falls Formation, as two prominent bands in the Winnipeg River area, and as a single band in the area north of Bird River (see accompanying Map A). These features, exposed as rubbly gossans, contain magnetite - chert, and iron sulphide assemblages.

PETROCHEMISTRY

Seventeen chemical analyses of metabasalt from the Lamprey Falls Formation are presented in Table II. Of these, four analyses are of samples from north of the Bird River; thirteen analyses are of samples from south of the Winnipeg River.

Alkali ratio data of the analyses of Table II are tested in Figure 12 against the "igneous spectrum" of Hughes (1973). The general correspondence of these data with the igneous spectrum field boundaries indicates an absence of extensive alteration of these rocks during diagenetic or metamorphic events, and permits the supposition that their chemistry approaches that of the original rock.

From Table II it is evident that silica contents are indicative of basaltic composition, and the alkali data (Na_2O, K_2O) support a sub-alkaline affinity. Alumina contents vary; in general those rocks of the Winnipeg River area being characterized by higher alumina contents with concommitantly higher calcium contents. Total iron contents of rocks of the northern area are greater than those of the south, a pattern also exhibited by magnesia. Titania values vary, but in general are less than 1 percent.

FIGURE 11: Hyaloclastite in metabasalt of the Lamprey Falls Formation west of the Page Property (see accompanying Map C).

TABLE II: Chemical analyses of metabasalt; Lamprey Falls formation.

SAMPLE NUMBER	72-112	72-110	72-105	6	75-498	75-497	75-496	75-482	75-481	75-480	75-479	75-478	75-503	75-504	75-739	75-740	75-741
OXIDE																	
SiO_2	50.35	49.35	50.15	51.65	51.75	50.65	53.00	52.20	53.60	49.15	51.80	50.10	52.05	52.20	49.00	53.55	47.95
Al_2O_3	15.1	14.35	14.95	14.53	19.00	17.45	16.10	18.00	16.50	15.40	16.40	15.20	16.45	16.65	16.41	16.46	15.79
Fe_2O_3	1.85	2.43	1.60	3.24	1.65	1.11	1.56	1.79	1.78	2.88	.51	1.93	1.74	1.57	1.91	1.32	1.97
FeO	10.85	12.76	10.19	8.94	6.47	6.93	7.60	7.48	8.07	8.57	9.78	9.84	9.88	9.20	10.55	8.12	12.16
MgO	6.63	5.97	7.92	7.30	3.99	6.70	5.27	3.92	4.29	7.32	4.65	5.56	4.89	5.19	3.94	4.32	6.66
CaO	9.96	9.63	9.83	7.82	12.3	13.6	11.4	11.2	9.85	12.7	11.6	11.9	12.1	11.9	12.50	11.26	11.96
Na_2O	2.87	2.38	2.49	3.22	2.77	1.65	2.34	2.93	3.34	1.73	2.50	2.35	.86	1.13	1.90	2.20	1.33
K_2O	.22	.35	.64	.70	.25	.14	.20	.14	.12	.12	.22	.27	.19	.20	.22	.21	.30
TiO_2	.97	.48	.75	.93	.84	.76	1.17	.75	1.28	.82	1.08	1.36	.76	.93	1.03	.76	.71
P_2O_5	.09	.08	.08	.10	.06	.07	.12	.05	.09	.07	.10	.13	.07	.08	.07	.04	.05
MnO	.16	.21	.29	.19	.24	.23	.28	.29	.30	.19	.30	.36	.26	.20	.33	.25	.41
S	.06	.02	.05		.06			.57	.02	.08			.02	.15	.01	.10	.02
Cr_2O_3	.04	.03	.03		.08	.08	.04	.08	.03	.06	.06	.04	.09	.05			
NiO	.01	.01	.02	.02	.03	.03	.02	.03	.02	.02	.02	.02	.02	.02			
CuO	.01		.01														
CoO	.01	.01	.01														
ZnO				.02													
H_2O	.68	1.00	1.16	1.58	.58	.77	.82	.59	.64	1.08	.74	.91	.88	.96	1.21	.97	1.23
CO_2	.20	.15	.25		.02		.05	.12	.10	.07	.17	.07	.07	.05	.19	.14	.08
TOTAL	100.96	99.21	100.42	100.22	100.07	100.17	99.97	99.91	100.02	100.23	99.93	100.04	100.32	100.42	99.33	00.64	100.61
NORM WT. %																	
Q				.4	3.0	2.5	6.6	4.5	5.2	1.4	2.7	1.3	10.3	9.5			
Or	1.3	2.1	3.8	4.2	1.5	.8	1.2	.8	.7	.7	1.3	1.6	1.1	1.2			
Plag	52.4	48.3	49.3	51.1	62.5	54.1	53.1	60.7	58.4	49.0	54.6	50.5	48.2	49.6			
Cpx	17.7	16.8	17.1	12.4	18.2	22.4	19.1	16.4	15.6	23.6	20.3	23.5	16.1	15.6			
Opx	20.0	27.0	18.7	25.1	10.4	16.8	15.2	12.0	14.9	19.1	17.9	17.3	20.1	19.4			
Ol	3.6	.1	7.0														
Mt	2.7	3.6	2.3	4.8	2.4	1.6	2.3	2.6	2.6	4.2	.7	2.8	2.5	2.3			
Il	1.9	1.9	1.4	1.8	1.6	1.5	2.2	1.4	2.5	1.6	2.1	2.6	1.5	1.8			
Cr	.1	.05	.05		.1	.1	.1	.1	.05	.1	.1	.1	.1	.1			
Ap	.2	.2	.2	.2	.1	.2	.3	.1	.2	.2	.2	.3	.2	.2			
Py	.1	.04	.1		.1			1.2	.04	.2			.04	.3			

TABLE II (continued)

72-112	Pillowed metabasalt- Lamprey Falls Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.
72-110	Pillowed metabasalt- Lamprey Falls Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.
72-105	Pillowed metabasalt- Lamprey Falls Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.
6	Pillowed metabasalt. Results excerpted from Ritchie (1972).
75-498	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-497	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-496	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-482	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-481	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-480	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-479	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-478	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-503	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-504	Pillowed metabasalt- Lamprey Falls Formation. Analyst: K. Ramlal, University of Manitoba.
75-739	Pillowed metabasalt- Lamprey Falls Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.

TABLE II (continued)

75-740	Pillowed metabasalt- Lamprey Falls Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.
75-741	Pillowed metabasalt- Lamprey Falls Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.

Sample locations are shown on accompanying Map C.

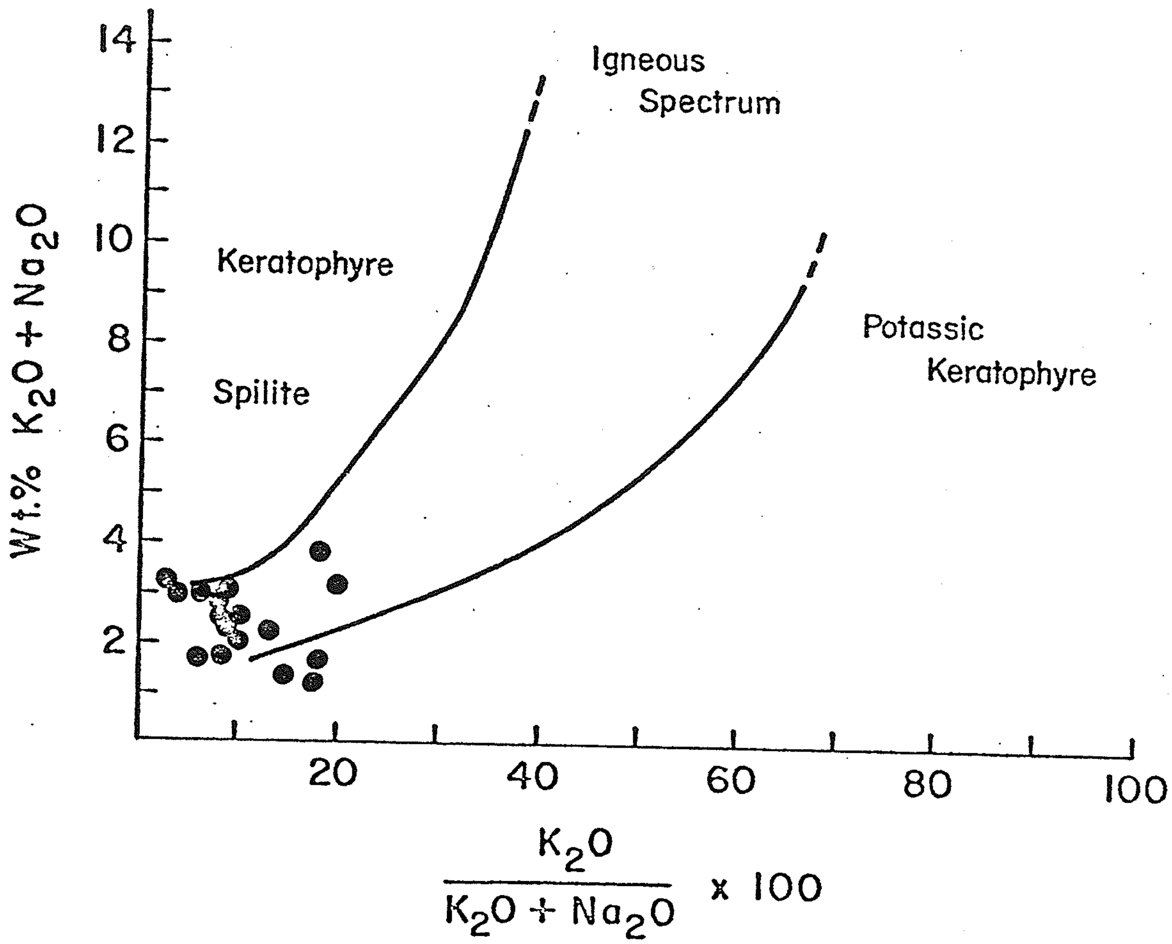

FIGURE 12: Alkali ratio diagram for analyzed rocks of the Lamprey Falls Formation.

Corresponding CIPW norms for the analyzed rocks of Table II are orthopyroxene normative, and indicate saturation with respect to silica (Yoder and Tilley, 1962). Most of the analyzed rocks are quartz normative.

Differentiation indices of Kuno (1968) are shown in Figure 13, from which it is evident that the analyzed rocks tend to occupy the pigeonitic or tholeiitic field. This is confirmed in Figure 14 which displays ternary alkalies - total iron - magnesia data for the analyzed rocks, and in which the data are seen to occupy the tholeiitic field of Irvine and Baragar (1971).

The Lamprey Falls Formation is dominated by subaqueously deposited rocks of basaltic composition which in the study area form the flanks of a major synclinorium occupied by younger parts of the stratigraphy. These rocks attain a maximum thickness of approximately 3 km, but thin laterally to the east and west, pinching out against younger rock types in fault or intrusive contact relationships.

The chemistry of the rocks of the Lamprey Falls Formation compares favourably with other Archean metabasalts (Goodwin, 1978; Condie, 1971; Jakes and White, 1971) and analysis of the major oxide data indicates these rocks are of tholeiitic kindred. Moderate iron - enrichment is evident in the higher parts of this succession, and ultimately the rocks yield to feldspar - phyric and hyaloclastic counterparts.

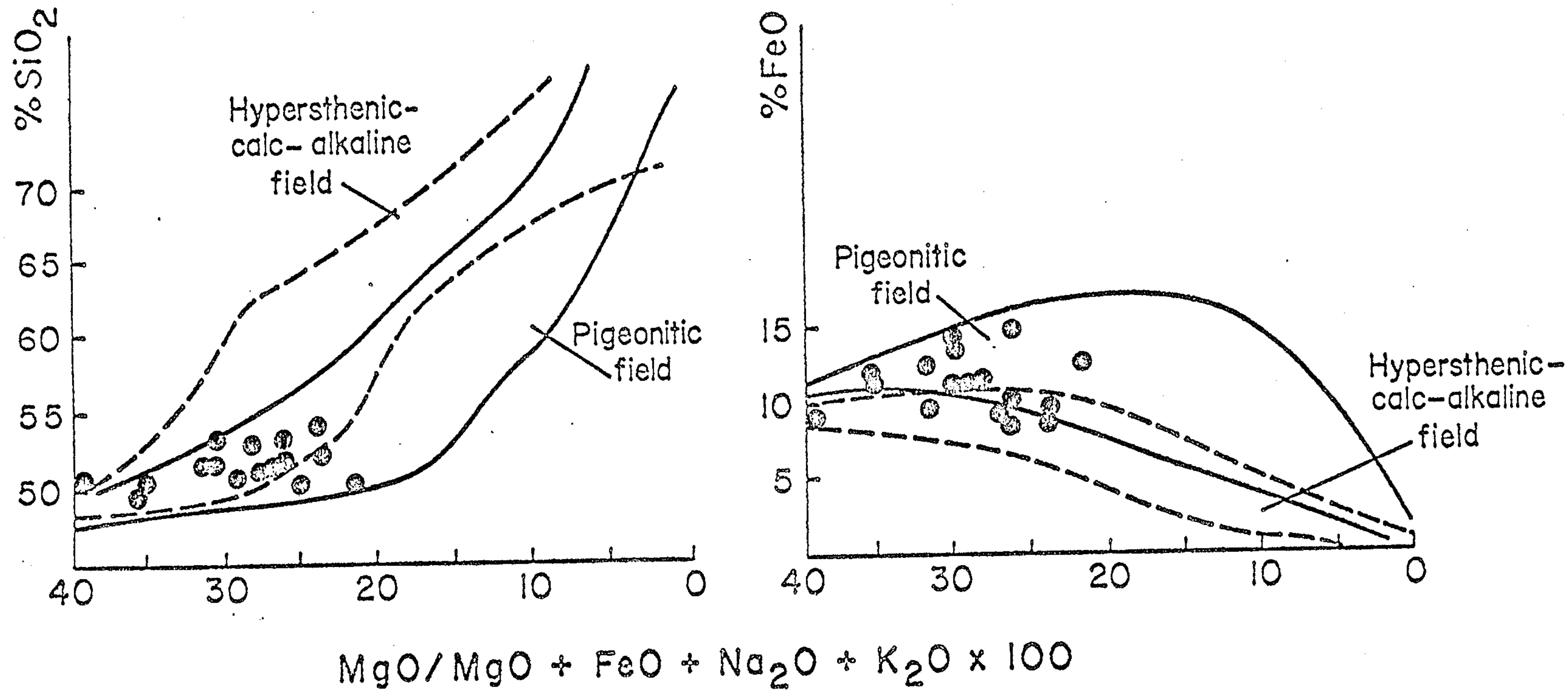

FIGURE 13: $MgO / MgO + FeO + Na_2O + K_2O$ vs. SiO_2 and FeO diagrams for analyzed rocks of the Lamprey Falls Formation. Pigeonitic field boundary shown by solid lines, and hypersthenic field boundary shown by dashed lines.

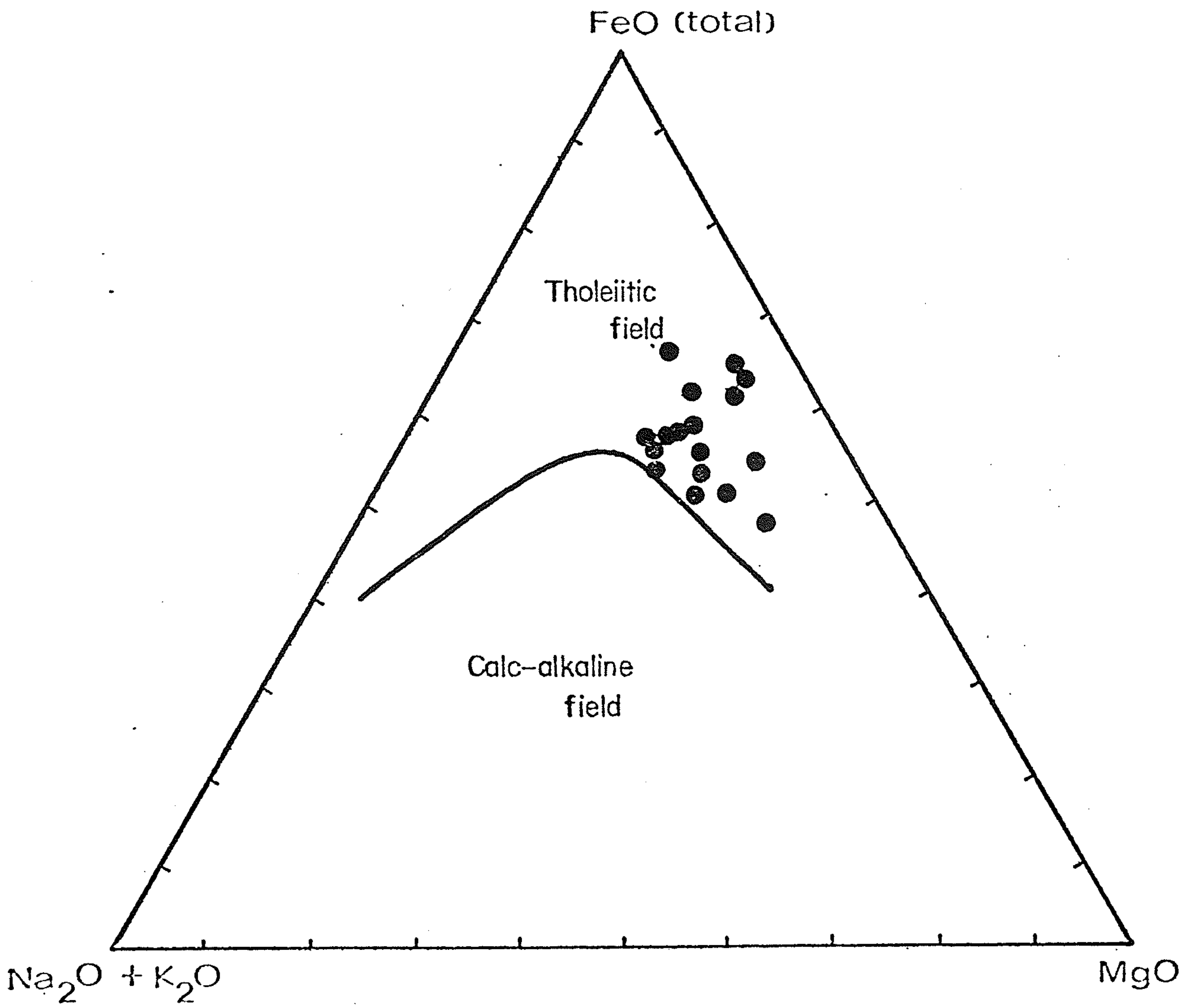

FIGURE 14: Magnesia - total iron - alkalies variation diagram for analyzed rocks of the Lamprey Falls Formation, (field boundary after Irvine and Baragar, 1971).

THE PETERSON CREEK FORMATION

DESCRIPTION OF ROCK TYPES (3)

The Peterson Creek Formation consists of felsic flow and clastic metavolcanic rocks which crop out along Peterson Creek, at Shatford Lake, south of Bird Lake, and east of Tulabi Lake (Fig. 15, see also accompanying Map A). Rock types include flowbanded metarhyolite, rhyolite breccia, rhyolite tuffs, and epiclastic felsic sandstone derivatives.

Metarhyolite flows are present in the western and central parts of the Bird River area (Map A). These rocks are present as moderately thick flows (6 - 20m) intercalated with clastic equivalents, are buff to greenish weathering, porphyritic, aphanitic to fine grained, flow banded, and weakly schistose (Fig. 16). Quartz forms the dominant phenocryst in these rocks; feldspars (albite - oligoclase) are less abundant. Phenocrysts (up to .5cm) are set in a fine grained matrix of finely comminuted quartz, feldspar, and sericite.

The clastic felsic metavolcanic rocks of the Peterson Creek Formation can be subdivided into tuffs, lapillistone, and pyroclastic breccia, according to the scheme of Fisher (1966). Pyroclastic breccia and lapillistone predominate in the western and central map area (Map A) and pass eastwards into lapillistone, tuffaceous, and ultimately, into the derived epiclastic counterparts.

Pyroclastic breccia occurs only in the western map area (Map A). These rocks are present in moderately thick beds (<100 m), are buff weathering, and schistose. Clasts range in size from lapilli and tuff sizes (Fig. 17), up to 8 metres and are aphanitic to fine grained, commonly porphyritic (quartz phenocrysts), and moderately stretched parallel to schistosity. Matrix material to these breccias consists essentially of brownish to green sericite, and includes finely comminuted quartz and feldspar crystal fragments.

Lapillistone and lapilli tuffs are ubiquitous, but proportionately most abundant in the west and central portions of the Peterson Creek Formation (Map A). Lapillistone and lapilli tuff strongly resemble pyroclastic breccia with which they are interbedded; the principal differ-

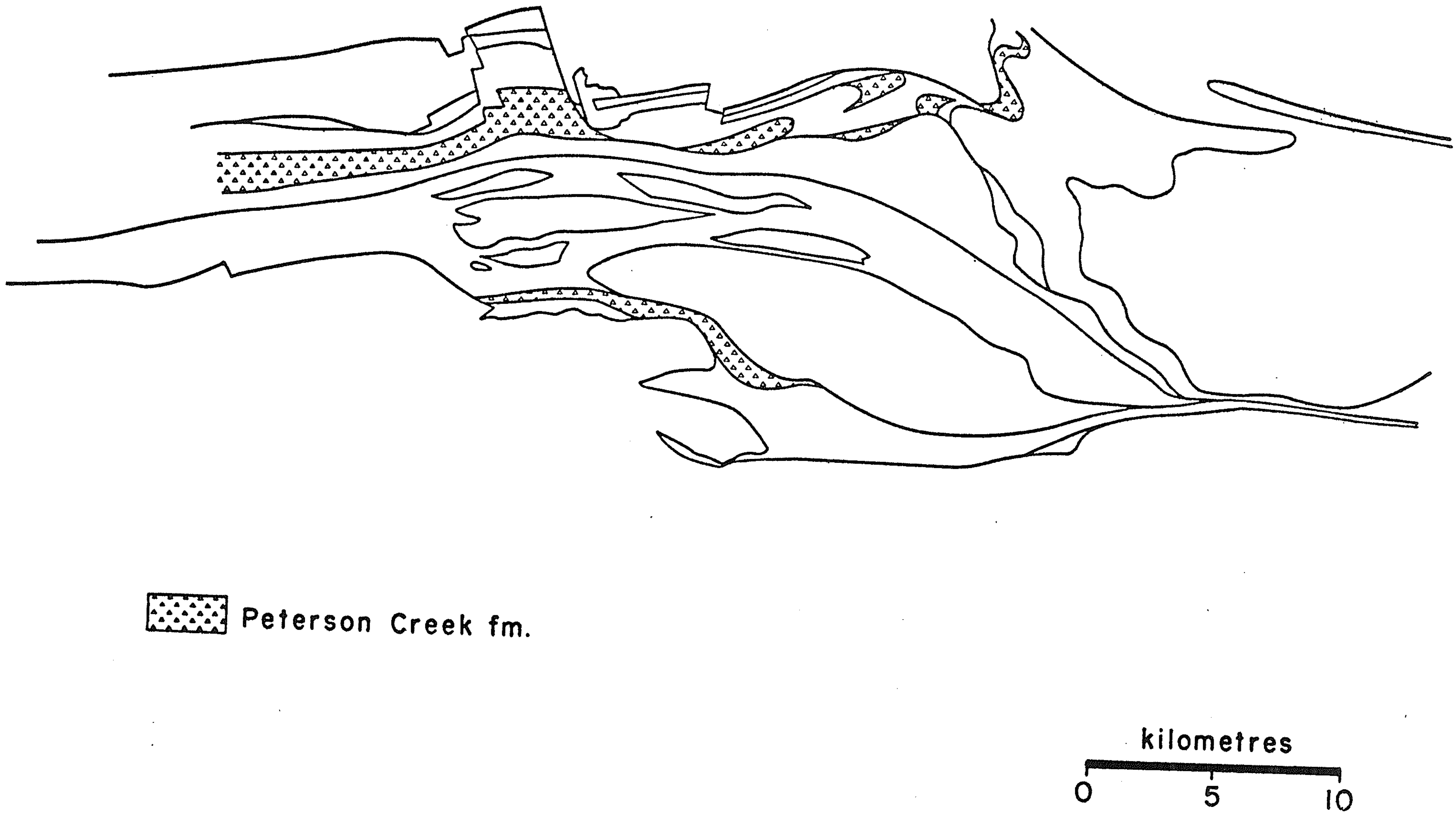

FIGURE 15: Location map of the Peterson Creek Formation.

FIGURE 16: Metarhyolite flow rock in the Peterson Creek Formation south of the Chrome Property.

FIGURE 17: Pyroclastic breccia in the Peterson Creek Formation south of the Chrome Property.

ence being one of clast size. The lapillistone and lapilli tuffs are brownish to buff or green weathering, carry up to 60 percent lapilli size clasts, are thinly bedded (<6m), lack internal bedding, are unsorted, and are moderately schistose (Fig. 18). Clasts exhibit moderate flattening and extension. Long axes of clasts pitch steeply in foliation surfaces.

Rhyolite tuff is abundant in the central portions of the Peterson Creek Formation. These rocks are generally fine grained, buff to white weathering, are marked by an abundance of quartz, feldspar, and lithic fragments, and are moderately schistose (Fig. 19). The thickness of beds in these rocks varies from 1 metre to 50 metres, and sorting is generally absent.

Sandstones of rhyolitic detritus are abundant in the eastern parts of the Peterson Creek Formation, and these rocks occur, in part, interlayered with minor tuffaceous equivalents. The sandstones are typically buff to white weathering, are well bedded, consist of well sorted quartz and feldspar detritus, lack the sericitic matrices common to their progenitors, are fine grained, and moderately schistose (Fig. 20). Locally these grade into thin beds of polymictic, felsic, pebble conglomerates which differ from the sandstones only by the presence of these epiclasts.

PETROCHEMISTRY

Seven analyses of felsic metavolcanic rocks from the Peterson Creek Formation are presented in Table III with corresponding CIPW norms. Their respective sample locations are shown on accompanying Map C.

All of the analyzed rocks of Table III are enriched in SiO_2; samples no. 15-1, 915, and 19 represent quartz-phyric rocks, no. 8, 96, 947, and 237 are volcaniclastic, or volcanic sandstones, and hence have probably suffered quartz enrichment through mechanical processes. Alkali data from Table III, plotted in Figure 21 provide a further confirmation of alteration of samples 8, 96, 947, and 237.

Figures 22 a and b are plots of the unaltered felsic rocks (15-1, 19) of Table III on a diagram showing the differentiation indices of Kuno (1968). In Figure 22b, the analyzed rocks cannot be resolved

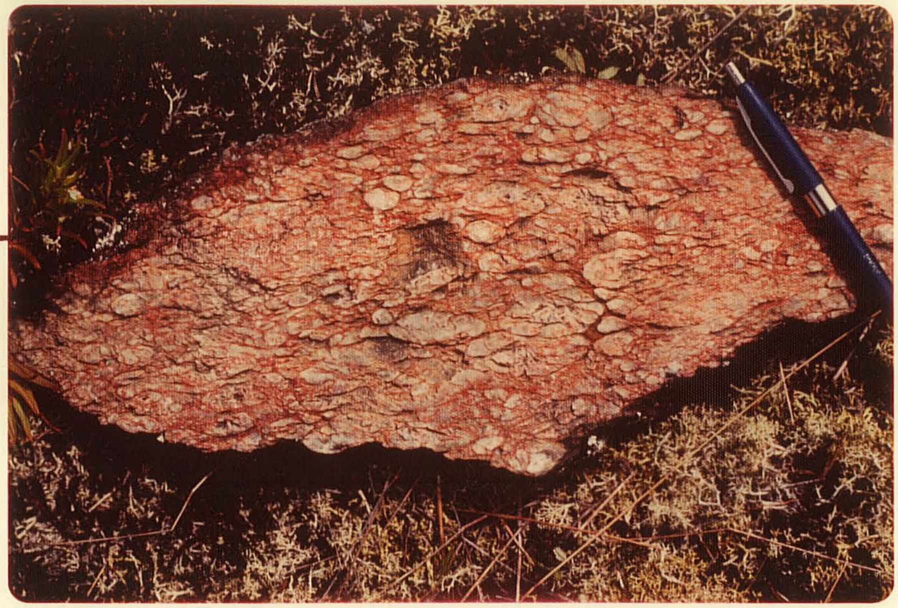

FIGURE 18: Lapillistone in the Peterson Creek Formation south of the Chrome Property.

FIGURE 19: Metarhyolite tuff in the Peterson Creek Formation south of the Chrome Property.

FIGURE 20: Felsic sandstones in the Peterson Creek Formation southeast of Bird Lake.

TABLE III: Chemical analyses of felsic meta-volcanic rocks; Peterson Creek formation.

SAMPLE NUMBER	74-8	74-19	74-96	75-237	72-15-1	76-947	76-915
OXIDE							
SiO_2	79.55	79.60	87.50	78.60	79.8	77.25	77.2
Al_2O_3	11.26	11.52	7.73	11.50	10.85	11.68	11.67
Fe_2O_3	.28	.31	.39	.22	.20	.43	.38
FeO	.12	.08		.08	.56	.84	.86
MgO	.03	.10	.01	.11	.0	.19	.35
CaO	.13	.23	.53	.06	.0	.06	.56
Na_2O	1.99	3.05	1.95	.20	3.82	1.08	2.93
K_2O	5.54	4.30	2.28	8.19	3.50	7.33	4.83
TiO_2	.08	.13	.05	.06	.09	.13	.12
P_2O_5	.0	.01	.0	.08	.0	.0	.0
MnO	.0	.0	.01	.0	.02	.02	.03
H_2O	.39	.33	.15	.60	.34	.6	.46
CO_2	.03	.06	.07	.04	1.8	.09	.39
TOTAL	99.40	99.72	100.67	99.74	99.36	99.70	99.79
NORM WT.%							
Q	46.9	45.1	66.0	46.4			
C	1.8	1.5	1.1	2.4			
Or	33.1	25.6	13.4	48.9			
Plag	17.7	27.1	19.0	1.7			
Cpx							
Opx	.1	.3	.03	.3			
Ol							
Mt	.2			.1			
Il	.2	.2	.02	.1			
Cr							
Hm	.2	.3	.4	.2			
Ap		.02		.2			
Py							
Ru		2.3	2.2				

TABLE III (continued)

74-8	Felsic sandstone- Peterson Creek Formation. Analyst: K. Ramlal, University of Manitoba.
74-19	Metarhyolite, quartz porphyry- Peterson Creek Formation. Analyst: K. Ramlal, University of Manitoba.
74-96	Felsic sandstone- Peterson Creek Formation. Analyst: K. Ramlal, University of Manitoba.
75-237	Felsic sandstone- Peterson Creek Formation. Analyst: K. Ramlal, University of Manitoba.
75-15-1	Ash flow tuff- Peterson Creek Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.
76-947	Felsic sandstone- Peterson Creek Formation. Analyst: K. Ramlal, University of Manitoba.
76-915	Metarhyolite, quartz porphyry- Peterson Creek Formation. Analyst: K. Ramlal, University of Manitoba.

Sample locations are shown on accompanying Map C.

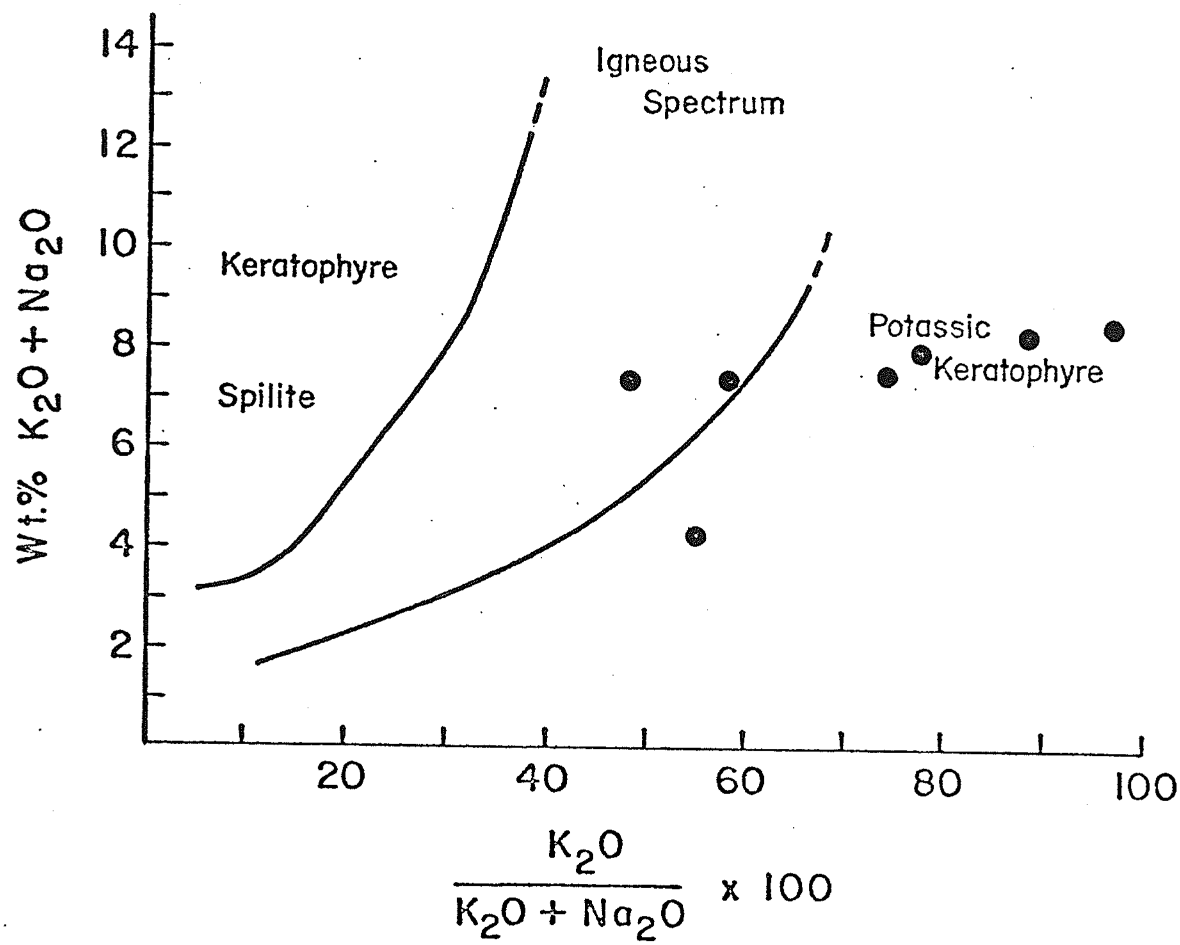

FIGURE 21: Alkali ratio diagram for analyzed rocks of the Peterson Creek Formation.

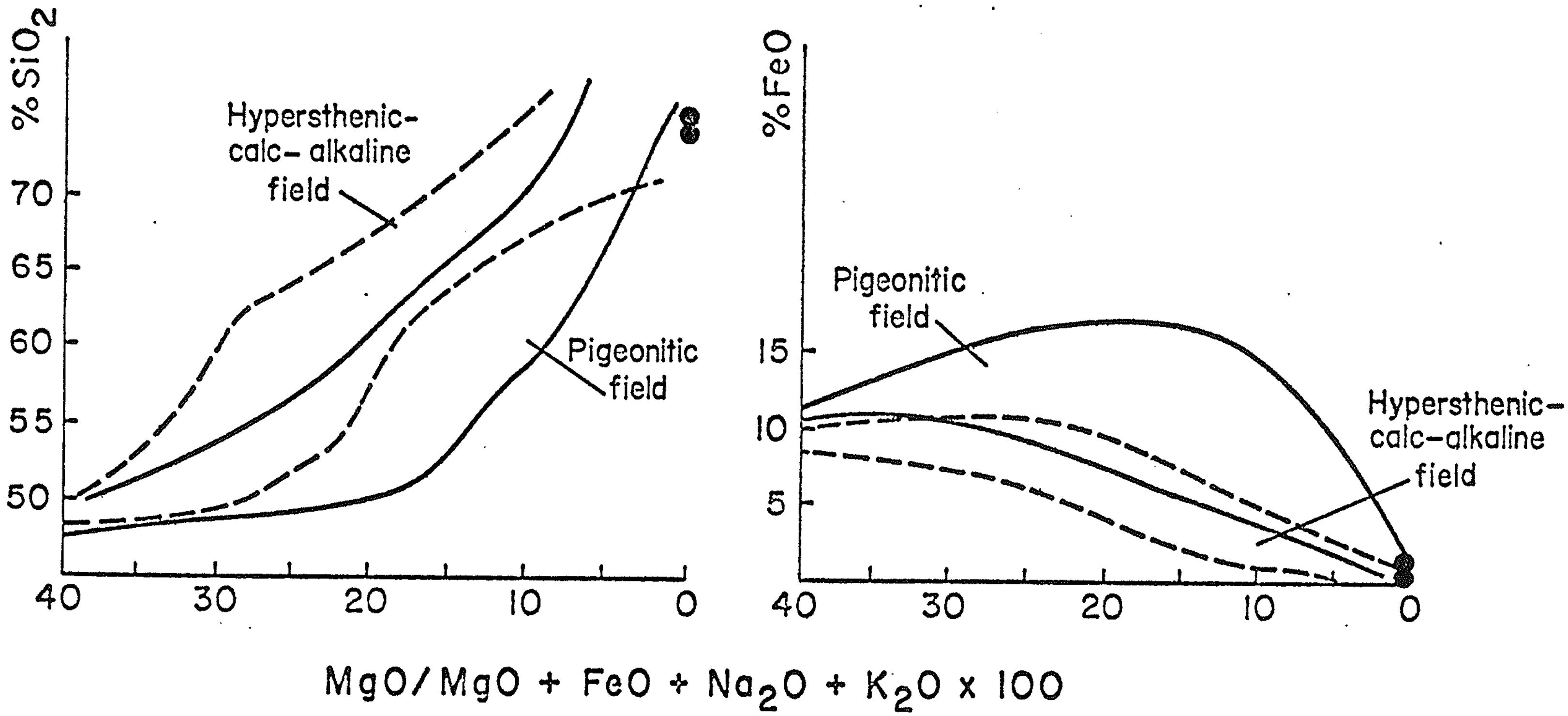

FIGURE 22a: $MgO/MgO + FeO + Na_2O + K_2O$ vs. SiO_2 diagram for analyzed rocks of the Peterson Creek Formation.

FIGURE 22b: $MgO/MgO + FeO + Na_2O + K_2O$ vs. FeO diagram for analyzed rocks of the Peterson Creek Formation.

clearly into a rock series. In Figure 22a however, a preference for the hypersthenic or calc-alkaline series is suggested. This is confirmed in Figure 23 which is an AFM plot of the analyzed rocks, the field boundary of which separates the calc-alkaline and tholeiitic fields of Irvine and Baragar (1971).

The Peterson Creek Formation consists essentially of meta-rhyolites of flow and clastic origin, some of which was subaerially erupted, transported, worked, and redeposited subaqueously as felsic sandstones. All of these rocks lie in fault contact with, and along both flanks of the synclinorium formed by the Lamprey Falls Formation, and are in turn overlain and infolded with mixed rocks of the Bernic Lake Formation.

Whole rock analyses of the rhyolitic rocks indicate a calc-alkaline kindred for these rocks, but they differ from previously published data (Goodwin, 1978) of other Archean metarhyolites, by being enriched in silica and total alkalies, and slightly lower in calcium and alumina contents.

Current, and ongoing studies involving metarhyolite from the Peterson Creek Formation (Černý et al., 1979) and other felsic but intrusive rocks of the area, have revealed interesting rare earth element (REE) patterns. REE data, from Černý et al. (1979), are shown in Figure 24, from which it is evident that the light REE elements exhibit fractionated patterns, there exists a strong negative Eu anomaly, and heavy REE elements are horizontally disposed and have high values.

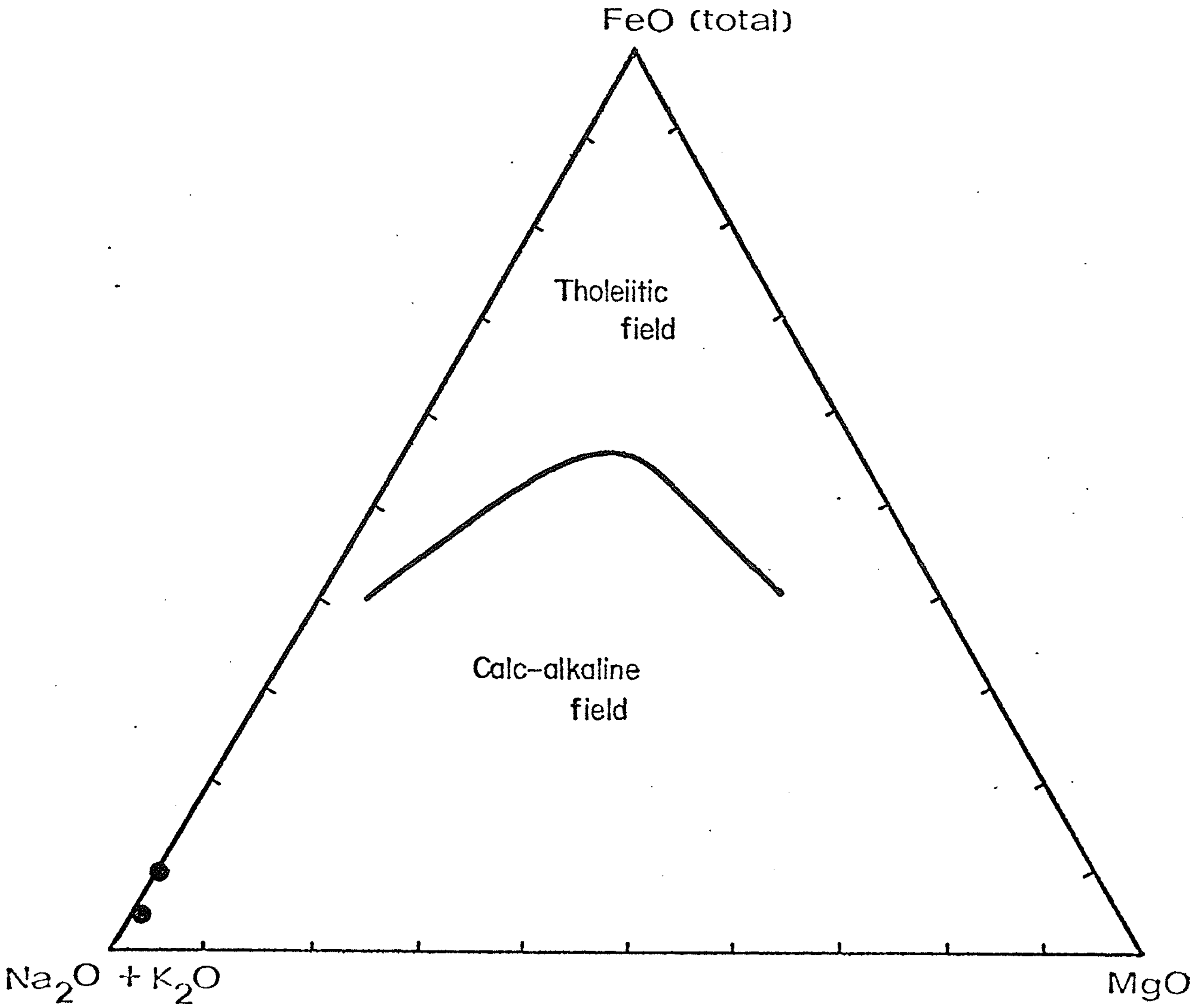

FIGURE 23: Magnesia - total iron - alkalies variation diagram for analyzed rocks of the Peterson Creek Formation.

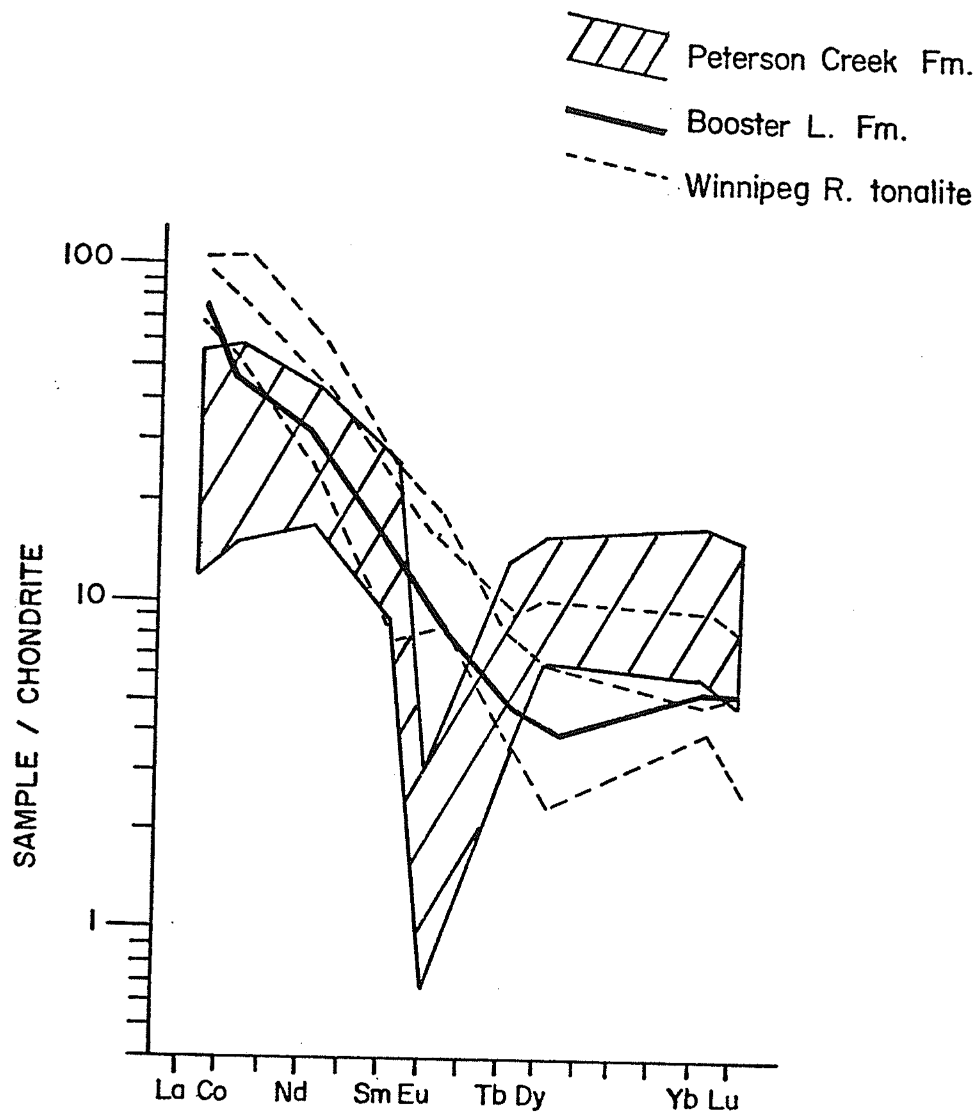

FIGURE 24: REE data from the Peterson Creek Formation, Booster Lake Formation and tonalite from the Winnipeg River batholithic belt.

THE BERNIC LAKE FORMATION

DESCRIPTION OF ROCK TYPES (5)

Outcrop areas of the Bernic Lake Formation are shown on Figure 25 (see also accompanying Map A). Rock types present in the Bernic Lake Formation include metamorphosed basalt, andesite, dacite, rhyolite, iron formation, polymictic and oligomictic conglomerates, volcanic wackes and sandstones. Of these, metabasalt and iron formation form the only units which display a persistent lateral continuity. The volcanic sandstones are less continuous and the meta-andesite, metadacite, and metarhyolite crop out only intermittently in thin flows of short lateral extent. Polymict and oligomict metaconglomerate are the dominant rocks of the formation, and these are chaotically interlayered with each other, and the other rock types.

Metabasalt is the most abundant of the flow rocks of the Bernic Lake Formation and forms two prominent units; one in the Bernic Lake area and one immediately south of the Bird River on the central part of the belt (Map A). Elsewhere, metabasalt is present as thin laterally persistent flows, intercalated with clastic rocks.

The metabasalts typically occur as pillowed flows, are greyish-black weathering and are marked by moderate to strongly developed schistosity. Pillow selvages are generally well preserved as in the Bernic Lake area and are suitable for top determinations. Elsewhere, particularly in thin flows, pillow structures may be largely obliterated and flattened by superposition of the schistosity (Fig. 26). A flow or succession of flows north at the Provincial Road 314 -315 junction is not pillowed, but is marked by the occurrence of narrow bands of .5 mm to 1.5 mm quartz and quartz - carbonate filled amygdales. The metabasalts consist largely of nematoblastic tremolite-actinolite, chlorite, albite, and zoisite with minor amounts of biotite, leucoxene, and secondary quartz and carbonate.

Meta-andesite is present as thin (<10 m) flows in the Bernic Lake Formation. These rocks are essentially identical to metabasalt in outcrop, but differ by a tendency to a greyish-white weathering, and display thick prominent selvages (Fig. 27). In general however, the pillow structures are strongly deformed and foliated and facing directions are unreliable. The meta-andesites consist chiefly of fine to medium grained

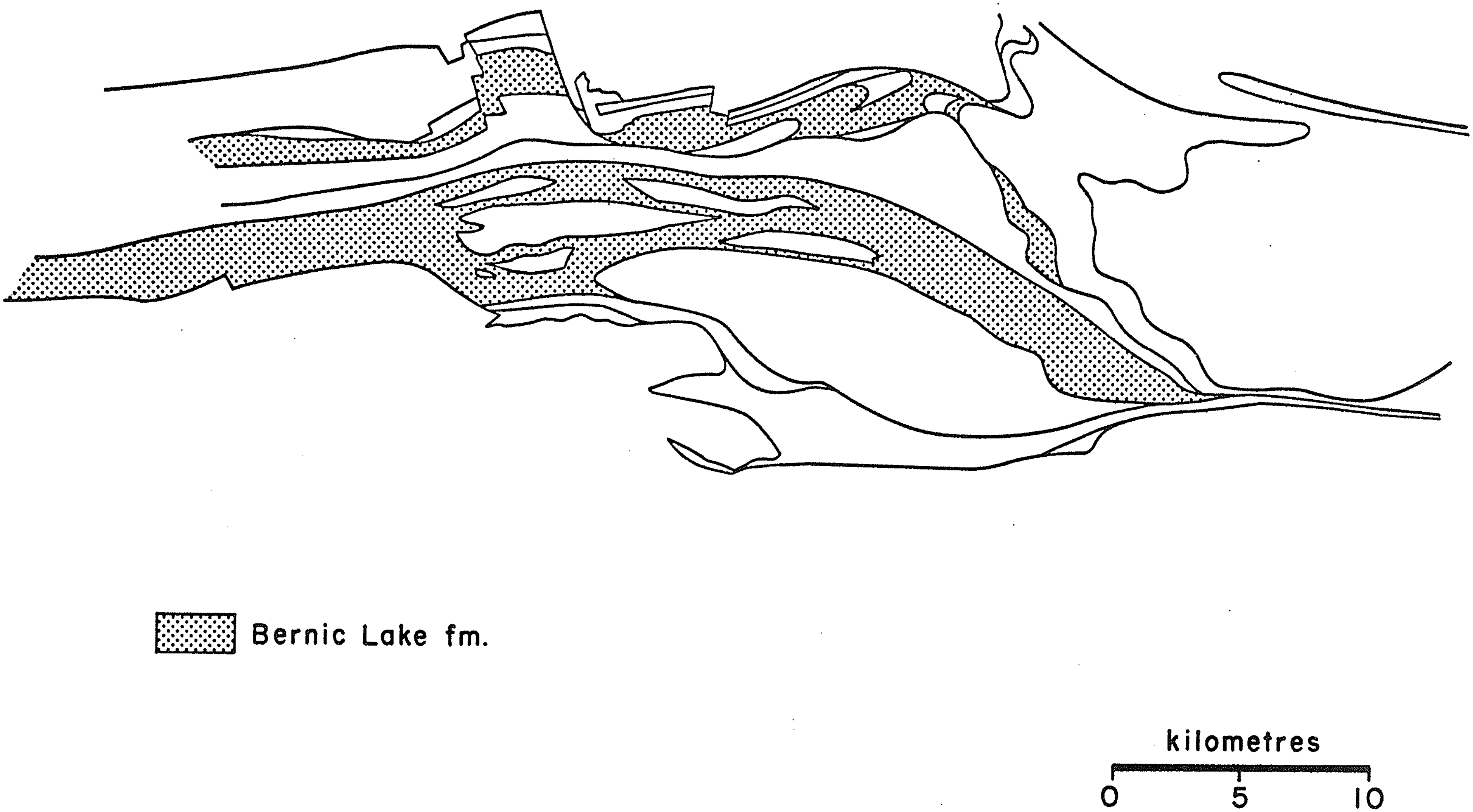

FIGURE 25: Location map of the Bernic Lake Formation.

FIGURE 26: Deformed pillowed metabasalt in the Bernic Lake Formation southeast of Poplar Bay, Lac du Bonnet.

FIGURE 27: Pillowed meta-andesite in the Bernic Lake Formation east of Osis Lake.

lepidoblastic biotite, chlorite, tremolite-actinolite, albite and zoisite, with lesser leucoxene, carbonate, and granular secondary quartz.

Metadacite forms thin (<10m) flows, of limited lateral extent, in the Osis Lake area (Map A). These rocks, buff to grey-white weathering, are typically pillowed with thick selvages, and exhibit a moderate degree of stretching in a pronounced schistosity (Fig. 28). The metadacite is comprised largely of granular quartz and albite, set in a matrix of biotite, trimolite-actinolite, chlorite, and zoisite, and locally is marked by occurrence of small (< 2 mm) phenocrysts of altered plagioclase.

Metarhyolite is not abundant in the Bernic Lake Formation, and was only observed in an area west of Bernic Lake (Map A). In this locality, the metarhyolite forms a thin (<10 mm), translucent greenish to buff weathering unit marked by a weak schistosity and small (<1 mm) quartz phenocrysts. The rock is comprised essentially of quartz, feldspar, sericite, and secondary quartz and carbonate veining. Contacts of this unit were not observed, and the rock lacks primary structures diagnostic of an extrusive origin suggesting, therefore, the possibility that this unit is a sill.

Polymict metaconglomerate is the most abundant rock type in the Bernic Lake Formation. These rocks are typically dark grey to black weathering, and for the most part, outcrop surfaces do not reveal diagnostic features. Locally however, clasts weather in considerable relief over matrix and the rocks are otherwise characterized by fine to coarse grained biotite - amphibole rich quartz - feldspar assemblages with a strong lineation imparted down-dip of the schistosity by the elongation of clasts. In some exposures bedding is in evidence resulting either from variation in clast content, or size, or variation in matrix composition.

The polymict metaconglomerates further exhibit considerable areal variation in composition. In the western map area (Map A) the metaconglomerate consists of a mixture of pebble to boulder (<2 m) detritus variously derived from mafic and felsic metavolcanic sources (Fig. 29), hypabyssal metagabbro, and the Bird River Sill. Detritus from the Bird River Sill includes anorthosite, anorthositic gabbro, chromite, and small chromite rich chlorite blebs which may represent original lherzolite detritus.

In the area east of the Dumbarton Mine (Map C), polymict metaconglomerate is similar to that described above, but is dominated by

FIGURE 28: Pillowed metadacite in the Bernic Lake Formation east of Osis Lake.

FIGURE 29: Polymict metaconglomerate in the Bernic Lake Formation east of Poplar Bay, Lac du Bonnet.

pebbles and cobbles of quartz porphyry, sericite schist, and hypabyssal metagabbro. Anorthositic gabbro clasts from the Bird River Sill are rare.

Oligomict metaconglomerate is dominant in the southern part of the Bernic Lake formation (Map A). These rocks, greyish weathering and fine to coarse grained, are marked by pebble to boulder size materials set in a grey to black strongly schistose matrix. Clasts are chiefly of intermediate or felsic composition, are greyish or buff weathering, and are strongly deformed, and locally folded with schistosity (Fig. 30). Continuous bedding (Fig. 31) is in evidence only locally, and the rocks are otherwise of chaotically intercalated lensoid distribution.

Metamorphosed volcanic wackes and volcanic sandstone occur interlayered with the polymict and oligomict metaconglomerate throughout the Bernic Lake formation. The volcanic wackes are essentially fine to medium grained, greyish weathering, thin (<1 cm) to thick (<5m), moderately well bedded schists composed essentially of detrital quartz and feldspar with varied proportions of biotite, actinolite-tremolite, and chlorite. In higher metamorphic grade equivalents diopside, cordierite, anthophyllite, and garnet are locally developed in these rocks. These rocks may also be marked by fine laminae of cherty or tuffaceous material (Fig. 32). In the western, central, and southern parts of the Bernic Lake formation, the volcanic wackes are interlayered with pebbly variants (Fig. 33). These rocks are identical with the volcanic wackes, except for the presence of from 5 to 30 percent pebble size material of quartzo-feldspathic composition.

Metamorphosed volcanic sandstones are buff to white weathering rocks characterized by abundant detrital quartz, thin (<3 cm) bedding, and good sorting (Fig. 34). Schistosity is weak in these rocks and is imparted by minor sericite which forms matrix to granular quartz and feldspar, minor biotite, amphibole, hematite, and quartz and carbonate.

Iron formations are interlayered throughout the Bernic Lake formation as thin laterally persistent bands which crop out extensively, and are also marked as laterally persistent AEM conductors. Their distribution on the accompanying Map A is based on both outcrop occurence and geo-

FIGURE 30: Oligomict metaconglomerate in the Bernic Lake Formation southeast of Poplar Bay, Lac du Bonnet.

FIGURE 31: Bedding in metaconglomerate in the Bernic Lake Formation north of Birse Lake.

FIGURE 32: Thinly laminated tuffs and volcanic wacke in the Bernic Lake Formation east of the Dumbarton Mine.

FIGURE 33: Pebbly wacke in the Bernic Lake Formation southeast of Poplar Bay, Lac du Bonnet.

FIGURE 34: Volcanic sandstone in the Bernic Lake Formation at Osis Lake.

physical data (data from Mineral Resources Division cancelled assessment file "LYNX", and Falconbridge Nickel Mines Ltd. Aerodat Survey).

The iron formations form thin to thick (<10m), weakly to moderately schistose gossans of both ferruginous metasediments (Fig. 35) and banded iron formation (Fig. 36). Both oxide (magnetite) and sulphide (pyrrhotite,pyrite) assemblages occur.

In one location, north of PR 315 and 3.2 km west from the PR 314-315 junction, are several outcrops of a clastic rock which bears attributes of a reworked crystal tuff. The lateral extent of this rock type is uncertain, but in thickness is of the order of less than 50 m. This rock is marked by an abundance of plagioclase (An-65) crystals of equant or elongate euhedral or broken form set in a matrix of actinolite-tremolite, chlorite, quartz and feldspars (Fig. 37). In addition the rock carries fragments of equivalent composition up to 10 cm in size, and is further marked by an abundance of rounded (<2.5 cm) blebs of quartz and carbonate which bear resemblances to pebbles or possibly amygdales from a lava. These blebs are strongly rounded in a moderately developed schistosity, the development of which apparently had little or no effect on the plagioclase crystals.

In three locations within the Bernic Lake formation unusual metamorphic mineral assemblages are formed at the expense of their protoliths. These include cordierite-anthophyllite-garnet-diopside assemblages, garnet-biotite assemblages, and garnetiferous felsic breccia; all of which occupy the same approximate stratigraphic position near the base of the formation.

The cordierite-anthophyllite-garnet-diopside schists are developed along the Bird River, south of the Dumbarton Mine (Map A) and can be traced for approximately 5 km along strike in association with polymict metaconglomerate and volcanic wackes. At a location 2.4 km east of the Dumbarton Mine, these rocks are spatially ordered; diopside-rich beds occur in proximity to the Maskwa Lake batholith, and cordierite-anthophyllite-garnet assemblages lie adjacent to the south of these. The different assemblages are constrained in occurence to individual layers, form-

FIGURE 35: Schistose ferruginous metasediment in the Bernic Lake Formation south of the Bird River, east of Poplar Bay, Lac du Bonnet.

FIGURE 36: Banded iron formation in the Bernic Lake Formation south of Bird Lake.

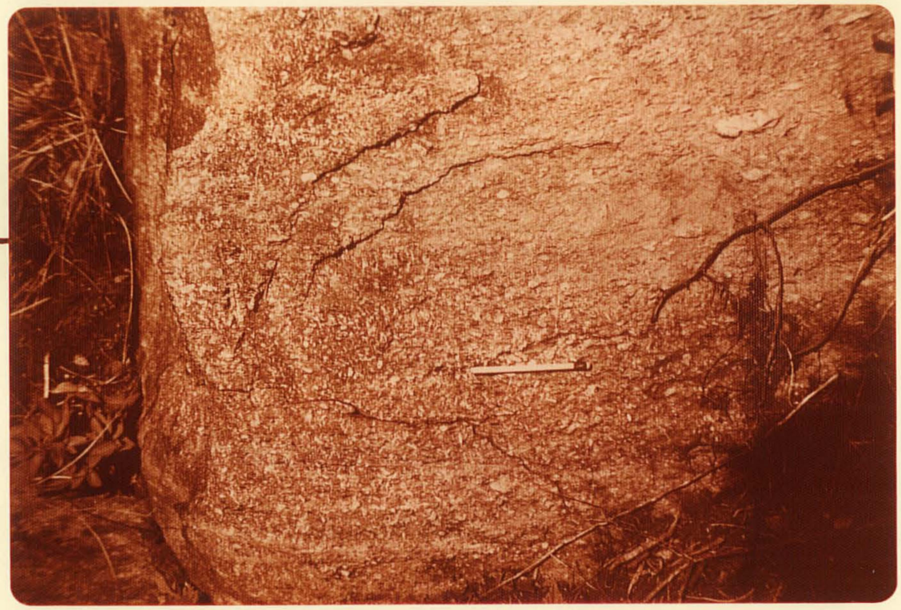

FIGURE 37: Plagioclase crystals and crystal fragments in tuffaceous rocks of the Bernic Lake Formation south of the Chrome Property.

ing for example, cordierite-rich beds alternating with anthophyllite-rich beds (Fig. 38 a, b). Of these assemblages, diopside anthophyllite, and garnet form randomly oriented idiomorphic porphyroblasts, and cordierite forms slightly ellipsoidal sericitized porphyroblasts which are locally perforated by the anthophyllite.

Garnet-biotite schists crop out intermittently along strike eastwards from the above cordierite-anthophyllite rocks and pass further along strike into graphite schist and iron formation. Associated rocks include polymict metaconglomerate, and this same association is seen to persist on the south side of the greenstone belt in the Shaftford Lake-Winnipeg River area. The garnet-biotite schist consists essentially of idiomorphic to slightly rounded and fractured garnet which forms up to 70 percent of the rock, and idioblastic biotite with lesser quartz, carbonate, magnetite and limonite.

The garnetiferous felsic breccias occur south of the Bird Lake (Map A) in stratigraphic continuity with garnet-biotite schist, graphite schist, and iron formation. These rocks consist largely of flow banded and quartz porphyry clasts (Fig. 39), which are in turn skeined by anastomosing garnet-biotite schist (Fig. 40). These rocks change gradationally downward into a more massive greyish weathering garnetiferous quartz porphyry (Map A, Unit 6); the nature of this boundary being marked by a decrease in fragment material and a decrease of garnet-biotite filled fractures into the massive porphyry.

PETROCHEMISTRY

Chemical analyses of some of the flow rocks of the Bernic Lake formation are presented in Table IV with corresponding CIPW norms and in Figure 41 the analyses of Table IV are tested against the igneous spectrum of Hughes (1972). All of the rocks appear to be unaltered with respect to additions or depletions of alkali metals.

From field identification all of the analysed rocks of Table IV were termed metabasalt, excepting 78-8-1 which was termed metadacite. For sample 75-507, the major oxide data suggest the term "basaltic andesite" may be appropriate (Irvine and Baragar, 1971).

FIGURE 38a: Alternating cordierite and anthophyllite -rich beds in the Bernic Lake Formation east of the Dumbarton Mine.

FIGURE 38b: Idiomorphic anthophyllite crystals in alternating beds in the Bernic Lake Formation east of the Dumbarton Mine.

FIGURE 39: Garnetiferous felsic breccia in the Bernic Lake Formation south of Bird Lake.

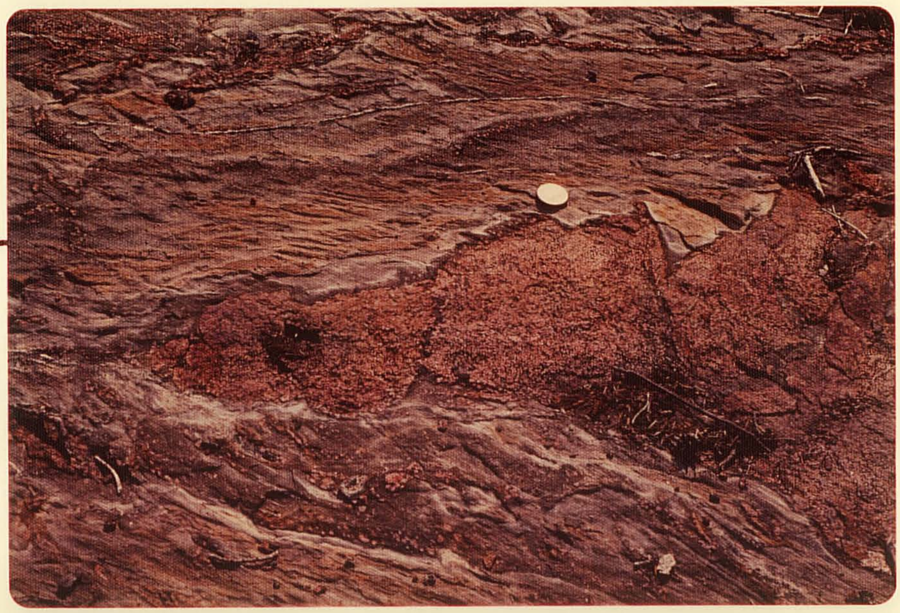

FIGURE 40: Garnet - biotite schist in felsic breccia in the Bernic Lake Formation south of Bird Lake.

TABLE IV: Chemical analyses of metavolcanic rocks ; Bernic Lake formation.

SAMPLE NUMBER	75-568	75-507	75-735	75-578	75-8-1
OXIDE					
SiO_2	49.85	54.45	53.00	49.45	68.90
Al_2O_3	15.47	16.40	14.70	15.60	13.50
Fe_2O_3	1.25	1.18	2.49	1.74	.47
FeO	10.21	7.47	10.76	9.14	3.90
MgO	6.75	5.29	3.99	8.33	1.48
CaO	12.75	12.3	6.30	11.8	5.24
Na_2O	.98	1.17	2.42	1.57	3.34
K_2O	.16	.13	2.52	.13	.41
TiO_2	.70	.74	1.80	.70	1.37
P_2O_5	.04	.05	.40	.06	.21
MnO	.23	.17	.20	.19	.12
S	.01	.09	.01	.02	.07
Cr_2O_3		.09	.01	.07	.02
NiO		.03	.01	.02	Tr
H_2O	1.33	.77	1.22	1.20	.53
CO_2	.23	.40	.05	.17	.36
TOTAL	99.96	100.69	99.88	100.18	99.92
NORM WT. %					
Q		12.5	5.6	.7	34.2
C					
Or		.8	15.1	.8	2.4
Plag		49.4	42.9	49.0	49.4
Cpx		17.8	5.8	19.0	3.4
Opx		16.1	22.4	26.3	6.6
Ol					
Mt		1.7	3.7	2.6	.7
Il		1.4	3.5	1.3	2.6
Cr		.1	.02	.1	.03
Hm					
Ap		.1	.9	.1	.5
Py		.2	.02	.04	.1

TABLE IV (continued)

75-568	Metabasalt- Bernic Lake Formation. Analyst: D.M. Brown, Mineral Resources Division analytical laboratory.
75-507	Metabasalt- Bernic Lake Formation. Analyst: K. Ramlal, University of Manitoba.
75-735	Metabasalt- Bernic Lake Formation. Analyst: K. Ramlal, University of Manitoba.
75-578	Metabasalt- Bernic Lake Formation. Analyst: K. Ramlal, University of Manitoba.
75-8-1	Metadacite- Bernic Lake Formation. Analyst: K. Ramlal, University of Manitoba.

Sample locations are shown on accompanying Map C.

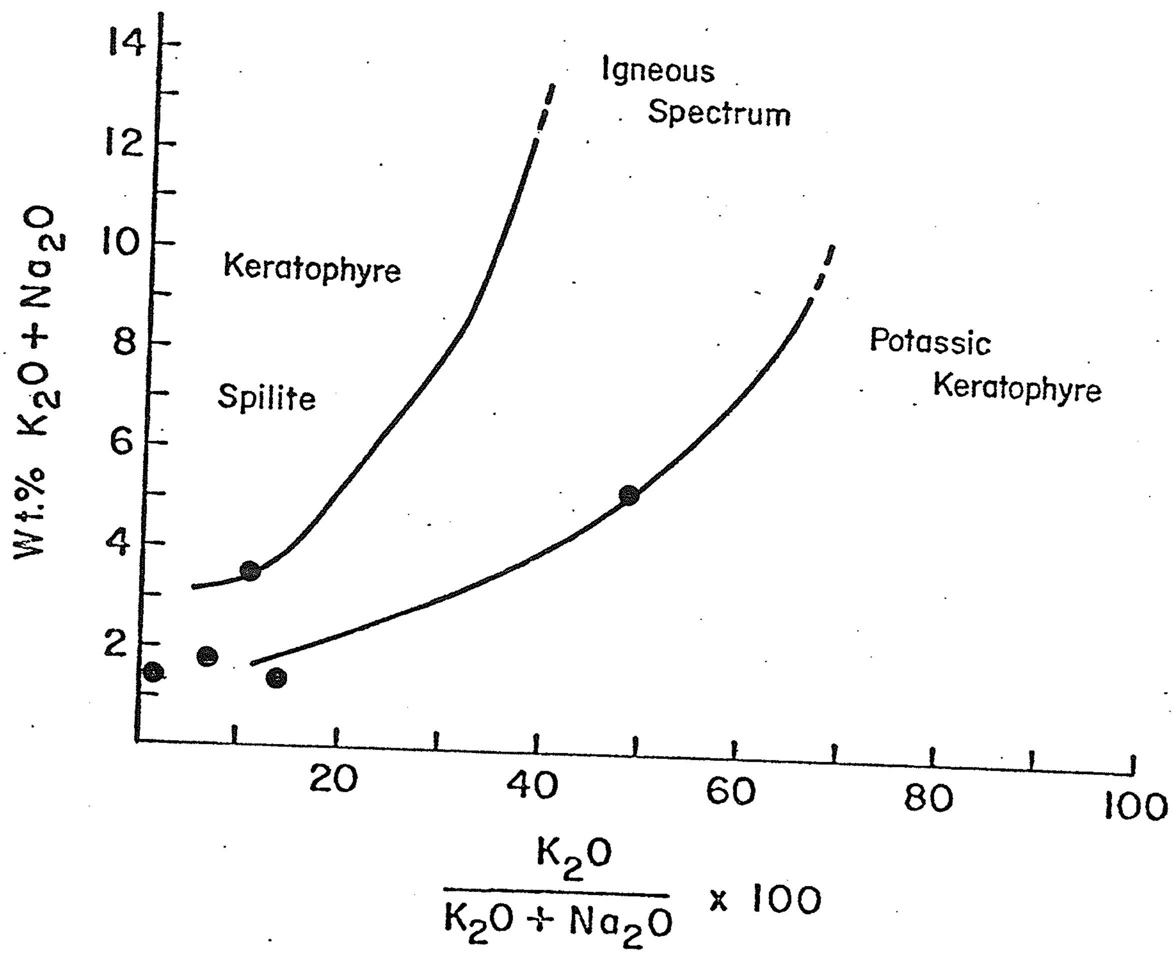

FIGURE 41: Alkali ratio diagram for analyzed rocks of the Bernic Lake Formation.

Normative data, where available, show the rocks to be both orthopyroxene and quartz normative. Normative anorthite and corresponding colour indices for 75-8-1 however indicate the rock to be of andesitic nature (Irvine and Baragar, 1971).

In Figure 42 analytical data from Table IV are compared with the differentiation indices of Kuno (1968), and it is evident that no preference for tholeiitic or hypersthenic series rocks is to be seen.

In Figure 43 the ternary alkali-iron-magnesia data are indicative of a tholeiitic kindred for metabasalt, and a calc-alkaline kindred for metadacite.

The Bernic Lake Formation is infolded with the Peterson Creek formation and also forms a separate structural entity in the core of the synclinorium of the Lamprey Falls Formation.

Rocks of the Bernic Lake Formation are dominated by clastic metasediments of chaotic internal constitution and chaotic areal distribution. Their apparent lack of diagnostic features, and in part a bi-modal (viz. mafic matrix-felsic clast) composition suggest a high energy, subaqueous deposition through debris flow or laharic mechanism. The apparent mixing of clast types in much of the formation, the moderately abundant matrix, and the generally small clast sizes, further suggest that a considerable reworking of these materials took place.

Detritus present in the polymict and oligomict conglomerates of this formation can be identified as having originated from formations underlying the Bernic Lake Formation. Such material includes coarse fragments of the Bird River Sill and rhyolitic fragments of the Peterson Creek Formation. It would be expected to find volcanic detritus in any volcanic sequence as an integral part of the stratigraphy or in disconformable relationships, especially so if volcanism was subaerial. Nevertheless, the exhuming of the Bird River Sill implies profound or deep erosion of the greenstone terrain formation, and for this reason an unconformity is postulated at the base of the Bernic Lake Formation.

Certain of the clastic rocks of the Bernic Lake Formation, east of the Dumbarton Mine (Map C), are characterized by unusual compositions. These include the cordierite, anthophyllite, diopside, garnet, biotite, andalusite assemblages, which, if projected along strike are seen to pass

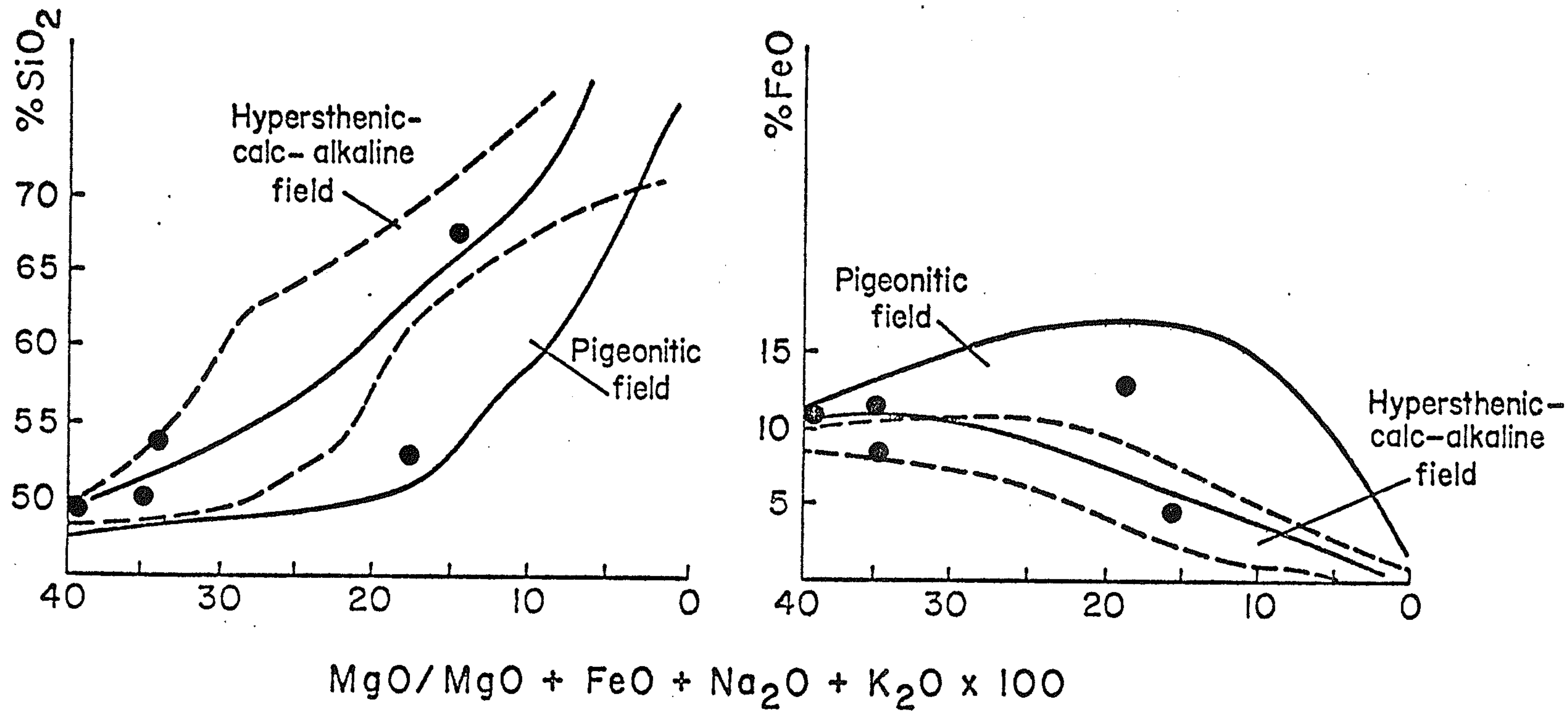

FIGURE 42: $MgO/MgO + FeO + Na_2O + K_2O$ vs. SiO_2 and FeO diagrams for analyzed rocks of the Bernic Lake Formation.

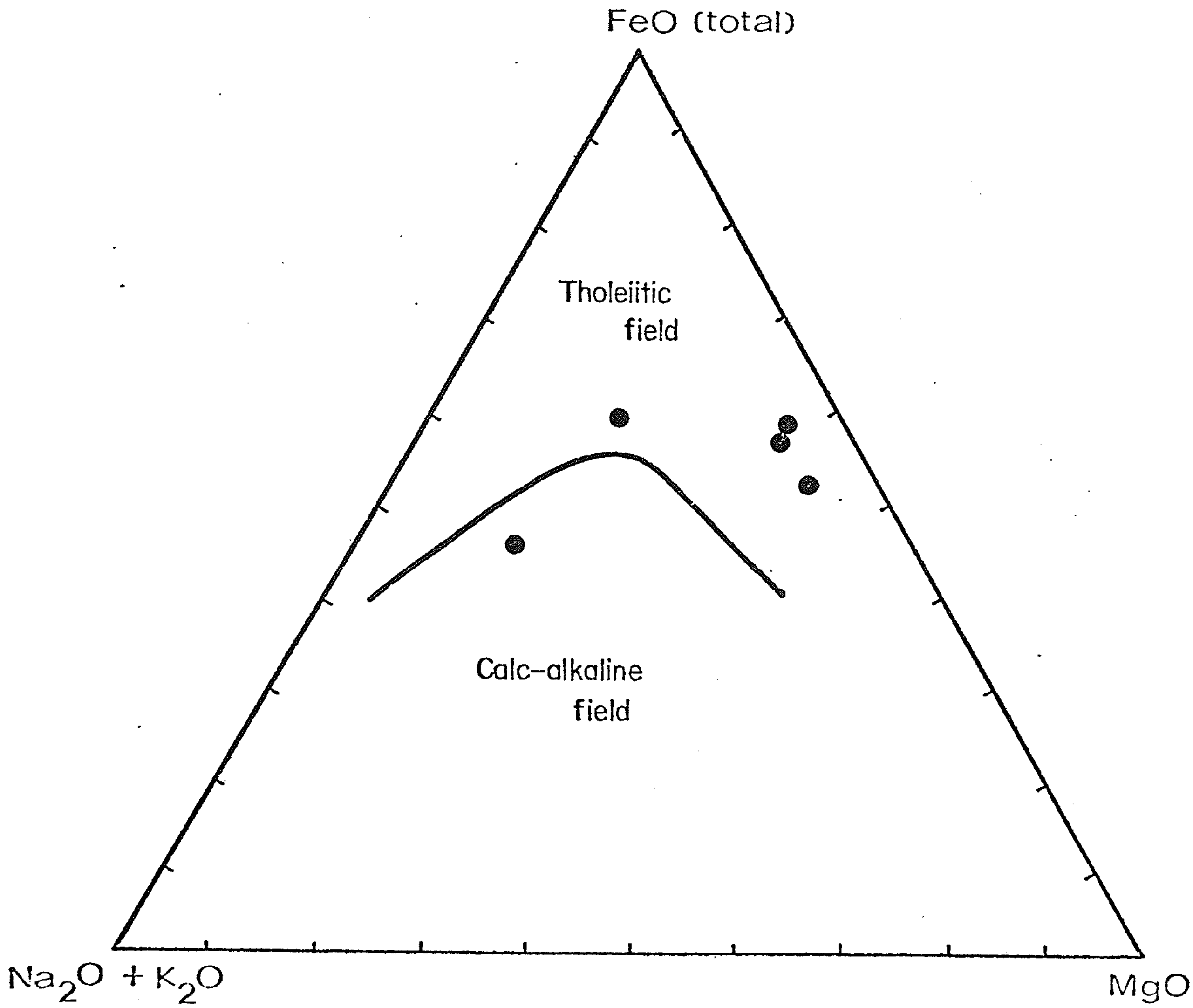

FIGURE 43: Magnesia - total iron - alkalies variation diagram for analyzed rocks of the Bernic Lake Formation.

into garnet biotite granoblastites, graphitic schists, and banded iron formation. All of these mantle a fractured and dismembered garnet-biotite-cordierite bearing quartz porphyry.

Two interpretations of the above rock types are plausible. The assemblages of cordierite-anthophyllite can be considered in a classical sense as "dalmatianites" such as found in the Noranda mining district of Quebec (DeRosen-Spence, 1969) and the subjacent diopside, garnet assemblages as paragenetic correlatives of the cordierite-anthophyllite (Upadhyay and Smitheringale, 1971). In such cases as described by DeRosen-Spence (1969) and Upadhyay and Smitheringale (1972), the assemblages are interpreted as having a two-stage origin involving (a) growth of ripidolite chlorite during volcanic exhalitive processes of alteration, and (b) subsequently, a thermal metamorphism of the chlorite assemblages.

An alternate hypothesis for the origin of the cordierite-anthophyllite assemblages is one of chemical reconstitution through weathering processes, an example of which is presented by Baldwin (1971). This hypothesis is attractive in that it is an expected process in a subaerial regime, and that it would also find keeping with an interpretaion of the rocks adjacent to the quartz-porphyry stock as being a regolith.

The lavas of the Bernic Lake formation are present as thin flows intercalated with the clastic rocks. Those flows in the Bernic Lake area display attributes of subaqueous deposition, and those west of Bird Lake appear to have been subaerially deposited.

The chemistry of the lavas indicates a tholeiitic kindred for the metabasalts, and calc-alkaline kindred for those of more felsic composition. This mixture of kindred for Archean lavas is not unusual, and has been documented in both Archean (Goodwin, 1978) and Phanerozoic (Jakes and White, 1971) regimes.

THE FLANDERS LAKE FORMATION

DESCRIPTION OF ROCK TYPES (8)

The Flanders Lake Formation crops out extensively in the Flanders Lake - Ryerson Lake - Starr Lake - Reynar Lakes area (Fig. 44, Map A). The rocks of the Flanders Lake Formation include polymict metaconglomerate and related meta-arenites which are best exposed in the area between Flanders and Booster Lakes (Map A). Descriptions of these rocks have been presented by Posehn (1976), and their continuity into the Manigotogan gneiss belt has been described by Trueman et al, (1976).

Meta-arenite is the dominant rock type in the Flanders Lake Formation. These rocks are typically greyish weathering, are moderately well bedded and sorted, and display a foliation which develops from a schistosity into a gneissosity in proximity to flanking intrusive rocks (Fig. 45). The bedding in meta-arenite forms a span of 1 - 2 cm, up to 2 m, and is marked principally by variation in biotite content. Graded bedding occurs locally, as does cross-bedding, but in general both features are rare.

The meta-arenites are largely comprised of quartz and feldspar detritus, now recrystallized, with lesser biotite, amphibole, muscovite, magnetite, and hematite. Sillimanite, andalusite, cordierite, and tourmaline occur locally, and the rocks may also be modified by occurrences of sparsely distributed clasts of pebble-size felsic metavolcanic or tonalitic detritus. In proximity to the intrusive rocks, the meta-arenites are commonly further modified by *lits* of intrusive material, and in the eastern extremities of mapping appear to have undergone partial anatexis with generation of a leucosomal phase. (Fig. 46).

Metaconglomerate crops out extensively in the Ryerson-Booster -Starr-Davidson Lakes area (Map A) where these rocks form fold-repeated units.

The metaconglomerate is distinctive, and is characterized by abundant pebble and cobble sized stretched clasts of differing composition (Posehn, 1976). These include metatonalite, metabasalt, metagabbro, metarhyolite, felsic sandstones, tourmaline rich sandstone, and iron formation clasts (Fig. 47). The clasts vary in absolute and relative

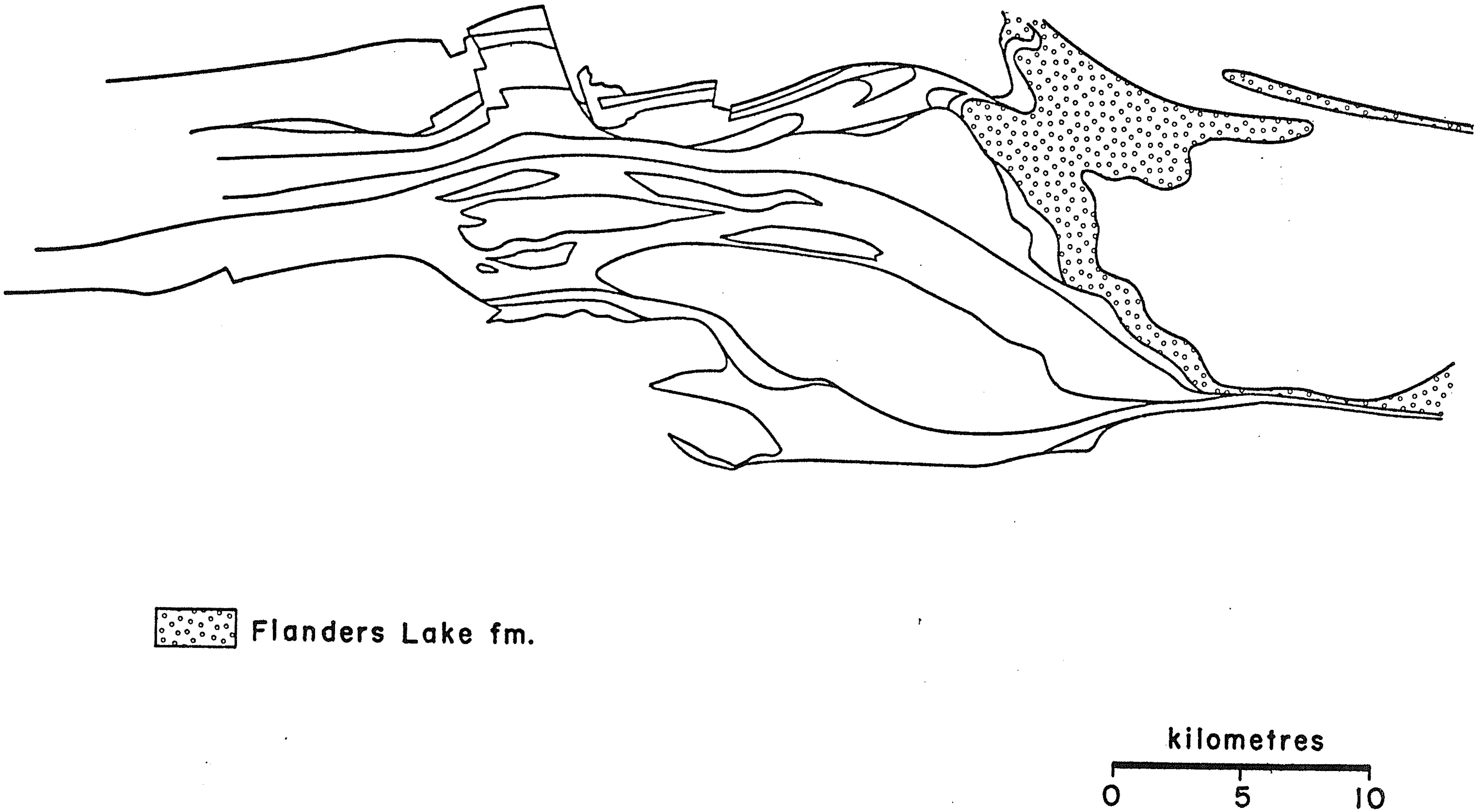

FIGURE 44: Location map of the Flanders Lake Formation.

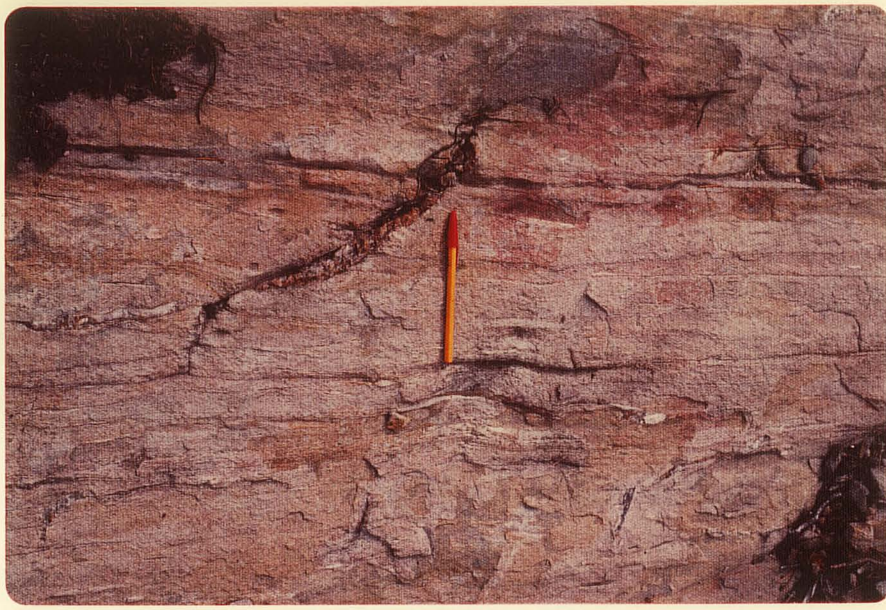

FIGURE 45: Meta-arenite in the Flanders Lake Formation east of Flanders Lake.

FIGURE 46: Granitic *lits* intercalated in meta-arenite in the Flanders Lake Formation southwest of Reynar Lake.

FIGURE 47: Metaconglomerate in the Flanders Lake Formation east of Tulabi Lake.

abundances giving rise locally to orthoconglomerates and paraconglomerates, although the former type is predominant. Matrices vary accordingly, and in thin section appear identical to the previously described meta-arenites with which the metaconglomerate is interbedded.

Primary bedding features are locally preserved in the metaconglomerate, and include poorly sorted beds, graded and inverse graded beds, cross-bedding, scour and fill structures, and lamination, most of which permit reliable top or facing direction determination and indicate deposition through turbidity and debris flow mechanisms with subsequent reworking in a fluviatile regime (Posehn, 1976).

The Flanders Lake Formation was derived in large part from the pre-existing effusive, intrusive, and epiclastic rocks of the volcanic edifice of the Lamprey Falls, Peterson Creek, and Bernic Lake Formations. The mix of materials in the Flanders Lake Formation (Posehn, 1976), their prescribed areas of origin, and the apparent absence of directly deposited volcanic rocks suggest that these deposits formed during a hiatus in, or cessation of volcanism in the areas, and during a period of profound erosion of the volcanic edifice.

The basal contact of the Flanders Lake Formation transgresses both the Peterson Creek Formation and the Bernic Lake Formation,and it is feasible to interpret the mutual inter-relations of the three formations as one of an angular unconformity.

The lithic arenites of the Flanders Lake Formation form the basis of correlation of the Bird River greenstone belt with the Rice Lake greenstone belt first put forward by Moore (1913). Subsequent work by Trueman et al. (1974) expanded on Moore's correlation, and identifies the arenites of the Flanders Lake Formation as being correlative with those rocks of the Manigotogan gneiss belt of sedimentary origin.

THE BOOSTER LAKE FORMATION

DESCRIPTION OF ROCK TYPES (9)

The Booster Lake Formation consists essentially of greywacke-mudstone turbidites which occur in an easterly trending belt between Poplar Bay on Lac du Bonnet and the Ontario - Manitoba interprovincial boundary (Fig. 48, Map A). The formation includes also minor iron formation, and fault-bound slices of grey wacke-mudstones which occur in the Bernic Lake Formation at Ryerson L., Booster L., Rush Lake., and intermittently along the western reach of the Bird River.

The greywacke-mudstones are everywhere well exposed in the map area. These rocks, interbedded on all scales up to 2 m, are typically buff weathering, well bedded, fine to coarse grained, and moderately schistose. In composition, the greywacke component consists principally of felsic detritus which exhibits considerable clast size range (Fig. 49) up to and including cobble-size material in conglomeratic phases. The mudstone component is largely metamorphosed to assemblages of biotite and cordierite throughout the formation.

Primary structures are abundant in the turbidites and include the classical Bouma sequence of graded bedding (Fig. 49), laminated bedding, and ripple cross-bedding (Fig. 50). Secondary, or diagenetic structures include flame structures developed through loading, as well as poorly preserved de-watering cusps. The distribution of these features within the formation, and of interbedded disorganized conglomerates is shown in Figure 51. This distribution indicates that the turbidites were deposited as a fan in the area, with a proximal facies in the west, and a more distal facies to the east. The disposition of the sequences also indicates a regressing source area, as evidenced by the upward (south) increase in the mudstone component of the turbidite pairs and the disappearance of the higher energy sequences coincident with the increased mud fraction (Fig. 51).

Iron formation associated with the greywacke-mudstones sequence crops out only in the western map area near Lac du Bonnet in association with conglomeratic phases. In this locale the iron formation consists essentially of massive iron sulphides interlayered with chert. Elsewhere in the map area the iron formation can be followed by strong AEM conductors, and has been confirmed by diamond drilling in the Booster Lake area (H.D.B. Wilson, pers comm).

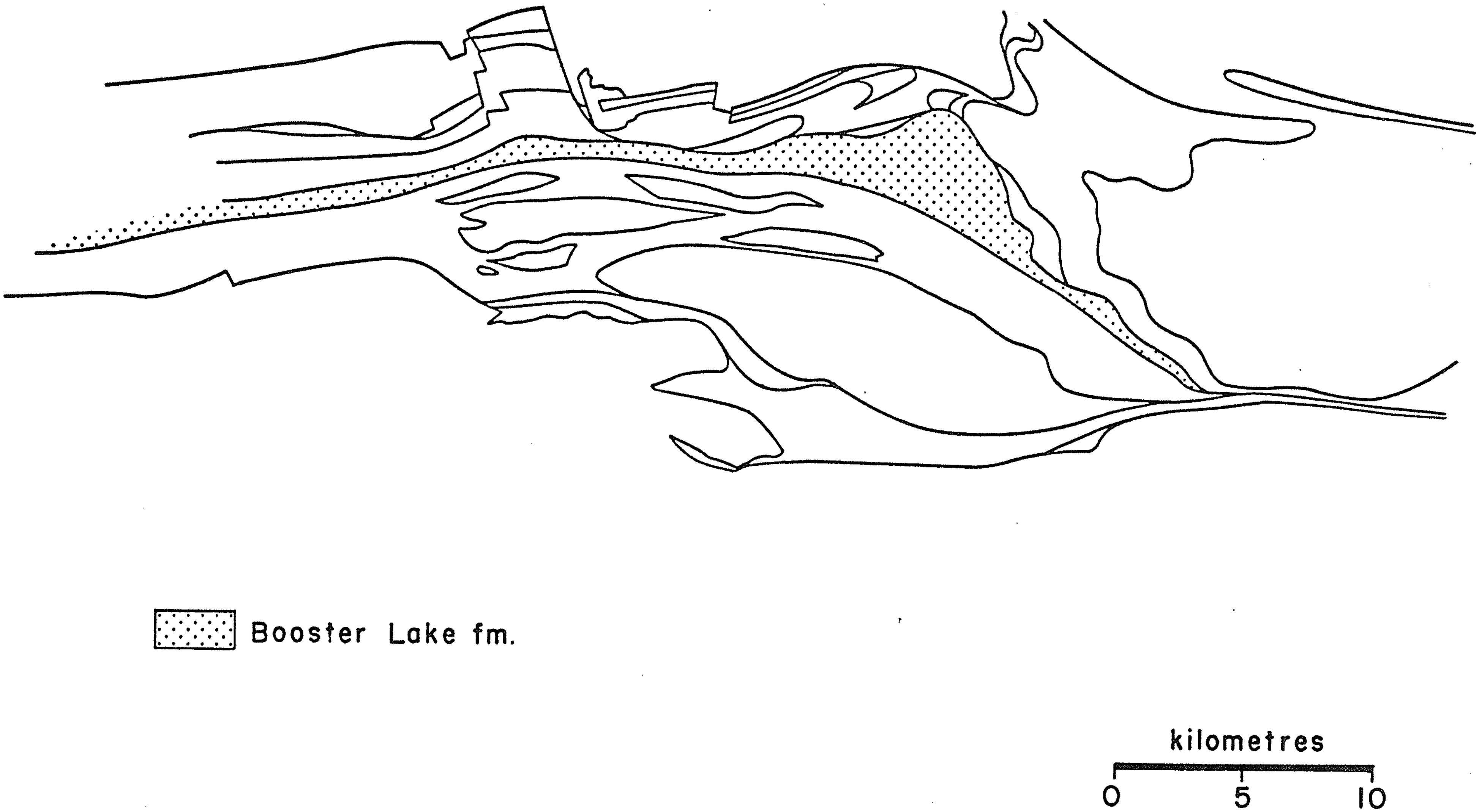

FIGURE 48: Location map of the Booster Lake Formation.

FIGURE 49: Metagreywacke in graded bed in the Booster Lake Formation south of the Chrome Property.

FIGURE 50: Cross-bedded greywacke-mudstone in the Booster Lake Formation south of the Chrome Property.

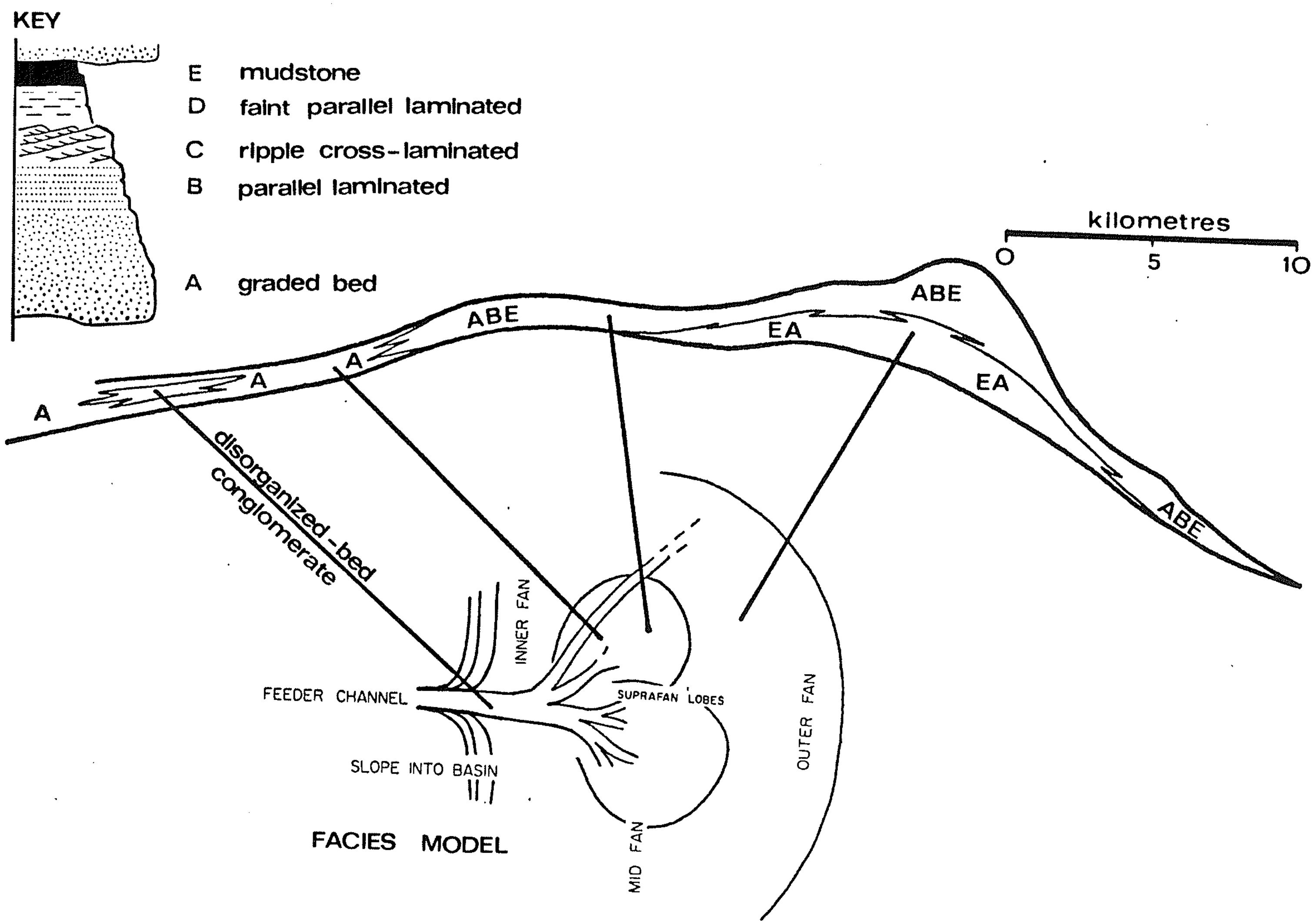

FIGURE 51: Interpreted facies of sedimentation of the Booster Lake Formation.

The relative age of the Booster Lake Formation is problematic. It is tentatively assigned to its position in the succession of Table I as the youngest part of the layered supracrustal sequence but there exists conflicting evidence for this.

The dominant, recognizable, detritus in the Booster Lake Formation appears to have been derived from a felsic source area, possible that of the Peterson Creek Formation. Such detritus consists largely of quartz and albite crystal fragments and also, in the proximal facies of the turbidites, includes felsic fragments. It might thus be logical to assign the Booster Lake Formation to an approximately equivalent age to that of the Peterson Creek deposit. Analogous situations are found in the Edmunds Lake Formation in the greenstone terrain at Bissett (Weber, 1971) or in the Snow Lake area where Bailes (1979) has correlated Amisk turbidites with their adjacent greenstones.

The interpretation of an equivalence of the Booster Lake and Peterson Creek Formations gains further support by virtue of the singularity of detritus in the Booster suite. If, for example, the Booster Lake Formation had been derived from a metamorphosed terrain, (i.e. it's assigned position in this treatise,) it would expectedly contain detritus from a variety of the older formations; erosion having occurred over a cross-section of folded metamorphic (M_1) rocks.

Data which support an assignment of the Booster Lake Formation to the young age (post M_1) herein include: a basement-cover structural relationship, an absence of volcanic deposits, the existence of distal felsic volcanic rocks within the Peterson Creek Formation, rare earth element (REE) patterns in both Peterson Creek and Booster Lake rocks, and volumetric considerations.

A basement-cover relationship is interpreted in the area on the basis of the presence of M_1 and M_2 structures in rocks underlying the Booster Lake formation and an absence of M_1 structures within the Booster Lake formation. The conclusion drawn from this observation is that at the time of the M_1 metamorphism the Booster Lake formation has not been deposited. Conversely, it could be argued that the formation lay outside of the M_1 metamorphic domain (Detailed structural data for the Booster Lake and the other formations are presented below under structural Geology).

The sole presence of turbidite beds in the Booster Lake formation and absence of volcanic deposits suggests that the turbidite suite post-dates active volcanism in the area, a relationship which is also noted for the Flanders Lake formation. This suggests an age for the Booster Lake formation that at least post-dates the age of the Bernic Lake formation. Again, it could be argued that the turbidites lay outside the leeward range of, for example, ash fall deposits.

In the eastern part of the area, viz. south of Bird Lake, (see Map A) the felsic sandstones of the Peterson Creek formation exhibit deposition through turbidite mechanisms and have been interpreted as distal products of the Peterson Creek formation. These rocks differ in appearance markedly from the Booster Lake rocks, particularly in composition, bedding thickness, mud fractions, and size of detritus, all of which tends to preclude a correlation of the two formations. The faulted base of the turbidite suite however, may, by virtue of apparent fault transport of the turbidites of an unknown distance, preclude the separation of the two formations.

REE data, published by Černý et al (1979) for rocks of the Peterson Creek formation and the Booster Lake formation warrant further examination, and these data are presented in Figure 24 above. Also included in Figure 24 are REE data from tonalitic gneisses in the Winnipeg River batholithic belt immediately south of the greenstone belt.

In Figure 24 it is evident that rocks of the Peterson Creek formation are characterized by gently sloping LREE values, a strong Europium anomaly and flat HREE values. REE data from the Booster Lake formation differ markedly from those of the Peterson Creek formation, and are marked by enrichment of LREE, a smooth curve (no Eu anomaly), and smaller enrichment of HREE.

Recent research has shown that the REE elements in clastic metasedimentary rocks maintain the signatures of their provenances (Dypvik and Brunfelt, 1976), and similarly exhibit little or no adjustment during metamorphic processes (Drury, 1978). The contrasts therefore between Peterson Creek, and Booster Lake REE patterns dispels any positive correlation of these formations. Rather, the REE data shown in Figure 24 tend to support derivation of the Booster Lake formation from the Winnipeg River batholithic belt tonalitic rocks.

It may thus be that the Booster Lake formation exhibits a source area not recognized in the greenstone belt, or derivation form a sialic foreland (Winnipeg River batholithic belt?) as has been suggested for the Pontiac turbidites of the Abitibi greenstone belt (Goodwin and Ridler, 1970) or turbidites of the Yellowknife Supergroup in the Slave Province (McGlynn and Henderson, 1970; Drury, 1978). McGlynn and Henderson further suggest that as the greywackes of the Yellownkife Supergroup are volumetrically in excess of the felsic volcanic rocks that an additional provenance was necessary for greywackes in that area, and accordingly they appeal to a pre-extant sialic foreland. This may also be the case at Bird River where inspection of accompanying Map A and Figure 64 suggest a 2:1 ratio of Booster Lake : Peterson Creek volumes.

INTRUSIVE ROCKS OF THE BIRD RIVER GREENSTONE BELT

Intrusive rocks of the Bird River greenstone belt have been subdivided on the basis of their relative ages of emplacement (Table 1, Fig. 6). Accordingly these have been assigned to a synvolcanic association, a syntectonic association, and a late tectonic association, descriptions of which are provided below.

SYNVOLCANIC INTRUSIVE ROCKS

Hypabyssal metagabbro (4c, 7f)

Hypabyssal metagabbro sills are ubiquitous in metabasalt flows of the Lamprey Falls and Bernic Lake formations. These sills are generally less than 20 m in thickness, and persist along strike for less than 150 m. Contacts of these bodies are sharp, exhibit finer grain size, and tend to be slightly sheared. Inclusion material is rare.

Typical hypabyssal metagabbro is a dark grey-green weathering, fine to medium grained, massive to weakly schistose rock, and is comprised essentially of saussuritized plagioclase in a matrix of tremolite-actinolite with lesser magnetite, leucoxene, and secondary quartz and quartz-carbonate veining.

Bird River Sill (4a)

The Bird River Sill is a layered ultramafic to gabbroic body formed through gravitational settling and accumulation of olivine, chromite, and plagioclase (Trueman, 1971; in prep.). A composite section of this body is shown in Figure 52, and a palinspastic reconstruction of this body is shown in Figure 53 (back pocket). From Figures 52 and 53, it is evident that the Bird River Sill is subdivisible into five principle units. These are: a feeder dyke, the layered ultramafic cumulates, a picrite layer, layered gabbroic cummulates, and a granophyre.

The feeder dyke to the Bird River Sill is constrained to the area enclosing the Bird River Mines Ltd. property through to the east end of the Dumbarton Mines Ltd. property (Figure 53). Rock types of the feeder

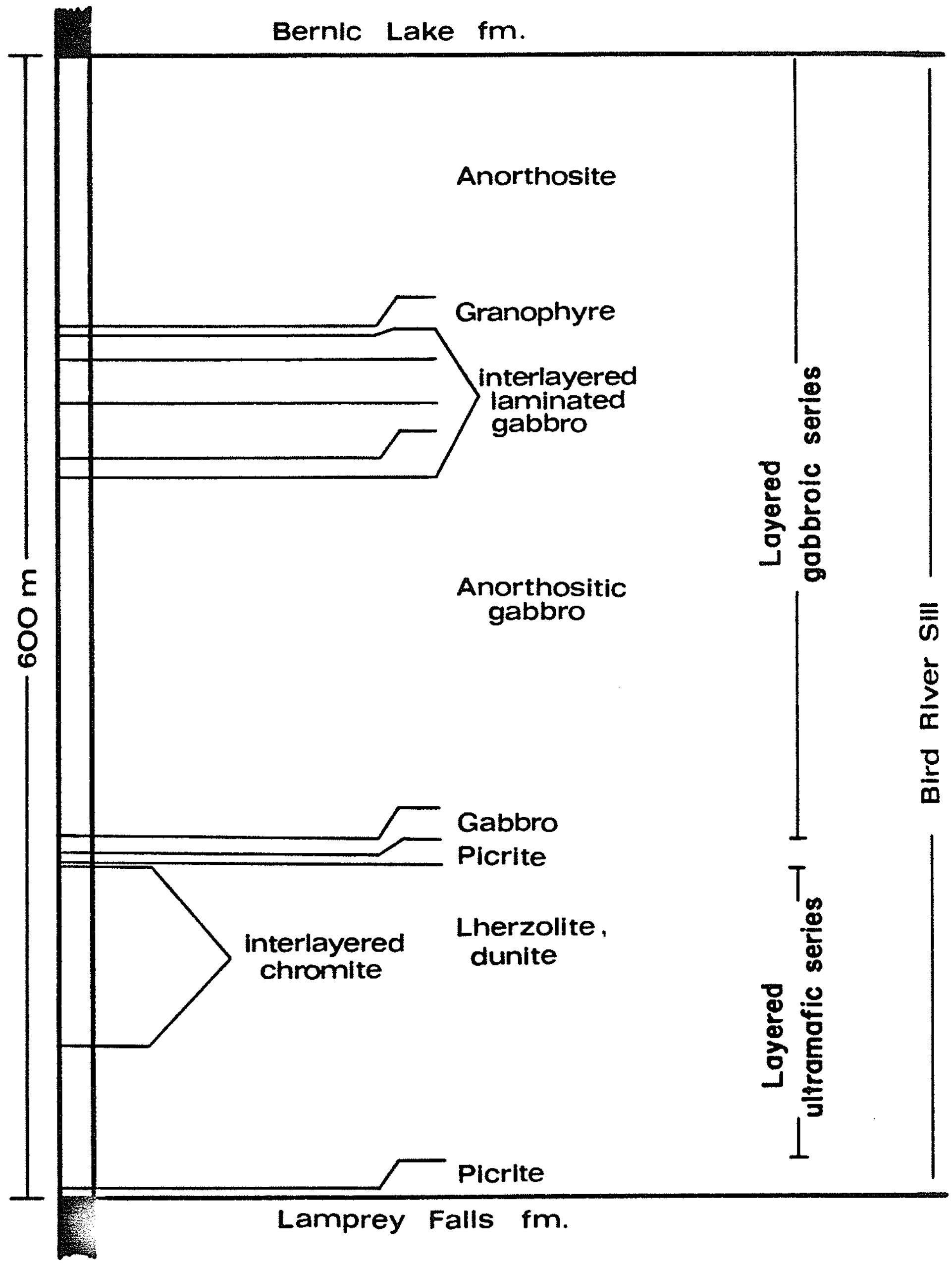

FIGURE 52: Composite section of the Bird River Sill from the Chrome Property.

dyke include picrite, pyroxenite, and lherzolite which are disposed in a poorly concentric, fault segmented zone (Trueman, in prep.). These rocks are in general severly altered, and consist of assemblages of serpentine, talc, carbonate, tremolite, cummingtonite, and magnetite which nearly completely replace assemblages of olivine, clinopyroxene, and plagioclase.

The layered ultramafic series of rocks (Fig. 52) comprises interlayered dunites, lherzolites, and feldspathic and chromiferous variants of these (Fig. 54a, b). These rocks, although texturally well preserved, consist essentially of serpentine pseudomorphous after cumulus olivine, intercumulus clinopyroxene and plagioclase, plus cumulus chromite. The chromite, generally mantled by chlorite, exhibits a magnetite enriched rim (Gait, 1964) formed through deuteric alteration.

Primary structures are abundant in the layered ultramafic rocks, and include such features as bifurcation and disruption of chromitite layers, and seriate layer contacts (Fig. 55 a,b,c).

Picrite lies in sharp, phase-layered (Jackson, 1967) contact above the layered ultramafic rocks. The picrite (Fig. 56) is marked by gradation in the content of the original olivine, from 15 percent at the bottom to zero at the top, and by the first appearance of cumulus plagioclase. The plagioclase, extensively altered to clinozoisite, is poikalitically enclosed by tremolite which in turn is pseudomorphous after original intercumulus clinopyroxene.

The layered gabbroic series of rocks, dominated by anorthositic gabbro and anorthosite (Fig. 52), lies in gradational contact above the picrite, and developed as plagioclase formed to the near exclusion of other phases. Cryptic variation of the anorthite content of the plagioclase indicates that crystal accumulation proceeded from the floor of the magma chamber upwards, and from the roof downwards (Trueman, 1971).

The plagioclase, equant in form, is mantled by coarse blades of actinolite (Fig. 57) formed at the expense of an original clinopyroxene. In addition, the plagioclase commonly exhibits resorption textures, concommitant with increases of clinopyroxene (viz. actinolite) contents and

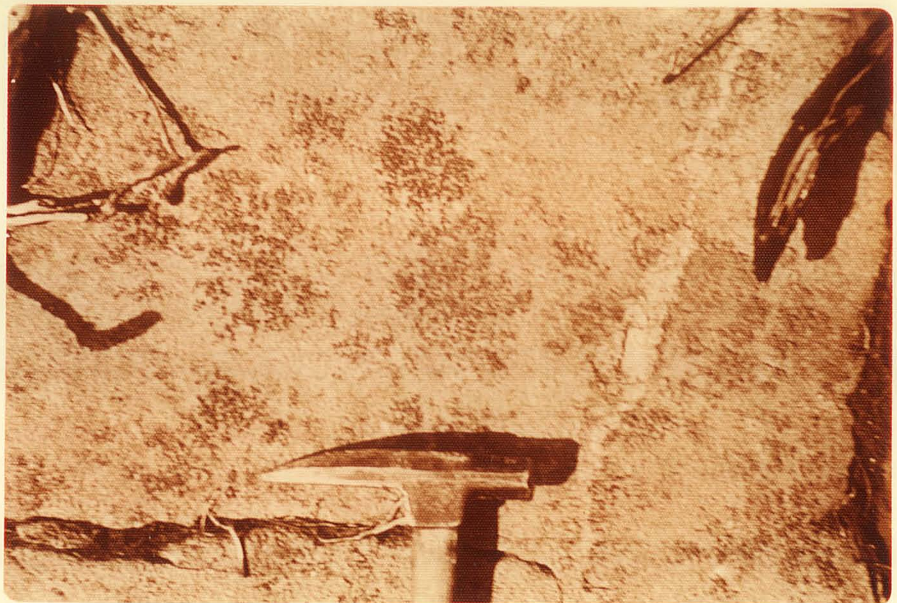

FIGURE 54a: Lherzolite in the Bird River Sill, Chrome Property.

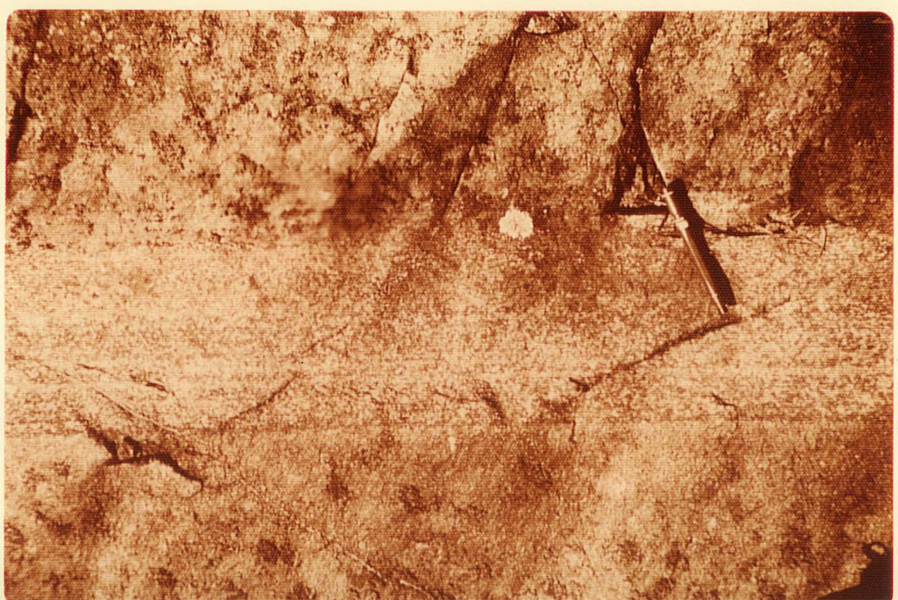

FIGURE 54b: Chromiferous dunite in the Bird River Sill, Chrome Property.

FIGURE 55a: Bifurcated chromitite layers in the Bird River Sill, Chrome Property.

FIGURE 55b: Disrupted chromitite layers in theBird River Sill, Chrome Property.

FIGURE 55c: Seriate layered contacts in the Bird River Sill, Chrome Property.

FIGURE 56: Picrite transitional between the ultramafic and gabbroic rocks of the Bird River Sill, Chrome Property.

FIGURE 57: Anorthositic gabbro of the Bird River Sill exposed on the Chrome Property.

gives rise to more mafic and igneous laminated variants (Fig. 58 a,b).

The granophyre in the Bird River Sill, approximately 6 m in thickness, occupies a position intermediately located in the gabbro layers (Fig. 52), in a position controlled by the upward and downward accumulation of the gabbros. The granophyre consists essentially of granophyric intergrowths of albite-oligoclase and quartz, mantled by fibrous actinolite and extensively saussuritized laths of plagioclase (Trueman, 1971).

Metagabbro (4b)

Metagabbro occurs as stocks and sills west of the Dumbarton Mine in the Lamprey Falls formation, and as a sill in the same rocks in the Winnipeg River area (Map A).

The metagabbro is typically mottled, greyish-green weathering, coarse grained, and massive (Fig. 59). Near contacts the rock becomes finer grained, and a schistosity becomes pronounced. The rock typically consists of varied amounts of actinolite, plagioclase (An 88 - 35), biotite, zoisite, chlorite, carbonate, ilmenite - leucoxene, hematite, pyrite, and secondary quartz. Inclusion material of volcanogenic metasediments occur locally in patches, and in one location several large inclusions of a tonalite material of unknown origin were noted.

Glomeroporphyritic metagabbro (7e)

Glomeroporphyritic metagabbro occurs as discrete lenses in the Bird River Sill, and as sills in metabasalt in the Bernic Lake area (Map A). These rocks are characterized by large ovoids of plagioclase crystals (An 80) set in a matrix of fine to coarse grained metagabbro, or bladed actinolite (Fig. 60). Detailed descriptions of these rocks have been presented by Bond (1973) and by Trueman (1971).

Quartz porphyry (not shown on map)

A small dyke of quartz porphyry crops out at the north-east end of the Dumbarton Mine, where it transects the ore zone (B. Weir, pers comm.) and has been described by Juhas (1974). A similar quartz porphyry intrudes

FIGURE 58a: Mafic variant of gabbro in the Bird River Sill on the Chrome Property.

FIGURE 58b: Laminated gabbro in the Bird River Sill on the Chrome Property.

FIGURE 59: Metagabbro west of the Dumbarton Mine.

FIGURE 60: Glomeroporphyritic metagabbro at Bernic Lake.

metarhyolite on the south shore of the Winnipeg River (see Map A).

In outcrop the quartz porphyry is a white weathering, inequigranular, strongly foliated rock which in thin section is best termed a cataclasite. It is marked by rolled and crushed quartz phenocrysts streamlined in a finely comminuted matrix of quartz, albite, and sericite.

Composite intrusive stocks of the Bernic Lake and Lamprey Falls formations (7 a, b, c, d)

Synvolcanic intrusive rocks in the Bernic Lake and Lamprey Falls formations occur as composite parts of stock-like bodies and as thin sills which show mutually intrusive relationships and differentiation from gabbro to diorite, quartz and feldspar porphyry, and granodiorite.

Metagabbro (7 a) forms the earliest intrusive phase of the composite stocks in the Bernic Lake formation, and is present in four of these bodies (see accompanying Map A). The metagabbro is typically grey to black weathering, medium to coarse grained, and moderately to strongly schistose (Fig. 61). At Osis Lake the metagabbro exhibits large metacrysts of amphibole which poikilitically enclose small plagioclase crystals. Elsewhere this body exhibits ophitic and coarse equigranular textures. The metagabbro at Bernic Lake (footwall amphibolite of Crouse and Černý, 1971) displays a normal ophitic texture and also a faint banding of plagioclase-enriched layers which give rise to phase-layering (Jackson, 1967) of a 1 to 10 cm scale parallel to the intrusion boundaries.

Metadiorite (7b) is present as the principal phase of the northernmost (north of Bernic Lake) of the intrusive stocks in the Bernic Lake formation (Map A) and is also present as thin sills in the area north and east of Osis Lake. The metadiorite is grey weathering, medium to coarse grained equigranular, and moderately schistose (Fig. 62). Within core areas of this body is a comagmatic phase otherwise identical to the above, but marked by the occurrence of 1 to 5 mm phenocrysts of hornblende. In composition the metadiorite consists of varied proportions of tremolite-actinolite, biotite, and chlorite set in a granular mozaic of saussuritized plagioclase. Leucoxene, after ilmentite, is the only accessory mineral in evidence.

The contacts of the metadiorite are characterized by a thin ($<$10 m)

FIGURE 61: Metagabbro (footwall amphibolite) at Bernic Lake.

FIGURE 62: Metadiorite north of Bernic Lake.

zone of dykes, and in proximity to the boundary is marked by an abundance of *schlieren* of volcanic and volcaniclastic inclusions.

Quartz-feldspar porphyry (7c) and non-porphyritic equivalents form the dominant part of the large stock centered south of Birse Lake, and also forms thin sills in the Greer Lake, Winnipeg River, and Bernic Lake areas (Map A). The quartz-feldspar porphyry is a grey weathering, inequigranular porphyritic, massive to strongly schistose rock. Phenocryst material is prominent along margins of these bodies, but decreases into core area giving rise to equigranular coarse grained phases. Similarly, the contact border zones exhibit strong schistosity which decreases inwards to the core areas. Inclusion material is rare and contacts are sharp.

In composition these rocks consist chiefly of granular plagioclase and quartz set in a matrix of biotite, chlorite, and amphibole all of which mantle large (<8 mm) augen of the quartz and plagioclase (albite) phenocrysts. Accessory minerals include minor leucoxene after ilmenite, and minor tourmaline. Zoisite group minerals are ubiquitous, formed after plagioclase in both the matrix and phenocrysts.

Granodiorite (7d) forms the youngest recognized phase of the composite stocks, and is constrained in occurrence to the west ends of the stocks in which it occurs (see accompanying Map A). Granodiorite is the only phase in evidence in the two bodies near Sarap Lake (Map A).

The granodiorite is a grey-white to pink weathering rock marked by equigranular texture, and a moderate to weak schistosity. In composition, the rock consists of coarse grained subhedral albite-oligoclase and microcline boundaries. Biotite, and sericite, are ubiquitous, and chlorite, leucoxene, magnetite, and carbonate are interspersed throughout.

The contacts of granodiorite are in general sharp, and these rocks are marked by minor inclusion material of metagabbro and metadiorite (Fig. 63, a,b).

PETROCHEMISTRY OF THE SYNVOLCANIC INTRUSIVE ROCKS

Three analyses of hypabyssal metagabbro from the Lamprey Falls formation are presented in Table V.

Chemical analysis of the chilled margin of the Bird River Sill, the

FIGURE 63a: Inclusions of gabbro and diorite in granodiorite at Bernic Lake.

FIGURE 63b: Gabbro inclusions in granodiorite cut by younger pegmatite on Bernic Lake.

TABLE V: Chemical analyses of hypabyssal metagabbro intrusive into the Lamprey Falls formation.

SAMPLE NUMBER	111	104	75-456
OXIDE			
SiO_2	49.3	51.6	51.40
Al_2O_3	14.7	12.9	14.02
Fe_2O_3	1.53	1.71	1.88
FeO	11.0	11.66	8.80
MgO	8.09	6.68	7.15
CaO	11.09	8.77	11.24
Na_2O	1.75	2.47	1.54
K_2O	.13	.51	1.30
TiO_2	.77	1.16	.76
P_2O_5	.05	.07	.18
MnO	.20	.37	.21
S	.03		
Cr_2O_3	.03	.01	
NiO	.02	.01	
CoO	.01	.01	
H_2O	1.35	1.62	1.42
CO_2	.15	.15	.09
TOTAL	100.02	99.7	99.99
NORM WT. %			
Q		2.7	2.9
C			
Or	.8	3.1	7.8
Plag	47.3	44.4	41.2
Cpx	19.1	17.3	22.6
Opx	28.0	27.5	21.0
Cl	.9		
Mt	2.2	2.5	2.8
Il	1.5	2.3	1.5
Cr	.05	.02	
Hm			
Ap	.1	.2	.4
Py	.1		

TABLE V (Continued)

111	Hypabyssal metagabbro - Lamprey Falls formation. Analyst: D. M. Brown, Mineral Resources Division analytical laboratory
104	Hypabyssal metagabgro - Lamprey Falls formation. Analyst: D. M. Brown, Mineral Resources Division analytical laboratory.
75-456	Hypabyssal metagabbro - Lamprey Falls formation. Analyst: D. M. Brown, Mineral Resources Division analytical laboratory.

Sample locations shown on accompanying Map C.

calculated bulk composition of the Bird River Sill, analysis of metagabbros, and analyses of glomeroporphyritic metagabbro are presented in Table VI.

Chemical analysis of quartz porphyry from the Peterson Creek formation is presented in Table VII.

Chemical analyses of hypabyssal metagabbro, metagabbro, metadiorite, tonalite (quartz and quartz feldspar porphyry), and granodiorite which intrude the Bernic Lake formation, and the Lamprey Falls formation are presented in Table VIII.

Respective CIPW normative data for the analyzed rocks are presented in the corresponding Tables, where available.

In Figure 64 the analytical data for Tables V, VI, VII, and VIII are plotted against the igneous spectrum of Hughes (1973). No strong chemical alteration is in evidence, and confirms an apparent lack of affects of such alteration in petrographic examination.

Examination of Al_2O_3 contents shown in Table VI are suggestive of high-alumina compositions for several of these rock types, and indeed most fall in the high-alumina field of Kuno (1968). Problematic in such an interpretation is that most of these rocks are also feldspar-phyric.

All of the analytical data of Tables V, VII, and VIII are plotted in Figure 65 against the differentiation indices of Kuno (1968) from which it is evident that the intrusive rock types in the Lamprey Falls formation exhibit a preference to the pigeonitic series, and those of the Bernic Lake formation exhibit correspondence to both the pigeonitic and hypersthenic series. This pattern is further confirmed in the alkalies - total iron - magnesia plot of Figure 66.

SYNTECTONIC INTRUSIVE ROCKS

Syntectonic intrusive rocks in the area of the Bird River greenstone belt include the Maskwa Lake and Marijane Lake quartz diorite - granodiorite batholiths (Fig. 6, Map A), for detailed petrologic and petrographic descriptions of which the reader is referred to McRitchie (1971), Carlson (1958), and Cerny et al. (1979).

The Maskwa Lake and Marijane Lake batholiths are assigned to a syntectonic association because their emplacement corresponds to the second

TABLE VI: Chemical analyses of the Bird River Sill (chilled margin), metagabbro, and glomeroporphyritic metagabbro.

SAMPLE NUMBER	BRS(CM)	BRS*	1096	01	10-2	75-408
OXIDE						
SiO_2	45.27	44.38	48.4	49.50	47.85	48.95
Al_2O_3	17.91	17.44	17.5	14.81	16.89	18.05
Fe_2O_3			.82	1.65	1.75	1.76
FeO	5.59	7.11	8.21	7.68	7.72	6.76
MgO	14.53	13.47	8.55	8.65	7.80	7.15
CaO	7.25	9.93	9.8	11.85	13.02	12.50
Na_2O	1.52	1.16	2.01	1.95	1.49	1.65
K_2O	.59	.23	1.50	.38	.33	.26
TiO_2			.44	.64	.54	.54
P_2O_5			.04	.17	.16	.13
MnO			.17	.17	.17	.17
S			.01			
Cr_2O_3	.09		.05			
NiO			.02	.08	.01	
H_2O	3.67		1.93	1.75	1.59	1.50
CO_2	Tr		.40	.33	.19	.24
TOTAL	99.49		99.85	99.61	99.51	99.66
NORM WT. %						
Q						.9
C	1.7					
Or	3.8		9.1	2.3	2.0	1.6
Plag	52.7		52.6	48.2	52.2	56.2
Cpx			11.8	22.6	21.0	16.7
Opx	20.9		7.8	20.7	17.3	20.7
Ol	20.8		16.5	2.1	3.5	
Mt			1.2	2.5	2.6	2.6
Il			.9	1.2	1.0	1.0
Cr	.1		.1			
Hm						
Ap			.1	.4	.4	.3
Py			.02			

*Calculated Bulk Composition

TABLE VI (Continued)

BRS(CM)	Analysis of chilled margin at the basal contact of the Bird River Sill. Sample from diamond drill core. Results excerpted from Osborne (1949).
BRS	Calculated bulk composition of the Bird River Sill excerpted from Trueman (in prep.).
1096	Metagabbro - Lamprey Falls formation. Analyst D. M. Brown, Mineral Resources Division analytical laboratory.
01	Glomeroporphyritic metagabbro. Results excerpted from Bond (1973).
10-2	Glomeroporphyritic metagabbro. Results excerpted from Bond (1973).
75-408	Metagabbro - Lamprey Falls formation. Analyst K. Ramlal, University of Manitoba.

Sample locations shown on accompanying Map C.

TABLE VII: Chemical anaysis of quartz porphyry from the Peterson Creek formation.

SAMPLE NUMBER	75-429
OXIDE	
SiO_2	70.50
Al_2O_3	15.72
Fe_2O_3	.74
FeO	.96
MgO	.66
CaO	1.65
Na_2O	4.25
K_2O	3.90
TiO_2	.26
P_2O_5	.13
MnO	.03
S	.15
Cr_2O_3	
NiO	
H_2O	.60
CO_2	.37
TOTAL	99.77
NORM WT. %	
Q	26.7
C	1.8
Or	23.3
Plag	43.8
Cpx	
Opx	2.5
Ol	
Mt	1.1
Il	.5
Cr	
Hm	
Ap	.3
Py	

TABLE VII (Continued)

75-429	Quartz porphyry - Peterson Creek formation. Analyst: D. M. Brown, Mineral Resources Division analytical laboratory.

Sample locations shown on accompanying Map C.

TABLE VIII: Chemical analyses of intrusive rocks in the Bernic Lake formation.

SAMPLE NUMBER	75-514	75-605	75-522	75-749	75-753	75-755	75-528	75-738	75-576
OXIDE									
SiO_2	46.50	44.40	58.50	69.75	71.05	71.55	70.00	74.75	51.60
Al_2O_3	15.90	16.90	15.55	14.10	13.78	13.52	13.51	12.76	14.09
Fe_2O_3	3.14	2.12	2.28	1.24	1.61	1.20	.98	1.31	2.63
FeO	11.60	9.38	5.44	3.24	3.08	2.16	3.24	1.52	12.8
MgO	5.20	10.23	4.25	.41	.45	.50	.39	.19	3.25
CaO	9.85	12.2	6.70	2.20	2.34	1.74	1.84	1.00	7.90
Na_2O	2.30	1.52	3.54	4.09	3.84	3.35	4.00	4.50	2.92
K_2O	.28	.17	1.24	2.82	2.65	3.34	2.68	2.76	.32
TiO_2	2.28	.88	.72	.54	.56	.53	.54	.42	1.85
P_2O_5	.19	.04	.25	.13	.02	.12	.20	.07	.15
MnO	.20	.21	.17	.07	.08	.09	.10	.06	.20
H_2O	1.81	1.14	1.11	.63	.58	.88	.89	.56	1.47
CO_2	.16	.05	.05	.10	.06	.91	.64	.13	.50
TOTAL	99.41	99.23	99.80	99.32	100.10	99.89	99.01	100.03	99.64
NORM WT. %									
Q	.1		11.9	28.7	31.9	34.8	31.3	35.5	
C				.6	.7	1.5	1.2	.7	
Or	1.7	1.0	7.4	16.9	15.7	20.1	16.3	16.4	
Plag	53.1	52.6	53.6	45.3	43.2	36.9	42.7	42.9	
Cpx	13.1	17.8	7.2						
Opx	22.5	1.2	14.5	5.3	4.7	3.6	5.5	1.6	
Ol		22.4							
Mt	4.7	3.1	3.4	1.8	2.3	1.8	1.5	1.9	
Il	4.4	1.7	1.4	1.0	1.1	1.0	1.1	.8	
Cr		.1							
Hm									
Ap	.5	.1	.6	.3	.4	.3	.5	.2	
Py		.04							

TABLE VIII (Continued)

75-514	Metagabbro - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-605	Metagabbro - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-522	Metadiorite - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-749	Quartz diorite - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-753	Quartz diorite - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-755	Quartz diorite - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-528	Quartz diorite - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-738	Granodiorite - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.
75-576	Hypabyssal metagabbro - Bernic Lake formation. Analyst: K. Ramlal, University of Manitoba.

Sample locations shown on accompanying Map C.

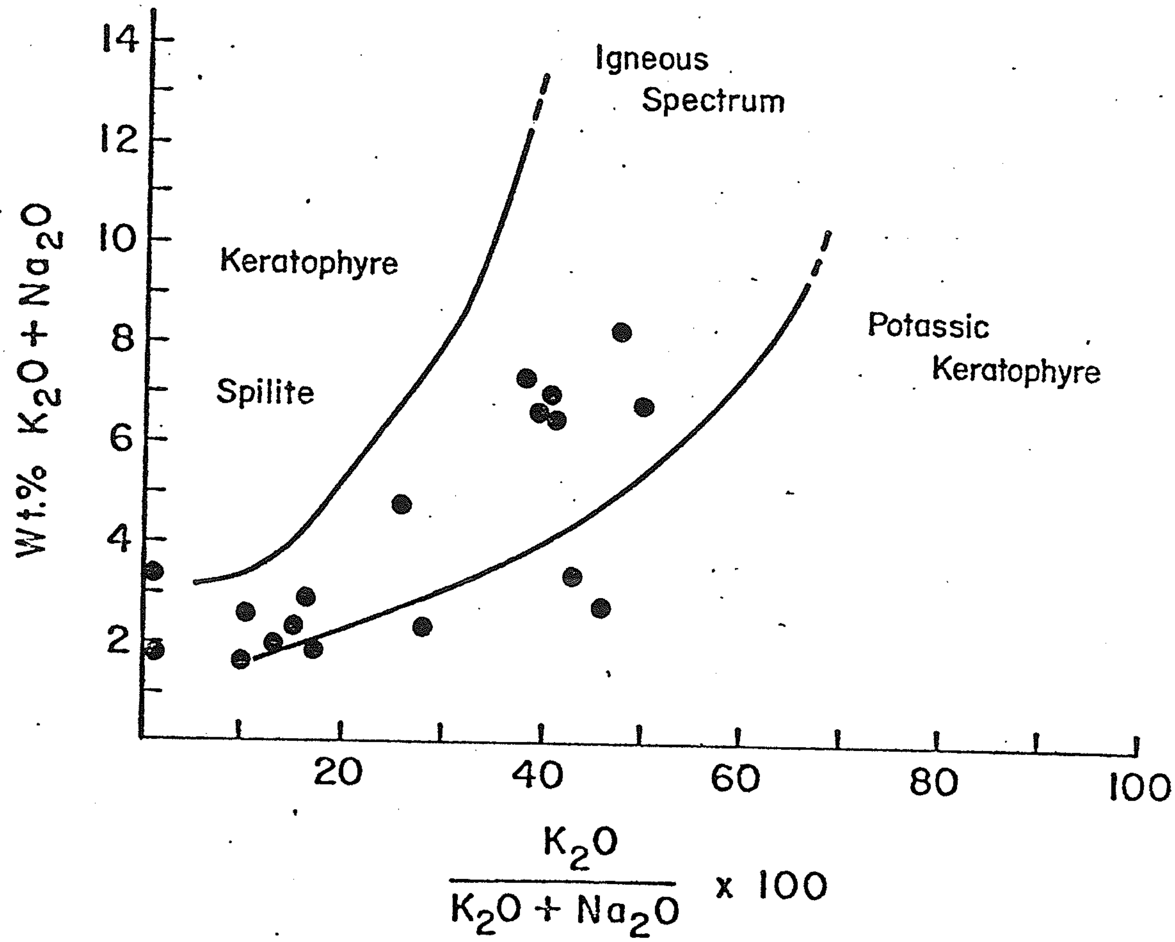

FIGURE 64: Alkali ratio diagram for analyzed synvolcanic intrusive rocks.

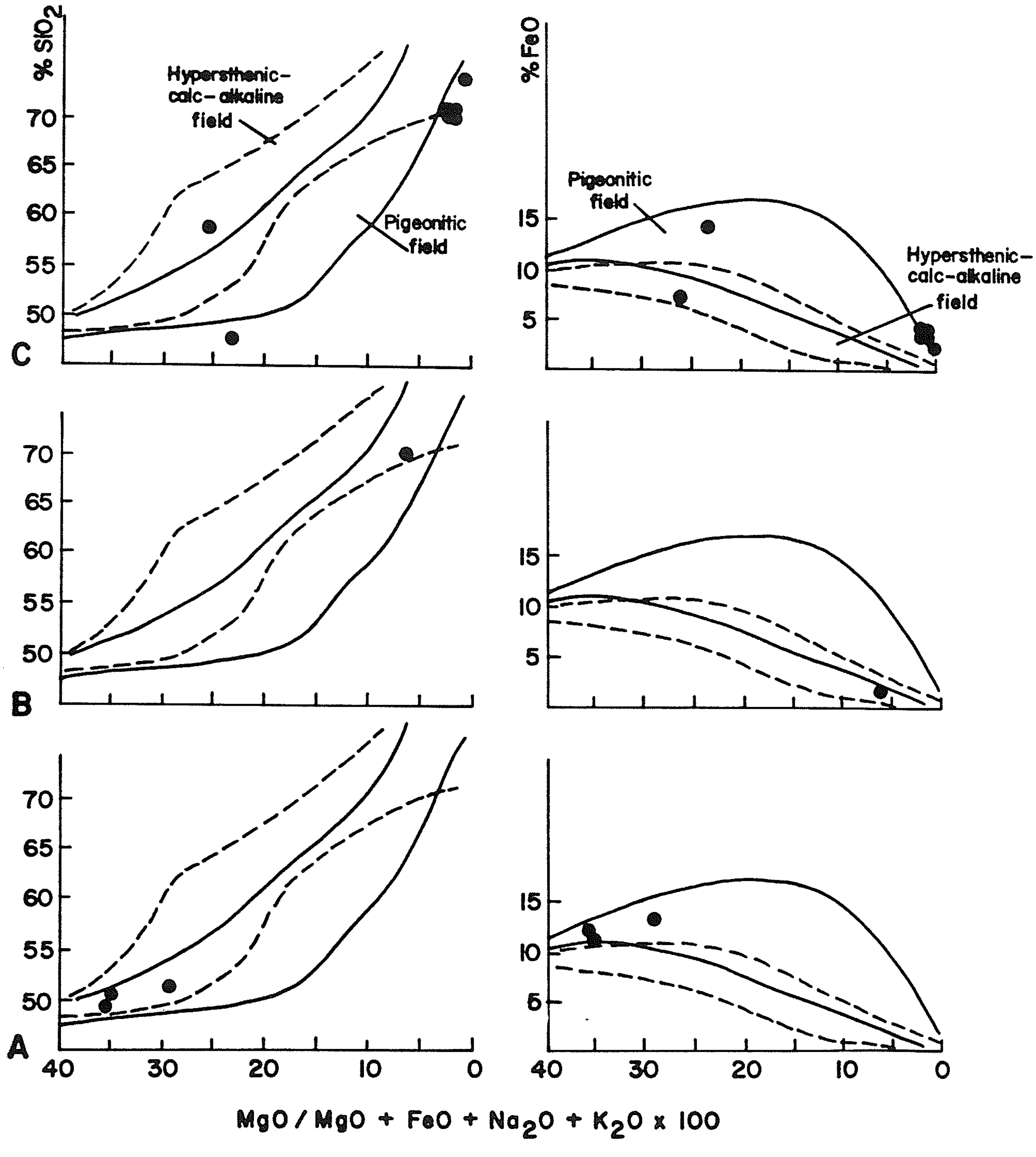

FIGURE 65: MgO/MgO + FeO + Na_2O + K_2O vs. SiO_2 and FeO diagrams for analyzed synvolcanic intrusive rocks in A) the Lamprey Falls Formation, B) the Peterson Creek Formation, and C) the Bernic Lake Formation.

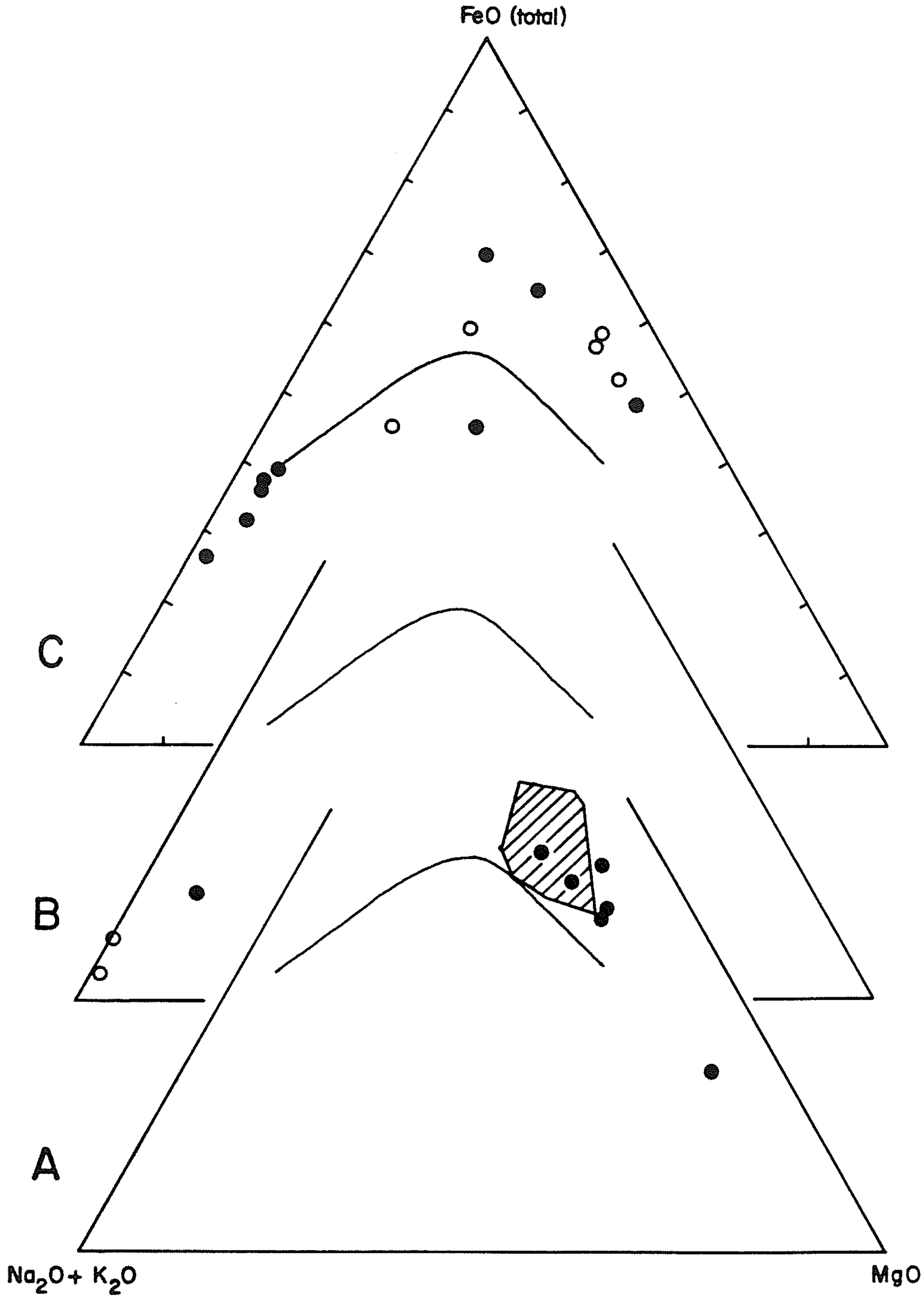

FIGURE 66: Magnesia - total iron - alkalies variation diagrams for analyzed synvolcanic intrusive rocks in A) the Lamprey Falls Formation, B) the Peterson Creek Formation, and C) the Bernic Lake Formation. Closed circles are intrusive rocks, open circles are corresponding lavas of respective formations (hatched field in the Lamprey Falls Formation).

regional metamorphic event (M_2) identified in the host greenstone assemblages. Accordingly, the s_2 schistosity in the greenstones is essentially parallel to the boundaries of these batholiths, and parallel to flow fabrics generated within the batholiths. In addition, mineral lineations in both the intrusive rocks (produced by flow), and in the host rocks (produced tectonically) are colinear and conform to the elongation directions of maximum dimensions of clasts in metasedimentary rocks.

Two essential phases or rocks are evident in the Maskwa Lake batholith. These are a coarse grained, equigranular to porphyritic, massive, locally gneissic, dark grey to buff quartz diorite, and an equigranular, medium to coarse grained, massive pink to buff coloured granite. Of these, the granite is the younger, forming dykes in the quartz diorite, and hosting inclusions of the same.

In the map area, the Marijane Lake batholith is marked by one essential rock type; that of a weakly foliated equigranular medium to coarse grained buff coloured granite. East of the map area however, Carlson (1958) has mapped an extensive area of dioritic rocks within this same body. These were not examined.

There are no dyke rocks associated with these batholiths in the host greenstone, excepting in close proximity to the boundaries of the Marijane Lake batholith at Marijane Lake where thin sills of quartz diorite and granodiorite conform to the foliation in the greenstones. A small irregular body of granite occurs in the core area of the saddle structure formed between the west end of the Marijane batholith and the east end of the Maskwa batholith near Cassiar Lake (Map A, C). This body is essentially identical to the Marijane Lake granite.

LATE-TECTONIC INTRUSIVE ROCKS

Late-tectonic intrusive rocks include the Lac du Bonnet quartz monzonitic batholith (Fig. 6, Map A) and related dykes, and stocks, sills and dykes of pegmatitic granite and pegmatite (Map A). Detailed descriptions of the Lac du Bonnet quartz monzonite have been presented by McRitchie (1971), of the pegmatitic granite by Davies (1957) and Černý et al. (1979) and of the pegmatites by Crouse and Černý (1972), and Černý and Turnock (1971).

The Lac du Bonnet quartz monzonite, of batholithic proportions, is a massive to weakly foliated, coarse grained, biotite-bearing, buff to reddish coloured rock which lies in intrusive contact with rocks of the Bird River greenstone belt. Along its southern boundary the body displays both intrusive and fault contacts with rocks of the Winnipeg River batholithic belt.

The pegmatitic granites consist of heterogeneous mixtures of buff weathering coarse grained (pegmatitic) feldspars, micas, and quartz intimately mixed with banded garnetiferous aplites or "line rock" (Schaller, 1938). These rocks, intrusive into the greenstones, are marked by knife sharp contacts, and few dykes extend into the greenstones, but do carry inclusion material. Locally, as in the case of the body at Greer Lake, faults marking late-tectonic activity transect these bodies.

The pegmatites, typically coarse grained assemblages of quartz feldspars and micas appear to occupy previously formed bedding, D_2 schistosity, and D_3 fault structures, and exhibit spatial preference to areas of pegmatitic granites with which they can be related genetically (Černý et al, 1979).

STRUCTURAL GEOLOGY AND METAMORPHISM OF THE BIRD RIVER GREENSTONE BELT

In the Bird River area, the metavolcanic and metasedimentary rocks display four recognizable metamorphic and deformational events (Table IX). These events include; folding of the layering in the greenstones with an attendant generation of a parallel schistosity, a superimposed folding with generation of a penetrative schistosity which produced interference folds and subsequently, episodic and perianticlinal faulting. Prograde metamorphic assemblages were developed during the folding events but suffered later retrogression during the periods of faulting.

STRUCTURAL GEOLOGY

The six formations and synvolcanic intrusive rocks which form the Bird River greenstone belt are disposed in east trending near vertically dipping attitudes on the flanks and in the core of a synclinorium, the outer limits of which are marked to the north by the Maskwa Lake batholith and to the south by the Lac du Bonnet batholith. All of the rocks within this synclinorium can be grouped into five fault-bound structural subareas. The boundaries and nomenclature of these subareas are shown in Figure 67 from which it is evident that the designated subarea 1 corresponds to the Eaglenest Lake formation, subarea 2 corresponds to the Lamprey Falls Formation, subarea 3 comprises segments of the Peterson Creek, Bernic Lake, and Flanders Lake Formations, subarea 4 contains the major part of the Bernic Lake Formation, and subarea 5 comprises the Booster Lake Formation. These subareas envelope differing structural styles developed during deformation and metamorphism and hence are described separately below. The boundaries of the subareas are faulted, and these faults are described separately below.

Figure 68 displays structural cross-sections of the above structural subareas, and is indexed into Map B which displays the principal structural elements of the area.

TABLE IX: Correlation of metamorphism, deformation, and structure in metavolcanic and metasedimentary rocks of the Bird River area.

METAMORPHIC EVENT	DEFORMATION EVENT	SURFACE DEVELOPED	STRUCTURE DEVELOPED	NOTE
M_4	D_4		F_4	NW and apical perianticinal faulting; retrogression.
M_3	D_3		F_3	E-W episodic faulting; retrogression.
M_2	D_2	s_2	f_2	Emplacement of Maskwa and Marijane to batholiths E-W regional folding of passive mechanism
M_1	D_1	s_1	f_1	E-W regional folding of flexural mechanism
		s_o		s_o = primary bedding

f - folding

F - Faulting

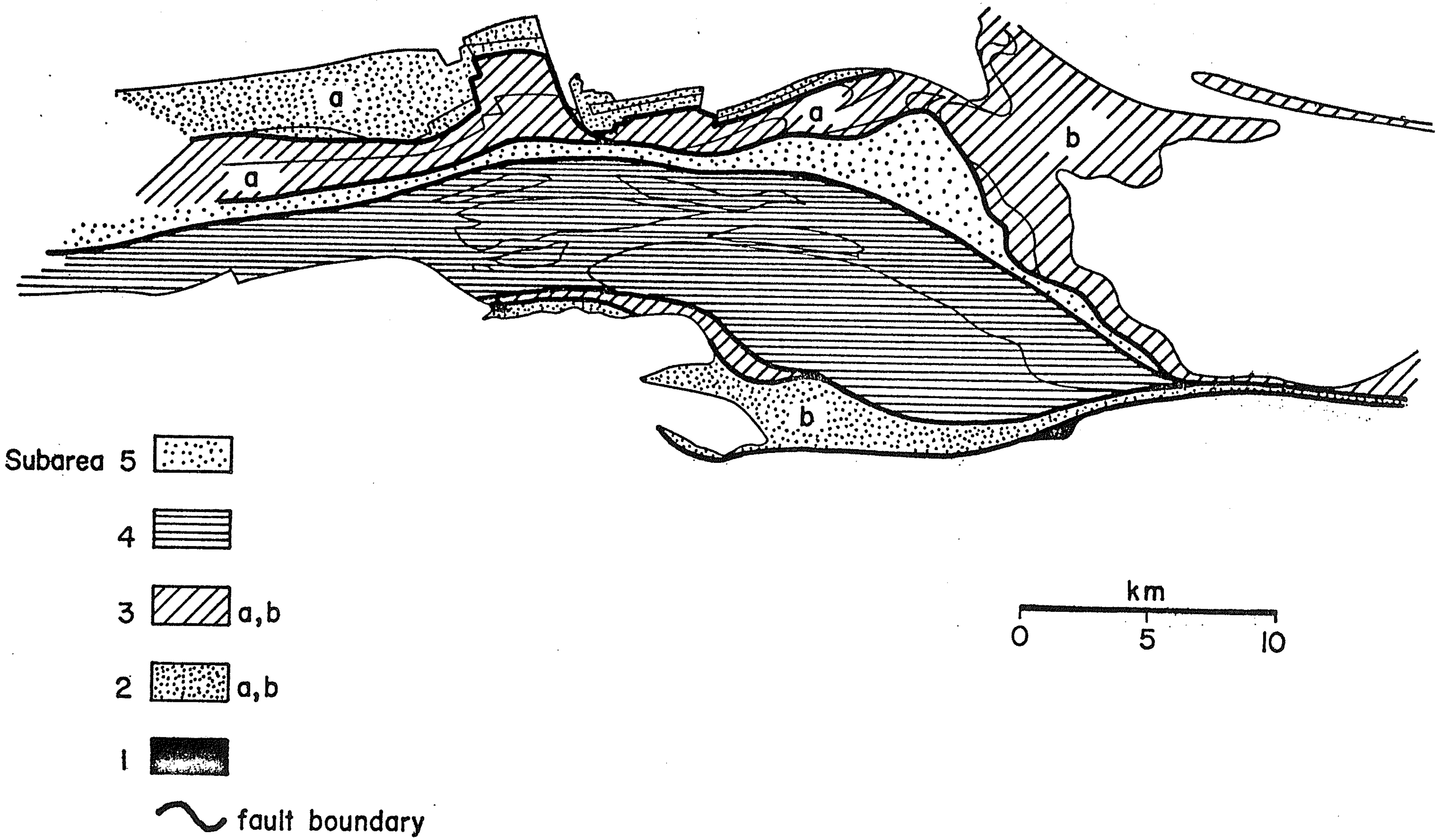

FIGURE 67: Structural subdivision of the Bird River area.

Subarea 1 (D_1, D_2)

Bedding (s_0) is evident in most of the metasedimentary rocks of subarea 1, and include such features as rip-up structures which according to Janes (pers. com.) in one location define north-facing tops.

Two schistosities are present in the rocks of subarea 1. Of these, the first or oldest (s_1) is everywhere parallel to bedding (s_0). Both of these (s_0 and s_1) are plotted as poles, and contoured in Figure 69. The second, or younger schistosity (s_2) is of a discrete, or widely spaced occurrence, and is only recognizable in hinge area of f_2 minor folds where it is parallel to the f_2 axial planes.

Minor folds, examples of which are shown in Figure 70, are present in several outcrops of subarea 1. The folds are of type III (Ramsay, 1962) interference pattern formed through passive (f_2) refolding on s_2 surfaces of earlier f_1 folds. In Figure 69 axes of minor folds are plotted, and compare favourably with the pole to the girdle defined by the contoured s_0 and s_1 data.

S and Z assymetries are evident in the minor folds of subarea 1 (Fig. 70), and serve to locate the axial trace shown on accompanying structural Map C. The orientation of the larger fold so defined, can be approximated from the minor f_2 fold data and from Figure 69, and the fold can be described as a west plunging (75^o) isoclinal synform.

Subarea 2 (D_1, D_2)

Structural subarea 2 corresponds to the Lamprey Falls formation. It is, for purpose of description, subdivided into areas a and b, as shown in Figure 64, area a being the south-facing sequence of rocks north of the Bird River, and area b being the north-facing sequence disposed along the Winnipeg River.

Bedding or layering (s_0) in subarea 2 a and b is manifest by continuity of particular lava flows, tuffaceous intercalations, gravity stratification in the Bird River Sill, and by bedding in iron formation. Facing directions in these are indicated by pillow structures in lavas, and in the sequence of differentiation products in the Bird River Sill.

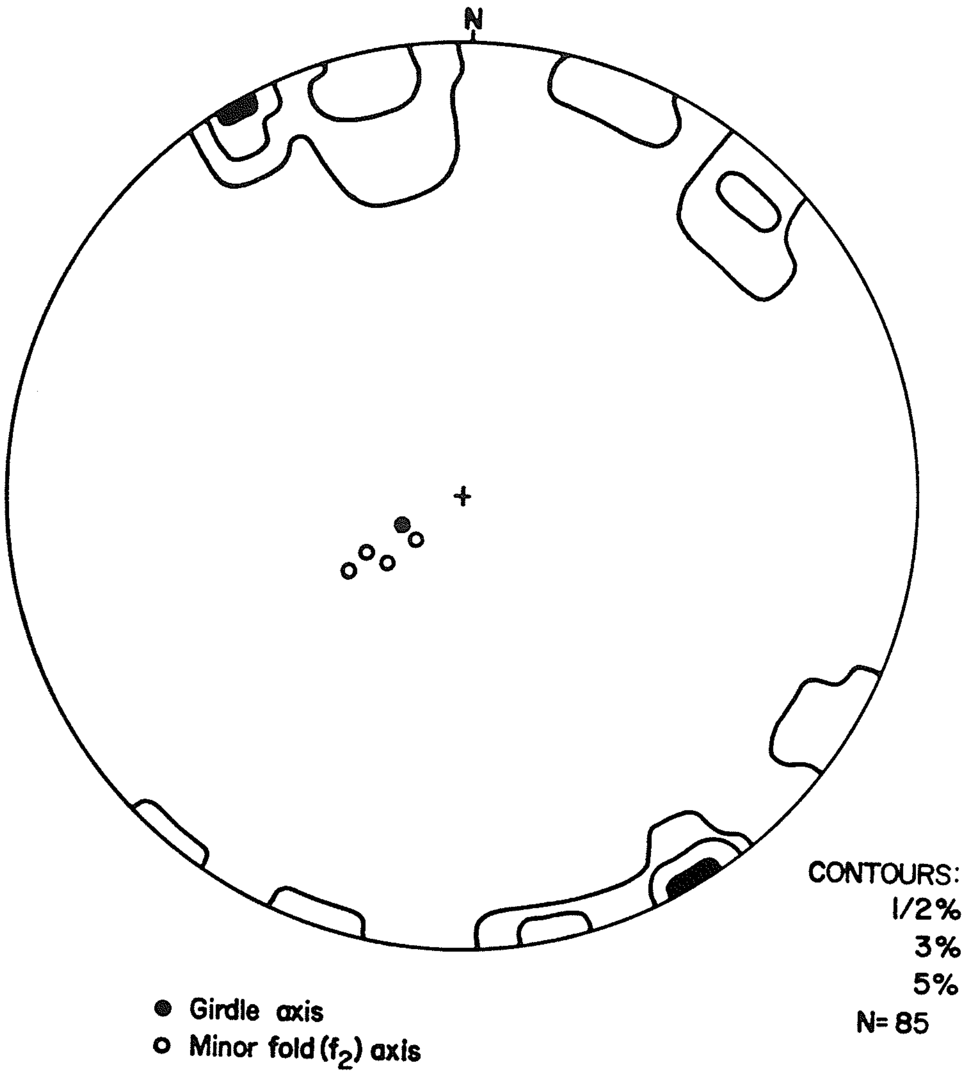

FIGURE 69: Equal area stereonet plot of structural elements in structural subarea 1.

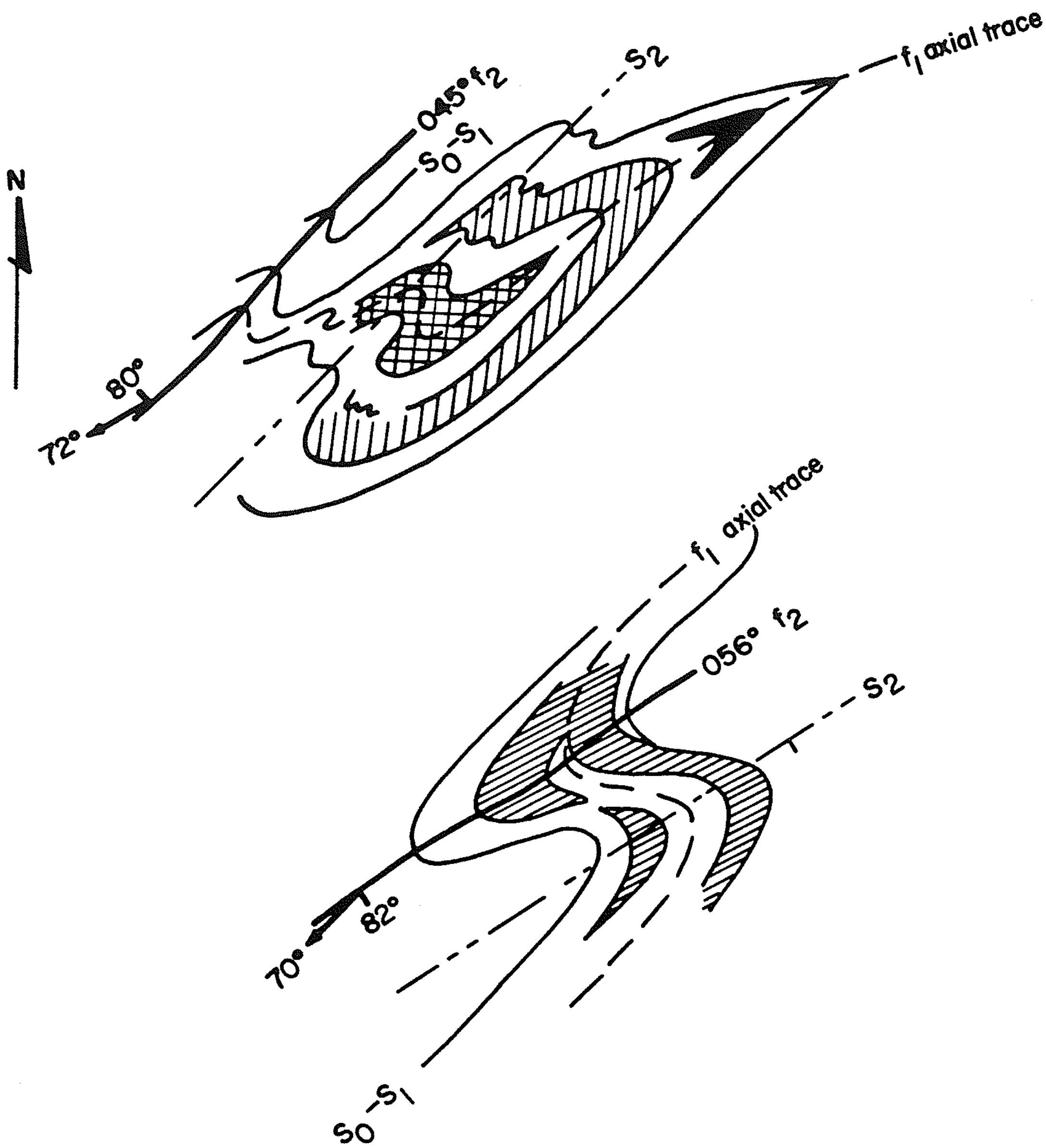

FIGURE 70: Minor fold types in structural subarea 1.

In general, bedding and layering in subarea 2 strike east-west and dip nearly vertically, or slightly to the south of vertical. These attitudes are shown in Figure 71, from which it is evident that a steep south dip is common to both subarea 2a and 2b.

A single penetrative schistosity is evident in most of the rocks of subarea 2 andin general is very weakly developed. No indications of an older foliation were observed. The schistosity in evidence however, corresponds in attitude to that identified as s_2 in adjacent areas and for this reason is interpreted as s_2 in these rocks.

Foliation (s_2) data for subarea 2a and b are presented in Figure 72 from which it is evident that foliations trend east-west in strike. Dips in the two areas are slightly convergent; the foliation in subarea 2a dips slightly south of vertical, and the foliation in subarea 2b dips slightly north of vertical.

Minor fold structures are absent in areas 2a and 2b. The existence of a major synclinal fold structure in the Lamprey Falls formation however, can be interpreted on the basis of opposed facing directions in subarea 2a and 2b (Map B).

Subarea 3 (D_1, D_2)

Structural subarea 3 incorporates the Peterson Creek formation, the Flanders Lake formation, and the northern segment of the Bernic Lake formation. This subarea is further subdivided for descriptive purpose as shown in Figure 67, as the dominant orientations of primary and tectonic fabrics in the rocks differ, and thus preclude meaningful stereonet analysis.

Bedding (s_0) is evident in most of the rocks of subarea 3, and includes primary sedimentary structures from which facing directions can be diagnosed. These are shown on accompanying Map C, and have been described above in the respective formation descriptions.

Two schistosities are evident in subarea 3. The first of these, or oldest (s_1) is moderately well developed and is parallel in attitude to strike and dip of layering (s_0). For subarea 3a, poles to s_0 and s_1 are plotted in stereographic projection in Figure 73. For subarea 3b, poles to

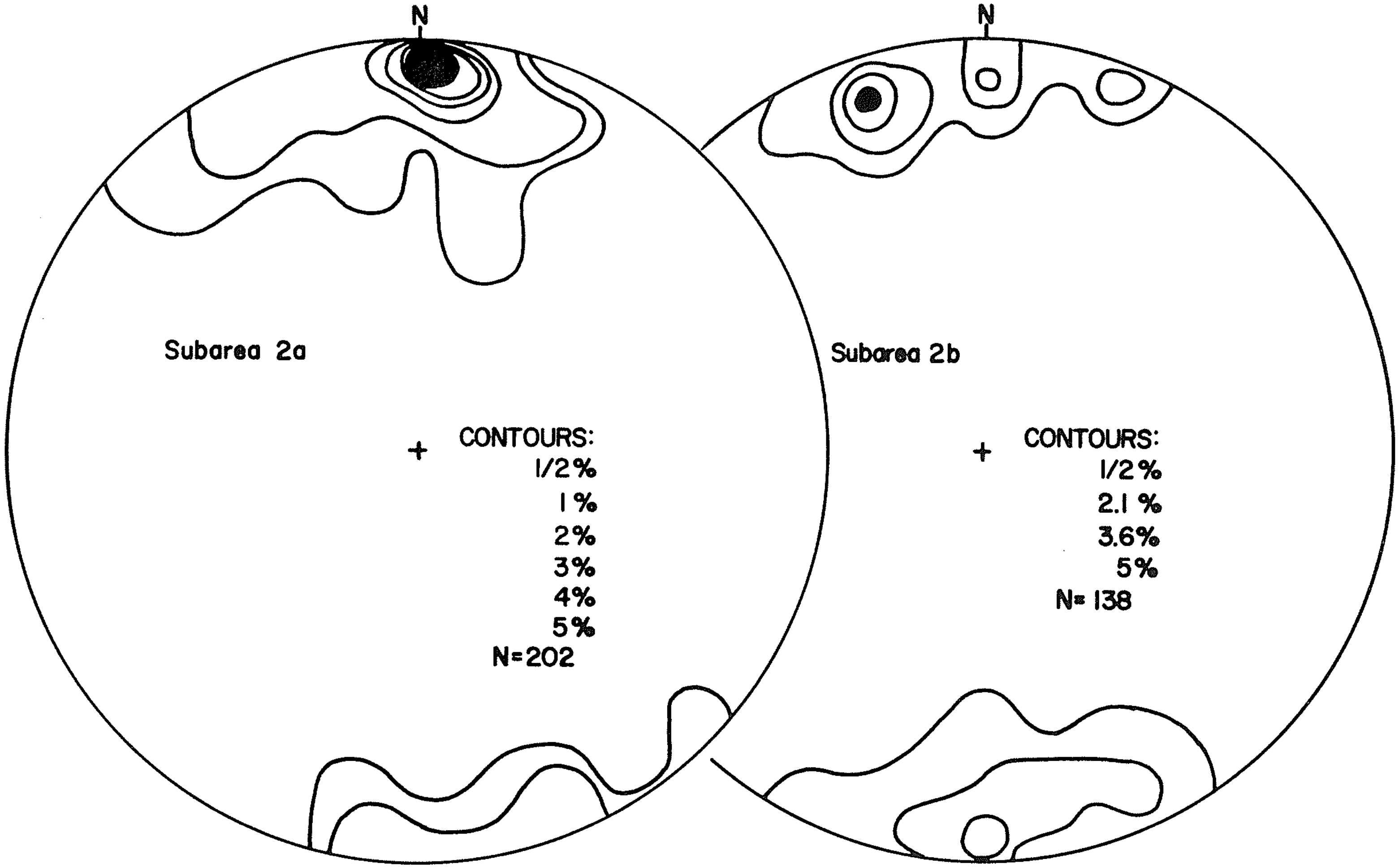

FIGURE 71: Equal area stereonet plot of poles to bedding in structural subareas 2a and 2b.

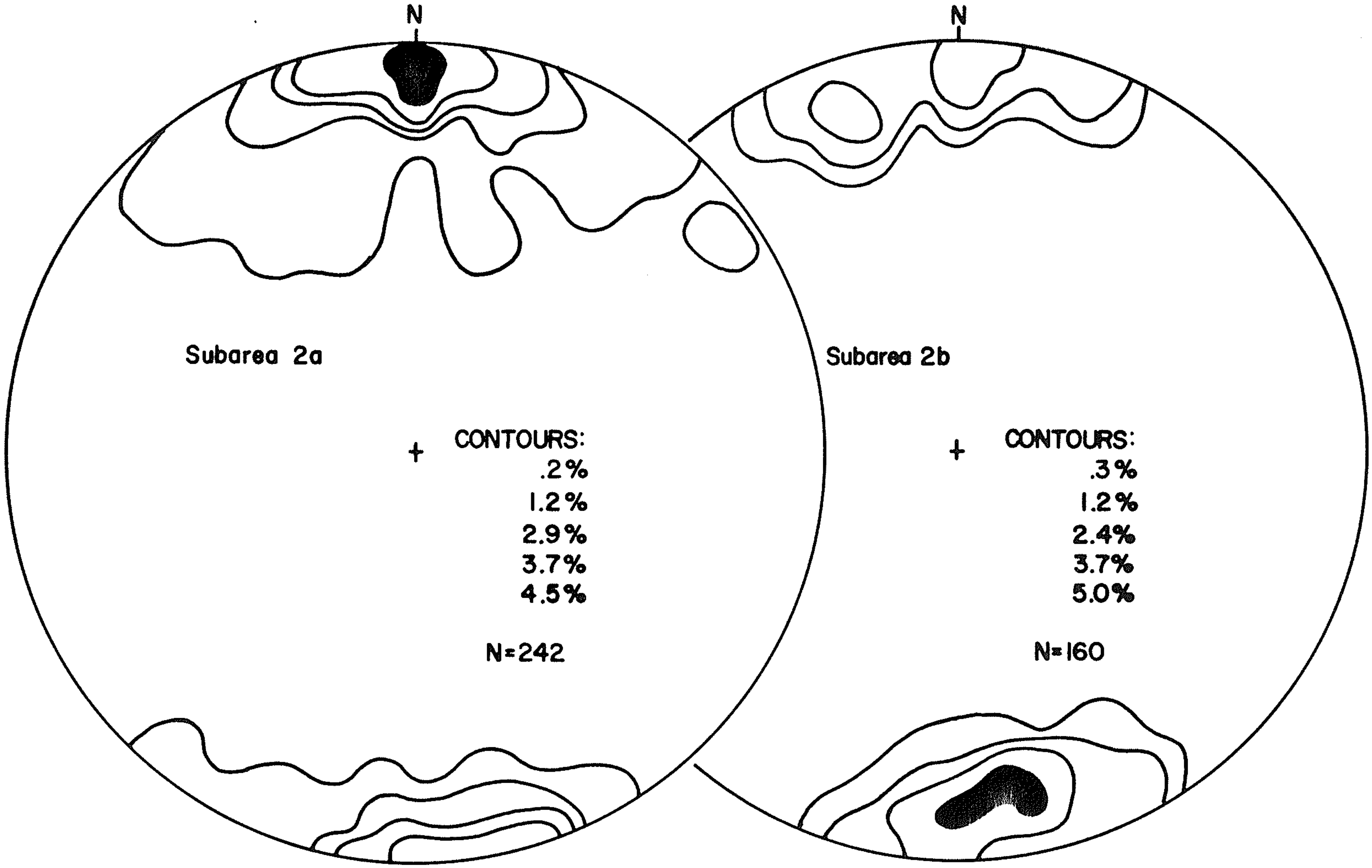

FIGURE 72: Equal area stereonet plot of poles to foliation (s_2) in structural subareas 2a and 2b.

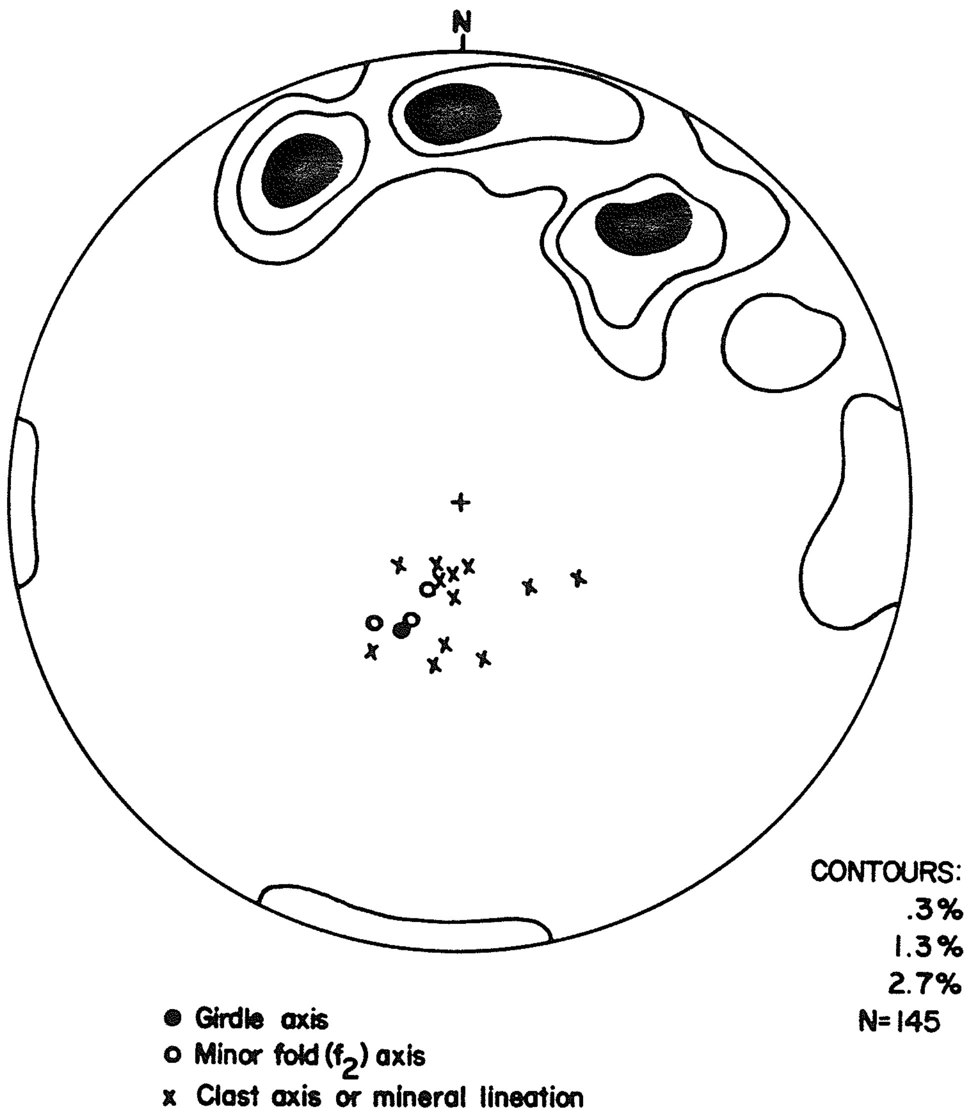

FIGURE 73: Equal area stereonet plot of poles to bedding (s_0) and foliation (s_1) in structural subarea 3a.

s_0 and s_1 are plotted in Figure 74.

The second, or younger schistosity (s_2) has an orientation that is parallel to the axial planes of the fold structures of subarea 3 which deform s_0 and s_1. The deformational event responsible for these fold structures has been designated as D_2.

The major cross-fold structures developed by D_2 in subarea 3a are displayed by the outcrop distribution of rock types in the area south of Bird Lake. Similarly major cross-folds in subarea 3b are shown by the outcrop distribution of metaconglomerate in the Flanders Lake formation. These folds are shown in Figure 75 in comparison with ideal Type III interference patterns, and are seen to display the diagnostic open forms with converging and diverging V - shapes (Ramsay, 1962).

The interference structures of subarea 3a, formed by the superposition of f_2 folds on f_1 folds have also resulted in the superposition of an axial planar s_2 fabric on s_0 and s_1. The f_2 fold axes pitch steeply to the south on east-striking south-dipping axial planes (Fig. 73) and are sub-parallel to mineral elongation, clast elongation, and minor fold axes.

The f_2 fold axes in subarea 3b are continuous with those of subarea 3a, and hence are products of the same D_2 deformational event. The axes of the f_2 folds are southwest plunging; the axial planes of the folds are northwest trending and dip to the southwest (Fig. 74).

Subarea 4 (D_1, D_2)

Structural subarea 4 corresponds to the major faultbound segment of the Bernic Lake formation; the disposition of which is shown in Figure 67.

Layering (s_0) in subarea 4 is generally poorly defined, and most of the rocks are characterized by thick, chaotic, intercalated beds. Bedding is, however, locally well preserved in zones disposed at the ends of the ellipsoidal synvolcanic intrusive stocks (unit 7) which perforate the subarea (Map A). In such areas bedding is paralleled by a schistosity, is oblique to a second younger schistosity, and converges to parallel to the boundaries of the intrusions. Poles to bedding (s_0) are presented in Figure 76, which illustrates the presence of folds involving s_0.

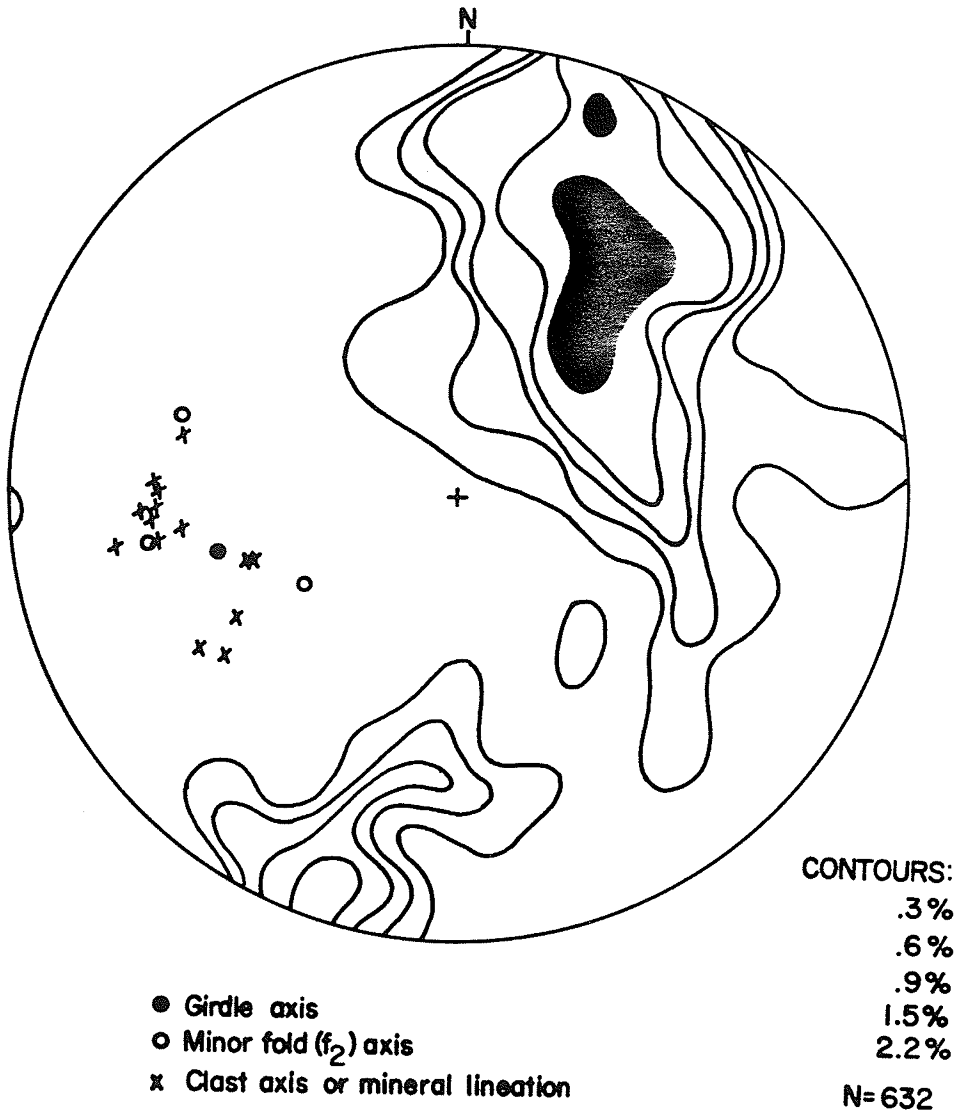

FIGURE 74: Equal area stereonet plot of poles to bedding (s_0) and foliation (s_1) in structural subarea 3b.

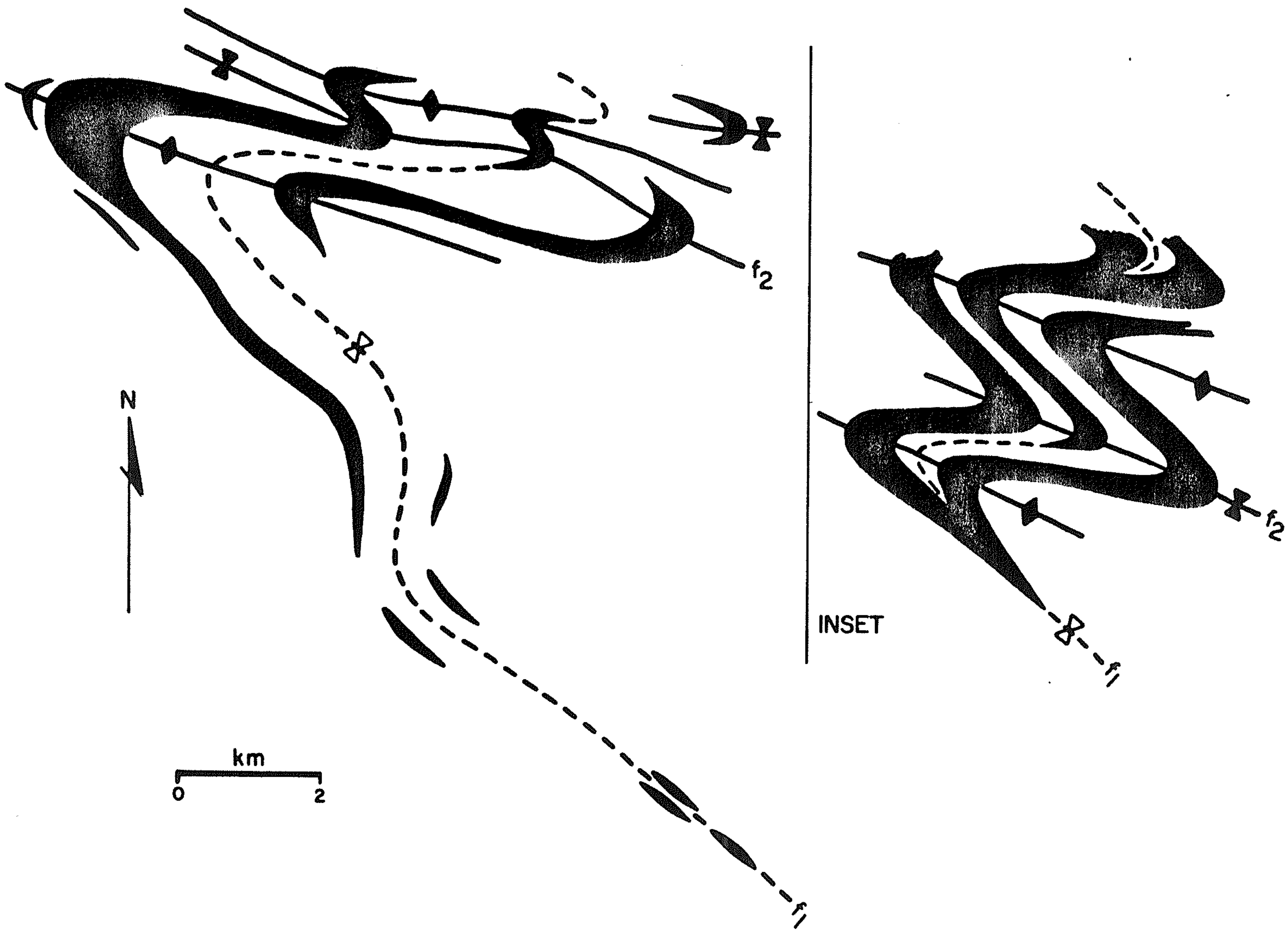

FIGURE 75: Outcrop pattern of metaconglomerate of the Flanders Lake Formation shown with ideal Type III fold pattern (inset).

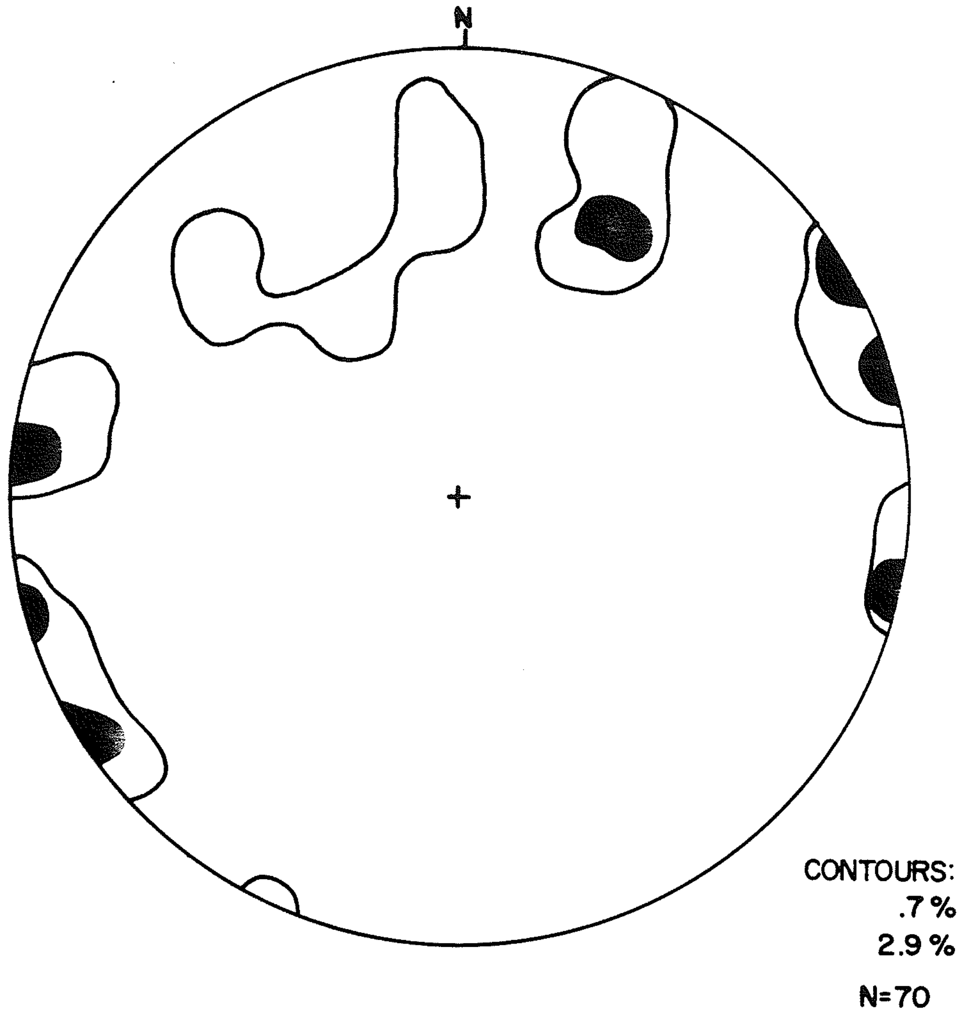

FIGURE 76: Equal area stereonet plot of poles to bedding (s_0) in structural subarea 4.

Two foliations, viz. schistosities, are evident in the rocks of subarea 4. Of these, one was only observed in the metavolcanic and metasedimentary rocks at the terminations of the composite intrusive bodies where alignment of micas parallels bedding, and both are observed folded about the noses of the intrusions. This schistosity is designated s_1.

The second schistosity is pervasive in subarea 4 as as east-west steep dipping alignment of micaceous minerals. This schistosity, poles to which are shown contoured in Figure 77, crosses the bedding and s_1 schistosity preserved at the terminations of the intrusive bodies and is designated s_2.

The folding evident in the pole plot of Figure 76 is also evidenced by minor fold structures, and by the systematic repetition in subarea 4 of the elongate units of metabasalt and the composite intrusive rocks. The axial traces of these folds are shown on accompanying Map B, and in which the s_2 schistosity is observed to be parallel to them. These folds are thus interpreted as being f_2 in age, and as having developed during the D_2 deformation.

An earlier (D_1, f_1) folding event is not in clear evidence in subarea 4, but its existence may be interpreted on the basis of the presence of the s_1 schistosity which lies parallel to bedding (s_0). Such an interpretation is shown in the cross-sections of Figure 64, from which it is apparent that a stratigraphic correlation of metabasalt and the composite intrusive bodies can be achieved by generating graphically a Type III interference pattern. In defence of such an interpretation it is apparent from examination of Type III fold orientations that if f_2 fold axes are of a horizontal plunge, the pattern will appear simply in plan as a series of elongate lithologies.

The interpreted f_1 fold axes of Figure 68 are excluded from Map B. for purposes of clarity of detail in Map B.

Subarea 5 (D_1, D_2)

Structural subarea 5 corresponds to the major fault segment of the Booster Lake formation (Fig. 67).

Bedding (s_0) in subarea 5 has been extensively described in a pre-

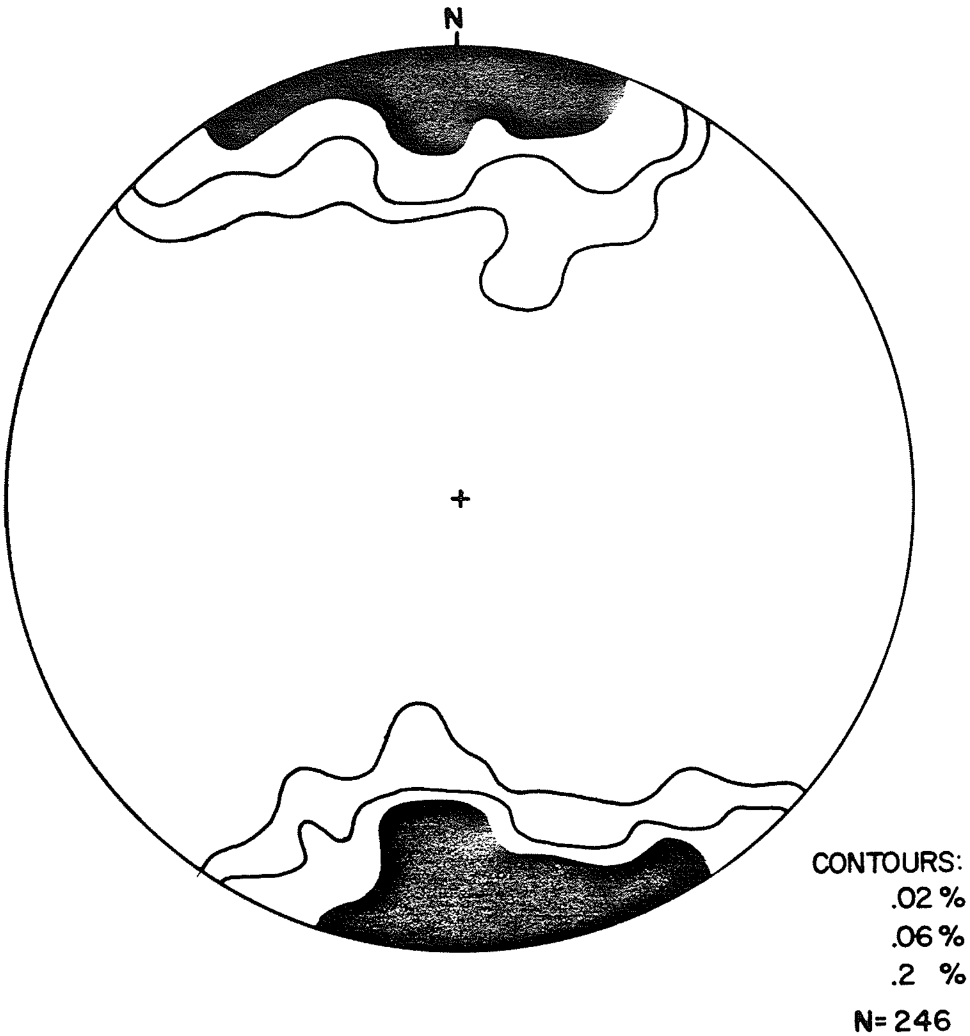

FIGURE 77: Equal area stereonet plot of poles to foliation (s_2) in structural subarea 4.

ceding section. Accordingly it has been noted that features diagnostic of top directions abound, and from inspection of accompanying Maps A and B it is evident that subarea 5 forms an east-west trending, south-facing, steeply dipping monoclinal sequence.

No early schistosity, i.e. one which would correspond to a D_1 event, is evident in subarea 5 and for this reason the Booster Lake formation is interpreted as being younger in age than the M_1 metamorphism and D_1 event.

A strong penetrative tectonic foliation (s_2) of D_2 age is present in all of the rocks of subarea 5. This fabric, for the most part, is parallel to bedding, but on bedding scale refracts between the less ductile greywacke and more ductile mudstone components (Figure 78).

Major and minor folds are evident throughout subarea 5. Minor folds display both S and Z assymetry in the west and east areas respectively (Map B), and display varied degrees of closure; becoming more tightly closed in the axial area of the major fold south of Bird Lake.

Poles to bedding (s_0) and schistosity (s_2) are presented in Figure 79. Analysis of this figure indicates that the folding in the subarea is of a conical style; the cone axis of which plunges moderately steeply in a north-northwest direction.

FAULTING (D_3, D_4)

The previously described structural subareas are fault bound, and in addition, the northern part of subarea 2 (i.e. 2a) is extensively faulted. These features are described below, the former as F_3 and the latter as F_4 events. Their respective ages are assigned on the basis of truncation and offset of the F_3 (boundary faults) by the F_4 faults in the area south of the Chrome and Page properties (see Maps A and C).

Subarea 1 - 2 Boundary Fault (D_3)

The subarea 1 - 2 boundary fault in the Eaglenest Lake area is an extension of the fault which separates subarea 2 from rocks of the Winnipeg River batholithic belt in the Greer Lake area (see accompanying Map B). This fault crops out on a small island in Eaglenest Lake, and in this locale

FIGURE 78: Refraction of foliation (s_2) across contrasting ductilities of beds in greywacke - mudstone turbidites of structural subarea 5, south of the Chrome Property.

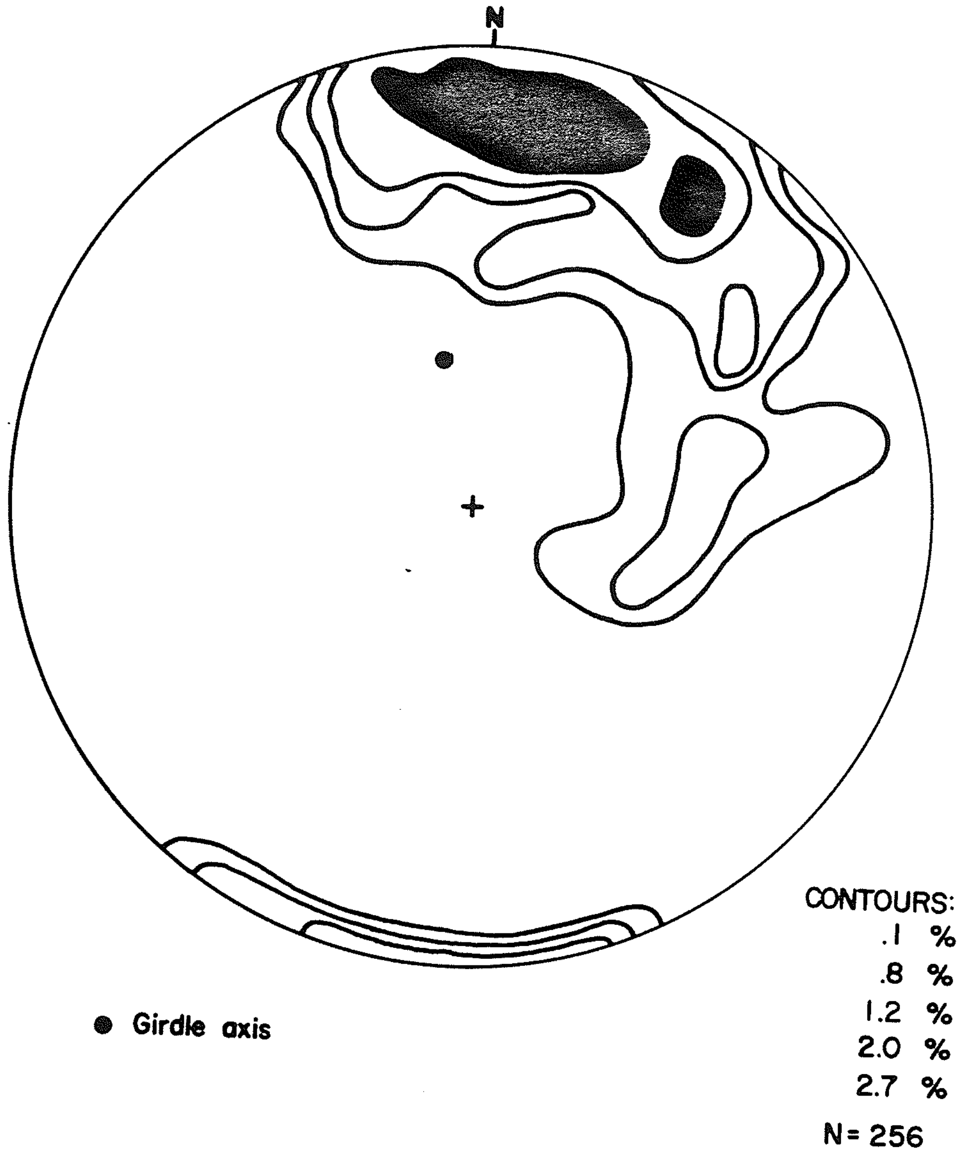

FIGURE 79: Equal area stereonet plot of poles to bedding (s_0) and foliation (s_2) in structural subarea 5.

is marked by a narrow (< 2m) zone of mylonite which strikes 085 az. and dips south at approximately 80 degrees. The mylonite appears to be developed at the expense of the polydeformed Eaglenest formation rocks. Deformation in Lamprey Falls formation rocks is negligible.

At Greer Lake this fault is marked by intense deformation, and the affected gneisses south of the fault vary between cataclasite and proto-mylonite. Attitudes in the zone of shearing strike 075 az. and dip vertically. Slickensides plunge approximately 90 degrees in the direction 225 az. These data, in conjunction with cusps perpendicular to slickensides indicate a movement of the south side (Winnipeg River batholithic belt) upwards and to the east.

Subarea 2 - 3 Boundary Fault (D_3)

The subarea 2 - 3 boundary fault separates rocks of the Lamprey Falls, Peterson Creek - Bernic Lake formations in the northern map area (Map A). In the southern map area this boundary transgresses the Lamprey Falls - Peterson Creek formations at Shatford Lake, and becomes the boundary between the intrusive stock centered at Birse Lake and the Lamprey Falls formation along the Winnipeg River. In the northrn map area the subarea 2 - 3 boundary is marked by mylonite (Fig. 80) in part, and elsewhere a gouge of chlorite schist. In the southern map area (viz., Winnipeg R.) deformation is less extreme and the affected rocks exhibit protoclastic to good cataclastic textures. In both cases the deformed rocks are largely confined to relatively narrow (< 10 m) zones.

Subarea 3 - 4 Boundary Fault (D_3)

The subarea 3 - 4 boundary fault separates the greywacke - mudstone turbidites (Booster Lake fm.) and the older metavolcanic and related rocks (Map A) and where exposed shows only minor cataclasis. Adjacent prograde regional metamorphic assemblages (eg. cordierite schists) are seen to be retrogressed with growth of idioblastic chlorite across foliation surfaces.

Drag folds, close to the north boundary at Louie Lakes (Map A), indicate a horizontal component of left lateral movement along the boundary.

FIGURE 80: Mylonite developed in the subarea 2 - 3 boundary fault south of the Chrome Property.

Plunges are unknown.

Subarea 3 - 5 Boundary Fault (D_3)

Much of the subarea 3 - 5 boundary which occurs at Shatford Lake is covered by the lake, and elsewhere along the north shore of Shatford Lake is covered by swamp and drift-filled lineaments. One outcrop, close to the powerline east of Shatford Lake (Map A), is intensely sheared, and occupied by a mix of sericite schist (metarhyolite) of the Peterson Creek fm., tectonic intercalations of polymict metaconglomerate of the Bernic Lake fm. and a cataclasite formed of the composite stock centered on Birse Lake. Strike and dip orientations measured in this area vary from 84 - 106 az. and 70 - 81 degrees north respectively.

Subarea 4 - 5 Boundary Fault (D_3)

The subarea 4 - 5 boundary is a zone occupied by two faults which anastomose about tectonic intercalations of both Booster Lake and Bernic Lake formation rocks (Maps A and B).

The major parts of these faults in the 4 - 5 boundary zone are shown in Map B with data bearing on orientations and sense of movement. Accordingly it is evident that two major faults are convergent upwards at angles of 5 to 15 degrees. Dips of these faults are varied, from essentially vertical to 56 degrees south. The smaller faults which mantle the greywacke - mudstone turbidite intercalations converge both up and down dip, as well as along strike. These data form the basis for these faults as shown in Figure 68.

The sense of movement along the above faults is not clear. Lineations, viz. slickensides, in general pitch steeply in the shear planes. Observed fault drag folds are of 'S' addition as the Older Bernic Lake fm. rocks are juxtaposed above the younger Booster Lake rocks, it is suggested that the fault movement was of reverse nature with the hanging wall (south side) moving upward and easterly.

Faulting (D_4)

In the Lamprey Falls formation, north of the Bird River, are faults which trend north-westerly into the Maskwa Lake batholith. These faults (Fig. 81) and corresponding air-photo lineaments, are shown on accompanying Map A. The pattern of distribution (apical-perianticlinal) of these faults and their sense of movement have previously been described (Trueman 1970).

In addition to the above faults a northwesterly trending fault is apparent.8 km east of Poplar Bay, Lac du Bonnet. There exists no outcrop evidence of this fault, rather it is manifest by an air-photo lineament and by fold and contact truncation. To the east and to the west of this lineament lithologic units of the Bernic Lake formation are truncated, and a corresponding change in facing directions of rocks is also noted. There is no evidence that this fault transects the Booster Lake formation.

METAMORPHISM

The metamorphic history of the Bird River area is complex, and the textures of metamorphic minerals in the schists in all areas of the belt are found aligned in relation to the structures of the two major deformational events, D_1 and D_2. These minerals, and assemblages, are termed M_1 and M_2 (Table IX). In addition, there exist minerals of hydrothermal replacement origin, concentrated near F_3 and F_4 faults. Texturally, these are post-tectonic, replace M_2 minerals, and are interpreted as having formed during the F_3 and F_4 faulting and are called M_3 and M_4 assemblages (Table IX).

M_1, M_2 assemblages

Little remains of the M_1 metamorphic assemblages in the area; those that are recognized consisting of deformed garnet and biotite which are preserved in, and form the relict s_1 schistosity in crests of f_2 folds.

The assemblages which formed in the pelitic rocks of the Bird River area during the M_2 metamorphic event contain cordierite and/or andalusite which are indicative of a low pressure - high temperature style of metamorphism such as that of the Abukuma Plateau in Japan (Winkler, 1967). The M_2 assemblages are therefore examined using the facies concepts, and designations (A1.1, A1.2, A2.1...) of Winkler (1967), and their dispositions are

FIGURE 81: D_4 fault surface on the north shore of Bird Lake.

shown in Figure 82.

Al.1 quartz-albite-muscovite-biotite-chlorite subfacies

The Al.1 subfacies of rocks includes parts of the Lamprey Falls, the Bird River Sill, Peterson Creek, and Bernic Lake formations (Fig. 78). For those rocks lying north of the Bird River, the Al.1 subfacies is bound on the east side by the fault designated "NW" in Figure 82.

Assemblages of the Al.1 subfacies are as follows.

Lamprey Falls formation metabasalt:

actinolite + epidote + albite ± chlorite ± quartz ± biotite

Bird River Sill ultramafic rocks:

tremolite ± serpentine ± chlorite ± talc ± magnetite ± chlorite

gabbroic rocks:

tremolite + epidote + albite ± chlorite ± biotite

Peterson Creek formation felsic rocks:

quartz + albite + epidote + sericite ± chlorite + biotite

Bernic Lake formation metaconglomerate:

actinolite + epidote + albite ± cholrite ± biotite ± quartz

Al.2 quartz-andalusite-plagioclase-chlorite subfacies

The Al.2 subfacies of rocks is confined to the fault-bound segment of the Bernic Lake formation which forms structural subarea 4 (Fig. 63), and the Eaglenest Lake formation (Fig. 78). Rocks of the Al.2 subfacies carry both actinolite-tremolite, and hornblende, the coexistence of which is indicative of the particular subfacies (Winkler, 1967).

Assemblages of the Al.2 subfacies are as follows.

Bernic Lake formation mafic to intermediate metavolcanic rocks:

actinolite + hornblende + epidote + plagioclase ± chlorite ± quartz ± biotite

Bernic Lake formation felsic rocks:

quartz + chlortie ± biotite ± plagioclase ± sericite ± actinolite

Bernic Lake and Eaglenest Lake formation metasedimentary rocks:

quartz + chlorite + biotite ± actinolite ± hornblende ± plagioclase ± epidote

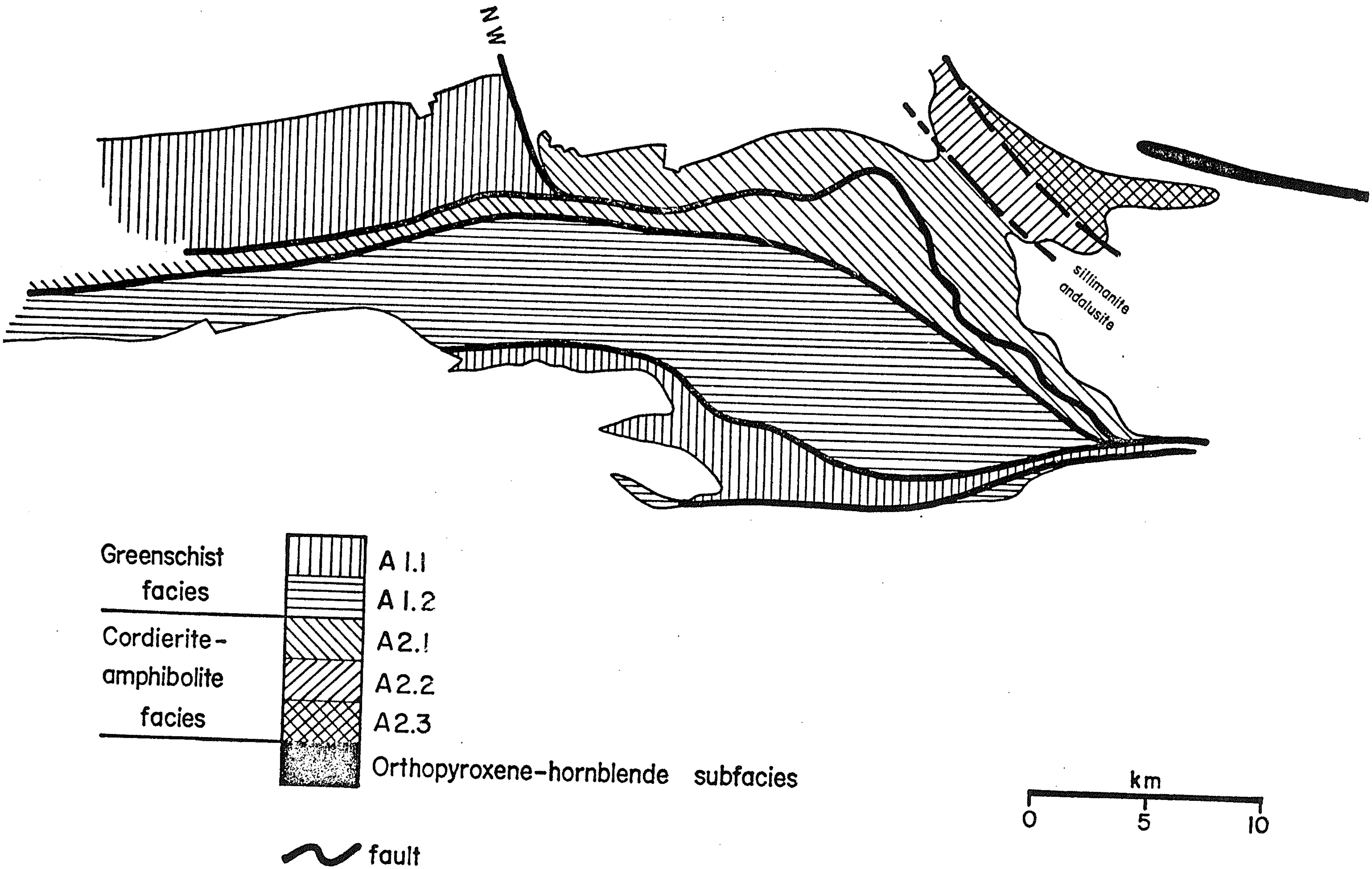

FIGURE 82: Disposition of M_2 metamorphic zones in the metavolcanic and metasedimentary assemblages.

From the Bernic Lake area eastward, most of the clastic rocks are characterized by the occurence of nodular and vermiform calc-silicate concretions of hornblende, plagioclase, and epidote.

A2.1 andalusite-cordierite-muscovite subfacies

The A2.1 subfacies is found in the Booster Lake, Flanders Lake, Bernic Lake, Peterson Creek, and Lamprey Falls formations, and the Bird River Sill, as far to the northeast as the andalusite-sillimanite isograd (Fig. 78). The andalusite-sillimanite isograd is located in Figure 78 on only one occurence of andalusite, and one of sillimanite. The extension (dashed projections) is speculative, except for the observation that metamorphic recrystallization and grain size is increased concommitant with obliteration of primary textures on the sillimanite side.

Assemblages of the A2.1 subfacies are as follows.

Lamprey Falls formation:

hornblende + plagioclase ± garnet

Bird River Sill ultramafic rocks:

olivine ± diopside ± cummingtonite ± plagioclase

(Rocks of the Bird River Sill containing the above assemblages are severely retrogressed, and the M_2 age assigned to these is uncertain. These assemblages have been interpreted by Juhas (1973) and Coates et al. (1979) as prograde metamorphic products, and they are herein assigned to the M_2 event on the basis of their equivalence to M_2, A2.1 assemblages in rocks of the surrounding formations).

Peterson Creek formation felsic rocks:

quartz + plagioclase + muscovite ± biotite

Bernic Lake formation pelitic metasediments:

cordierite + garnet + biotite ± hornblende ± plagioclase ± quartz ± anthophyllite ± diopside ± andalusite

In addition, rocks of the Bernic Lake formation in the A2.1 subfacies are marked by the occurence of nodular or ellipsoidal, calc-silicate concretions of hornblende and plagioclase.

Flanders Lake formation pelitic metasediments:

quartz + plagioclase + biotite ± hornblende ± andalusite

Booster Lake formation pelitic metasediments:

quartz + biotite + cordierite ± plagioclase ± garnet

In addition, in the eastern half of this formation nodular calc-silicate concretions of hornblende and plagioclase become abundant.

A2.2 sillimanite-cordierite-muscovite-almandine subfacies

The A2.2 subfacies is shown in Figure 78, bound to the southwest by the sillimanite-andalusite isogrand and to the northeast by the A2.3 boundary. Rocks of the A2.2 subfacies include Flanders Lake formation, Peterson Creek formation, and mafic to intermediate rocks of the Bernic Lake formation.

Assemblages of the A2.2 subfacies are as follows.

Peterson Creek formation felsic rocks:

quartz + plagioclase + muscovite + biotite

Bernic Lake formation:

hornblende + plagioclase + garnet ± biotite

Flanders Lake formation meta-arenites:

quartz + plagioclase + hornblende ± sillimanite ± muscovite ± biotite ± garnet

A2.3 sillimanite-cordierite-orthoclase-almandine subfacies

The A2.3 subfacies boundary is located in Figure 78 on the basis of the appearance of *lits* of granitic composition intercalated in the meta-arenites of the Flanders Lake formation, the disappearance of muscovite, and the appearance of orthoclase.

Assemblages of the A2.3 subfacies are as follows:

Flanders Lake formation meta-arenites:

quartz + plagioclase ± hornblende ± biotite ± orthoclase

Orthopyroxene-hornblende subfacies

Orthopyroxene bearing rocks are found in the northeast portion of the study area in an elongate synform of metasedimentary rocks correlative with the Flanders Lake formation (Trueman et al. 1975); these rocks are considered a part of the Manigotogan gneiss belt of McRitchie (1971).

Examination of samples from this particular area revealed the existence of relict orthopyroxene. The noted assemblages include:

quartz + plagioclase + orthoclase ± orthopyroxene ± diopside ± hornblende ± biotite.

M_3, M_4 assemblages

M_3 and M_4 metamorphic assemblages are retrograde, and consist of chlorite, albite, epidote, and actinolite bearing rocks in proximity to the east - west boundary faults, and the northwesterly striking F_4 faults. In addition, serpentine - talc - carbonate alteration is present in the F_4 faults where these faults transect ultramafic rocks of the Bird River Sill, and these may be in part responsible for wholesale retrogression in the part of the Bird River Sill located in the A2.1 subfacies (Juhas, 1973; Coates et al., 1979).

DISCUSSION

REGIONAL SETTING

The Bird River area is underlain by a thin lower crust, the base of which is marked by an upwarping of the Mohorovicic discontinuity, and a downwarping of the Conrad, or intermediate, discontinuity. The configuration of the lower crust is markedly similar to that of the Dneiper graben (Chekunov, 1967; Subbotin, 1968) and this apparent similarity has led to the previous suggestion (D.H. Hall, pers. comm.) that the area formed a graben or aulacogen type of structure.

Concomitant with the thinned basaltic crust of the area, is an increased thickness of granitic crust, the base of which is represented by the downwarped Conrad discontinuity. This structure, when projected upwards, is coincident with the metasedimentary gneiss of the Manigotogan gneiss belt and lends credence to the concept of a linear, or graben-like, trough having existed in the area during the Archean.

That the Bird River greenstone belt forms an intergral part of the history of the Manigotogan gneiss belt, was shown by Trueman et al. (1975) who correlated lithologic, metamorphic, and structural attributes of the Flanders Lake Formation with the unnamed metasedimentary gneiss in the Manigotogan gneiss belt. In the Bird River area, the Flanders Lake Formation lies unconformably on the older metavolcanic rocks, and appears to represent an erosional stage of the volcanic edifice, the detritus from which was sedimented into the Manigotogan belt.

MAGMATISM

Magmatic activity can be related to three stages of development of the Bird River greenstone belt, viz: (a) volcanism in the supracrustal rocks; (b) plutonic batholiths of the deformational stage; and (c) plutonic batholiths of the late-tectonic stage.

Volcanism, as completely as can be reconstructed for this area, initiated with outpouring of basaltic lavas which attained a 3 km thickness and was largely of subaqueous deposition. Examination of the chemistry of these rocks (Table II) shows a tholeiitic kindred, but of a two-fold nature.

The lavas of the north limb of the Lamprey Falls Formation are marked by higher magnesium and total iron contents, and lower calcium and alumina contents, than those of the south limb. Both types are comparable with high and low alumina tholeiites which have been documented in other Archean greenstone belts (Goodwin, 1977) and with primitive tholeiitic volcanic rocks of Phanerozoic island arc regimes (Jakes and White, 1971).

Felsic volcanic activity of the Peterson Creek Formation superseded the mafic Lamprey Falls Formation. It is of both subaqueous and subaerial nature, and appears to typify "upper diverse" volcanism of Wilson (1975) or the younger or "secondary" type of Archean volcanism noted by Glikson (1976). The chemistry of the rocks of the Peterson Creek Formation is unusual, however, in that these rocks are strongly enriched in total alkalies, alumina, and silica, and depleted in iron and magnesia, when contrasted to other Archean rhyolites (Goodwin, 1977). In addition, it is noted that the rhyolites display a profound Eu anomaly, and other characteristics which are more typical of felsic products in the Archean Yellowknife area (Condie and Baragar, 1974), itself interpreted as having undergone intracratonic rifting, (Lambert, 1977) or of rift, and back-arc environments of the sourthernmost Andes (Bruhn et al. 1978).

Volcanism of the Bernic Lake Formation forms the youngest effusive activity in the area, and was largely marked by varied thin subaqueous flows of mafic to felsic composition. Represented in this Formation, inclusive of intrusive counterparts is the complete basalt-andesite-dacite-rhyolite orogenic suite, the chemistry of which approximates that described for other Archean regimes (Goodwin, 1977), and typifies both the upper diverse sequence of Wilson(1975) and the secondary type of Glikson (1976).

One part of the volcanic suite at Bird River remains enigmatic, and that is the synvolcanic Bird River Sill. Layered ultramafic-gabbroic complexes documented on a global scale (Moore, 1971) are found in either: a) anorogenic or rift zones such as that of the Skaergard, or b) overlying subduction zones such as those of the"Alaskan type". Although there exists evidence at Bird River for a rifting environment (viz. the attenuated basaltic crustal structure) it is noted that the bulk composition of the Bird River Sill more closely approaches that of a picrite, but of a high-alumina composition which is more typical of the orogenic basalt of Kuno (1968).

The Maskwa and Marijane batholiths were emplaced during the major (M_2) deformation and metamorphism of the greenstone belt. They are similar in their diapiric style of intrusion, and in chemistry, to other diapiric intrusives of Archean areas (Anhaeusser, 1971; Wilson, 1971) for which mantle-derived origins through partial melting (Arth and Hanson, 1975) are postulated.

The youngest magmatic event at Bird River was the emplacement of the Lac du Bonnet batholith and pegmatitic rocks into the previously formed metamorphites. At this time tectonism was marked solely by faulting, and the final disposition of rocks in the greenstone belt was acheived.

Two periods of intrusion are evident in this event. The first involved intrusion of biotite granite forming the dominant part of the Lac du Bonnet batholith, and the second involved emplacement of the stocks of pegmatitic granite and their surrounding aureoles of pegmatite (Černý et al., 1979).

SEDIMENTATION

Sedimentation appears to have initiated at Bird River with deposition of the Eaglenest Lake Formation, but the reader is cautioned that these rocks may be a part of the Bernic Lake Formation.

Clastic rocks of the Peterson Creek Formation are, in part, erosional products generated from the subaerial buildup of the volcanic edifice during the felsic volcanism. The rocks so formed in the Peterson Creek Formation now appear to form a proximal, transitional, and distal scheme of facies disposed eastward from rocks of a vent facies environment in the western map area.

The cessation of volcanism of the Peterson Creek Formation was accompanied abruptly by profound erosion of both the Lamprey Falls, and the Peterson Creek Formations. A deep incision of erosional processes into these rocks is witnessed by the appearance of detritus from the Bird River

Sill (hosted by the Lamprey Falls Formation) in the Bernic Lake Formation, and this is a process which would be greatly facilitated through uplift, possibly by faulting.

The Flanders Lake Formation, devoid of synvolcanic sedimentation, appears to have stemmed largely from a source area in the Bernic Lake Formation which is an evident source for the cobbles of intrusive origin in the conglomeratic phases of the Formation (Posehn, 1975), and the sedimentary processes involved carried this detritus into the (now linear) trough represented by the Manigotogan gneiss belt. It is noted that other sources of sedimentation for the Manigotogan gneiss belt have been put forward by Weber (1971) and other workers (Beakhouse, 1977) who indicate a significant portion of the "fill" of the Manigotogan gneiss belt may have found origin in the Rice Lake and Red Lake areas respectively. Beakhouse (1977) further notes that some portion of this detritus may well have entered the gneiss belt from an unknown sialic hinterland.

The sedimentation of the Booster Lake Formation at Bird River appears to be the youngest such event recognized in the area. This greywacke-mudstone sequence lacks any indication of the M_1 metamorphism in the area, yet underwent folding synchronous with the M_2 diapiric intrusion of the Maskwa and Marijane Lake batholiths.

The source area of the Booster Lake Formation is uncertain. These rocks are dominated by felsic detritus which may have stemmed from a sialic foreland or basement, and possibly from one of the areas of basement interpreted to the south (Winnipeg River batholithic belt) or west (Pine Falls complex) by Ermanovics et al (1979).

DEFORMATION

Two major folding events are recognized in most of the rocks of the Bird River area. The first such event is recognized clearly in the rocks of the Peterson Creek, Bernic Lake, and Flanders Lake Formations, but is less evident in the Lamprey Falls Formation, and is apparently absent in the Booster Lake Formation.

That the Lamprey Falls Formation was extant before the earliest deformation of the greenstone terrain, is evidenced by detritus from these rocks which is present in the younger polydeformed Bernic Lake Formation. The apparent absence of D_1 tectonic fabrics in the Lamprey Falls Formation therefore has two possible interpretations. These are: that the Lamprey Falls Formation lay outside the D_1 deformational regime, but this requires a subsequent structural transport, possibly as Klippe to interpose the Lamprey Falls and the Peterson Creek, Bernic Lake, and Flanders Lake Formation for the later D_2 event, or alternatively, that the mineral composition of these lavas presented a high ductility contrast with adjacent clastic rocks; the compositions of which lent readily to lepidoblastic recrystallization. The Lamprey Falls Formation could thus have behaved as a competent block with tectonism being accomplished by shear along its peripheries.

The absence of an M_1 fabric in the Booster Lake Formation can be explained in a manner similar to that of the Lamprey Falls Formation. For reasons presented above (see Booster Lake Formation) the writer prefers to interpret the Booster Lake Formation as being unconformably deposited above the previously deformed (D_1) rocks, and as having suffered D_2 deformation with the older rocks in the subsequent event. This is interpreted as a "basement-cover" relationship.

The second (D_2) deformational event in the Bird River area affected all of the layered and synvolcanic intrusive rocks, and was accompanied by the development of a schistosity (s_2) in all of the rocks.

The D_2 event resulted in f_2 superposed folds which are most clearly evident in the Type III fold outcrop pattern in the Flanders Lake Formation. This style of folding has been interpreted as well in structural subarea 4 (Fig. 68) in which it is not readily evident. This is explained by the orientation of the respective f_2 axes, those of the Flanders Lake Formation plunging steeply enough to approach a right-section view, and those of structural subarea 4 being shallow, or horizontal and doubly plunging.

In the Lamprey Falls Formation the D_2 event failed to generate parasitic folds, and the writer prefers to interpret the absence of such folds to its behaviour as a competent block. The s_2 schistosity imposed on these rocks is of a nematoblastic type.

In the Booster Lake Formation (structural subarea 5), the greywacke-mudstone sequence suffered conic folding with the development of an s_2 schistosity which is subparallel to its bedding surfaces. In plan (see Map A) the subarea resembles a saddle-shaped structure draped over the Maskwa and Marijane Lake batholiths.

The observation by Ramsay (1964) that Type III folds are common in alpine style of deformation involving refolding of fold-nappe structures, suggests that they layered sequence at Bird River may have undergone similar processes. Accordingly, it could be suggested that the D_1 event at Bird River may have involved formation of nappes. Such a concept, i.e. nappe folding in the Archean, is currently gaining favour, and has been proposed in the Red Lake area (northeast of the study area) by Thurston and Breaks (1978), and has been well documented in Archean rocks of south-west Greenland by Hall and Freind (1979).

The diapiric emplacement of the Maskwa and Marijane Lake batholiths during the D_2 event typifies the Archean granite-greenstone relationships and has been documented globally in Archean terrains (Wilson, 1971).

METAMORPHISM

Two prograde metamorphic events are recognized at Bird River. These are M_1 and M_2.

The M_1 event is poorly preserved in the area, being preserved for the most part in hinge areas of f_2 folds. The M_2 event is evident everywhere in the area, and displays increasing pressure and temperature regimes from lowgrade assemblages in the western map area to high grade assemblages in the eastern map area. This pattern is in contradistinction to that noted by Ayres (1978) in other Archean greenstone terrains of the Superior Province, in which the highest grade assemblages tend to occur on the borders of greenstone belts in proximity to the granitic batholiths which perforate the greenstones.

At Bird River, the metamorphic zones are fault bounded. There exists however a pattern of increasing grades which culminate in a yet undefined axial zone in the Manigotogan gneiss belt. It is of interest therefore to suggest that the principal heat source involved in the M_2 metamorphism of the Bird River area was focussed in the Manigotogan gneiss belt. The M_2 event coincided with emplacement of the diapiric Maskwa and Marijane batholiths. This event of metamorphism and granitic plutonism in the upper crust suggests increased heat flow, centered in the Manigotogan gneiss belt and moving outward and upward. A relationship of this event to the crustal structure, i.e. the thinner basaltic crust and thicker upper crust, is speculative because they are not known to have contemporaneous origin.

SUMMARY

Rocks of the Rice Lake Group which form the Bird River greenstone belt are disposed in the study area as a faulted synclinorium which can be internally divided into six formations.

Of these, the Eaglenest Lake formation of volcanic derived metasediments is though to be the oldest in age, although some consideration may be given to its having originated as a faulted segment of the Bernic Lake formation.

In turn, the Lamprey Falls formation of metabasalt, and the Peterson Creek formation of metarhyolite represent successively younger rocks, portions of which can be assigned to relative proximal, transitional, and distal facies of a volcanic edifice centered in the greenstone belt.

The Bernic Lake formation is comprised of interlayered volcaniclastic and effusive rocks with counterpart synvolcanic intrusive materials. The volcaniclastic rocks of the Bernic Lake formation are formed of debris derived from the Lamprey Falls and Peterson Creek formations, on which this formation is considered unconformable. Effusive and intrusive rocks in the Bernic Lake formation have both tholeiitic and calc-alkaline kindreds, and are present as thin flows of subaqueous deposition intercalated with the clastic rocks.

The Flanders Lake formation was derived through erosion of an uplifted source area, principally in the Bernic Lake formation, and is comprised of detritus derived from that formation. The absence of volcanic flows or tuffs in the Flanders Lake formation implies that at the time of depostion volcanic activity in the area had ceased. The nature of sedimentation in the formation further implies a deposition of these rocks in proximity to their source area as a fan type of deposit in a tectonically active basin.

The Booster Lake Formation, interpreted as lying unconformably on the older rocks was possibly derived in part from a sialic foreland, and is disposed as a turbidite fan spread out from a regressing source.

The intrusive rocks of the area can be subdivided on the basis of their synvolcanic, syntectonic, and late-tectonic associations. Rocks of synvolcanic kindred closely mirror the effusive rocks in composition, are confined to formations deposited during active volcanism, and suffered all stages of subsequent tectonism.

Syntectonic intrusive rocks are present as large batholiths of

quartz diorite to granite composition. Their contacts generally display a minor foliation, and their internal fabrics correspond closely to the margins and dispositions of the formations of the greenstone belt. The emplacement of the batholiths, through diapiric mechanisms, was synchronous with the M_2 metamorphism and the D_2 deformation.

Late-tectonic intrusive rocks include the Lac du Bonnet quartz monzonite, related dyke rocks, and other rocks of granitic pegmatite kindred. Of these, the Lac du Bonnet quartz monzonite appears to have intruded with only gentle warping of the present belt boundaries and structures. Related dyke rocks, and the rocks of pegmatitic origin occupy structures developed during the D_2 deformation and during the subsequent faulting events.

The area is characterized by a complex structural history involving two early periods of folding (D_1, D_2) accompanied by metamorphism (M_1, M_2), and two later periods (D_3, D_4) of faulting. The overall structure is that of a faulted synclinorium, in which the faults isolate five blocks of differing lithologies and structural characteristics.

The D_1 deformational event is evident in all of those rocks of the area which are older in age than the Booster Lake formation, excepting the Lamprey Falls formation, and is present as an s_1 schistosity which lies parallel to bedding planes in the hinge areas of the younger f_2 folds. The development of the s_1 fabric was attendant with development of early f_1 folds which accompanied the M_1 metamorphism, but appears to be absent in the Lamprey Falls formation for reasons which may involve the original mineralogy of these lavas.

The D_2 deformation is manifest in all of the metavolcanic, metasedimentary, and synvolcanic intrusive rocks of the area, and is present in these rocks as the s_2 schistosity. This fabric corresponds in its orientations to boundaries and fabrics observed in the Maskwa and Marijane Lake batholiths, and the M_2 metamorphic minerals which form the s_2 fabric are considered synchronous in origin with the emplacement of the batholiths.

The superposition of the s_2 fabric on the early f_1 folds has resulted in fold patterns which can be classed as being of Type III interference. Such folds are best displayed by the metaconglomerate of the Flanders Lake formation, and are interpreted as being present in the Peterson Creek and

Bernic Lake formations, but of an essentially horizontal plunge.

Folding in the Booster Lake formation is of a single-phase (f_2) origin, and assumes a conic form plunging southwesterly.

Faults, of D_3 age, segment the metavolcanic, metasedimentary, and intrusive rocks of the area, delimit the five structural subareas, and in conjunction with a fault of D_4 age, serve to delimit the M_2 metamorphic zones.

The metamorphic history of the area is correlative with the deformational events. Thus the M_1 metamorphism was attendant with development of assemblages of at least greenschist facies which form the s_1 schistosity in f_1 folds.

The second metamorphic event (M_2) saw the highest grades of metamorphism developed in a regime of high temperature and low pressure conditions, and the M_2 assemblages which form the s_2 schistosity can be assigned to the Abakuma facies series of metamorphism.

Retrograde assemblages overprint the M_2 metamorphic assemblages, and are largely confined to F_3 and F_4 fault zones.

Little information is available on the subcrustal attributes of Archean greenstone belts of other areas, but from that of the Bird River area there appears to be a coincidence of lower and upper crustal configurations with the present disposition of the Bird River and Manigotogan belts.

The Bird River greenstone belt displays many attributes of the typical greenstone-granite diapir association of Archean Shield areas. In this regard its volcanic and clastic assemblages typify those of other Archean belts which can be assigned to a younger category, but similarly they exhibit the chemistry and mixed kindreds found in Phanerozoic island arc environments. It is also noteworthy that some of the rocks of the area, i.e. the Bird River Sill and the Peterson Creek Formation, display attributes which in other Archean or Phanerozoic rocks have been assigned to crustal extension or rift environments.

Deformation (D_2) of the Bird River and adjacent rocks typifies Archean volcano-tectonic basins with the principal metamorphism (M_1) and folding (f_1) being accompanied by emplacement of diapiric graintoid batholiths. An earlier folding event at Bird River (f_1) is also typical of that of other Archean greenstone belts but which is rarely deciphered. At Bird River there exists evidence that this early event may have involved formation of nappes.

The metamorphism at Bird River was one of a high temperature - low pressure regime (Abakuma type) which typifies Archean greenstone terrains, and is not unlike a high temperature - low pressure series of contact metamorphism. The M_2 metamorphic facies series established at Bird River however, progradesinto and become an integral part of the series established in the Manigotogan gneiss belt.

Continued research in the study area should focus on obtaining REE data from other of the described rock types in an attempt to define the origin and source of the mafic and intermediate volcanic rocks and their relations to both felsic rocks, possible adjacent sialic forelands, and the tectonic environment in which the area orginated.

Little research, other than that of descriptive nature, is available onthe mineralization and ore deposits of the area. It is noted that the chromite and tin deposits of the area are quite unusual in the Canadian Shield, but do find similarity in, for example, South Africa and Nigeria respectively, and it is felt that the tectonic environment of the Bird River area might find favourable comparison with those well documented continental nucleii and rift zones.

In view of the documentation available on the Rice Lake greenstone belt, the Manigotogan gneiss belt, and the Bird River greenstone belt, it would be of further considerable importance to have these areas fit as tripartite members into an integral model involving the origin of this part of the earth's Archean crust.

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Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Science and Technology
Science et Technologie

Your file Votre référence

Our file Notre référence

February 18, 1980

Professor A. Turnock,
Department of Earth Sciences,
University of Manitoba,
Winnipeg, Manitoba
RST 2N2.

Dear Al:

I have checked through our records and can find no previous formal use of most of the names listed in your "Table of Formations in the Bird River Area, Manitoba". Those that have been used are Bird River (Intrusive Complex - Precambrian, Manitoba, Bateman, 1943) and Peterson Creek (British Columbia), and of course Rice Lake Group.

Therefore, I have reserved for eventual formal description by you and/or Trueman the following: Booster Lake, Bernic Lake, Eaglenest Lake, Flanders Lake, Lac du Bonnet, Lamprey Falls, and Peterson Creek. Batholith terms are not recorded in stratigraphic nomenclature.

Thanks for the opportunity to check and reserve these names. Everything reasonably normal here!

Best regards,

Tom

Thomas E. Bolton

TEB/rl

Geological Survey of Canada
601 Booth Street
Ottawa Canada
K1A 0E8

Commission géologique du Canada
601, rue Booth
Ottawa Canada
K1A 0E8

MAP C

Sample location and geographic reference map of the Bird River area

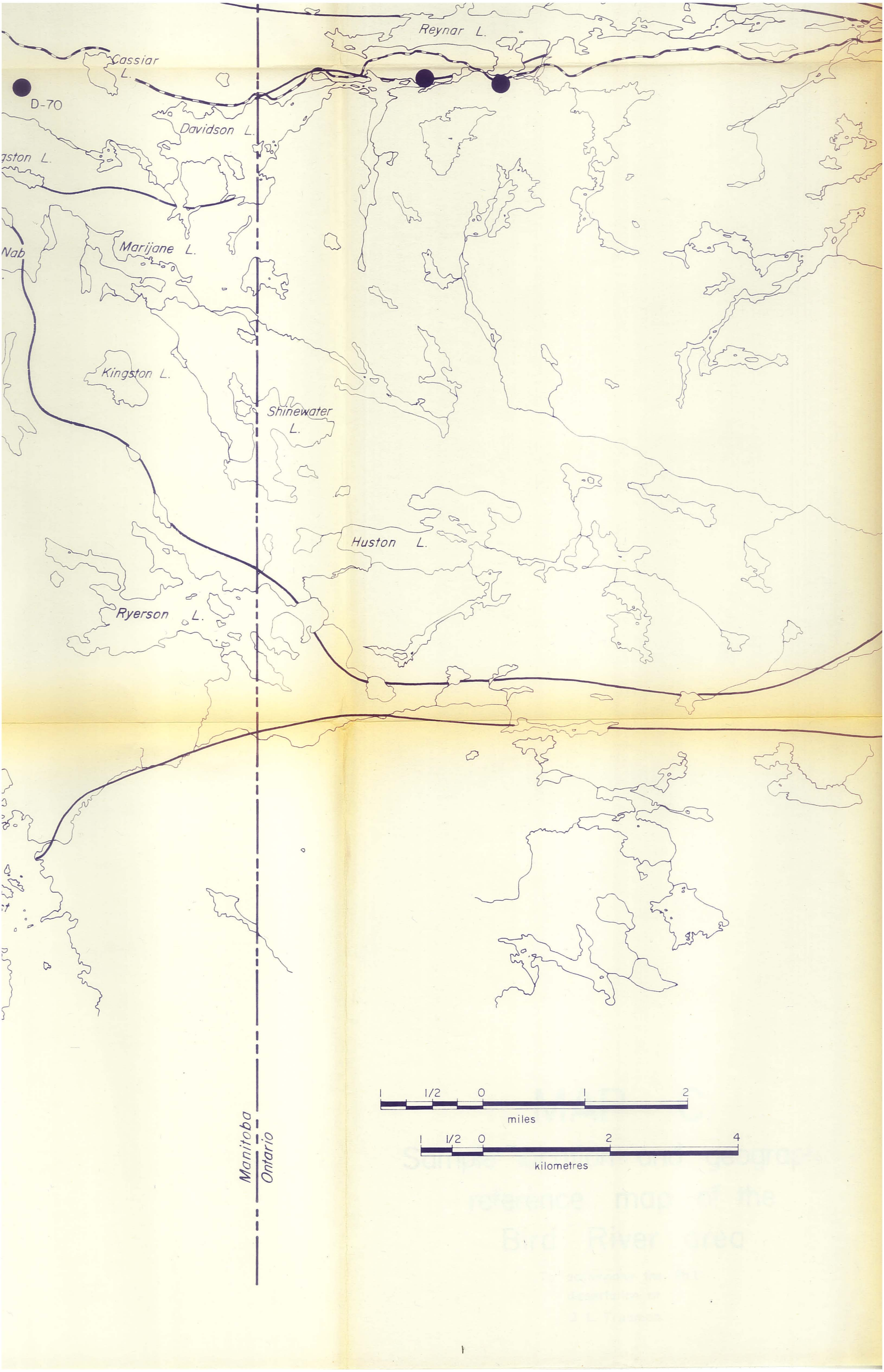
To accompany the Ph.D. dissertation of D.L. Trueman

Mine, present or past producer

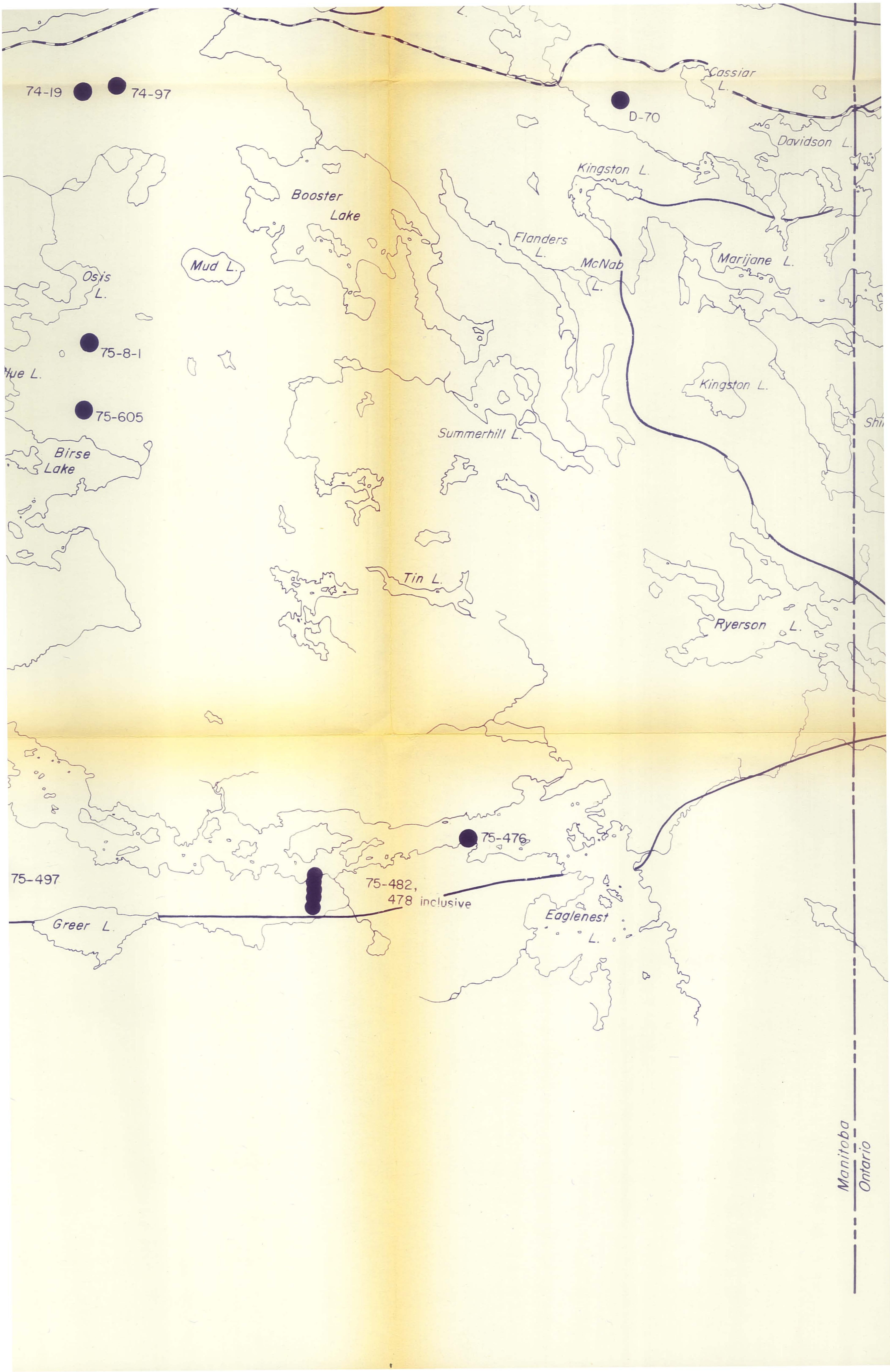
74-2 Location of chemically analyzed sample

Mining property boundary

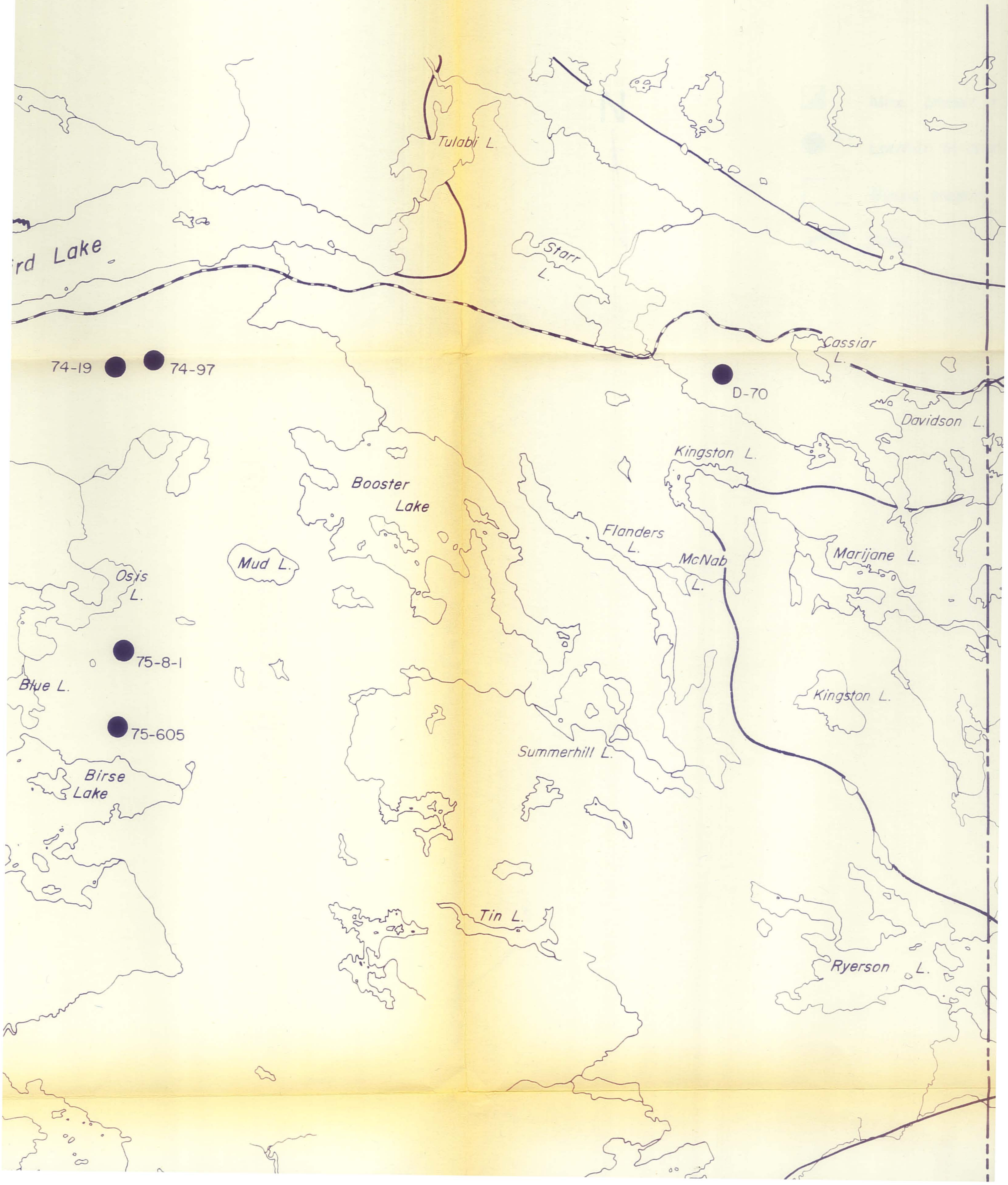
Road


Reynar L.
Cassiar L.
D-70
Davidson L.
Marijane L.
Nab
Kingston L.
Shinewater L.
Huston L.
Ryerson L.
Manitoba
Ontario
1/2 0 1 2
miles
1 1/2 0 2 4
kilometres

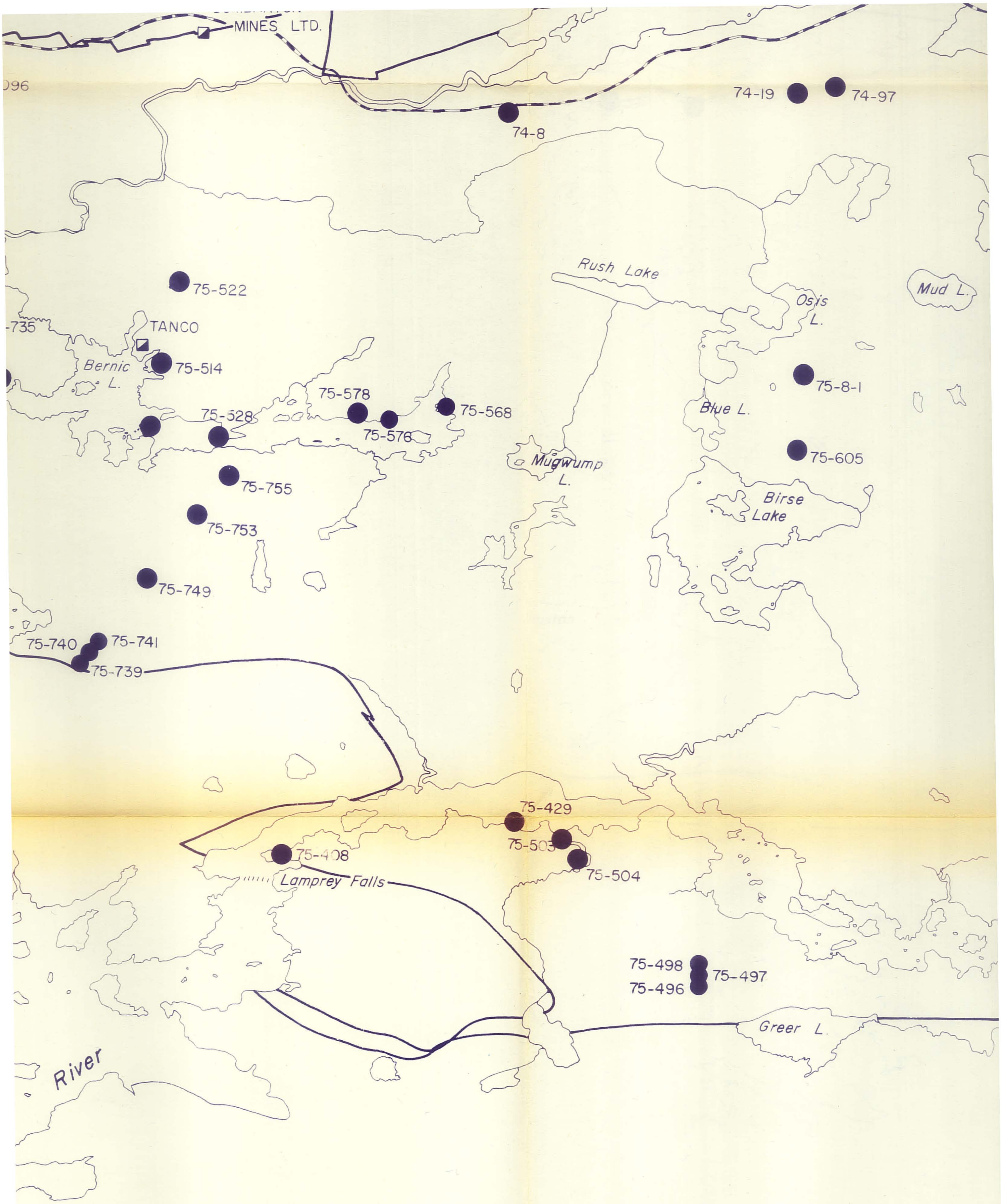
Reynar L.
Huston L.
Shinewater L.
Davidson L.
Cassiar L.
Marijane L.
Kingston L.
Ryerson L.
D-70



74-19
74-97
D-70
Cassiar L.
Davidson L.
Kingston L.
Booster Lake
Flanders L.
McNab L.
Marijane L.
Mud L.
Osis L.
75-8-1
75-605
Birse Lake
Kingston L.
Summerhill L.
Tin L.
Ryerson L.
75-476
75-497
75-482, 478 inclusive
Greer L.
Eaglenest L.
Manitoba
Ontario



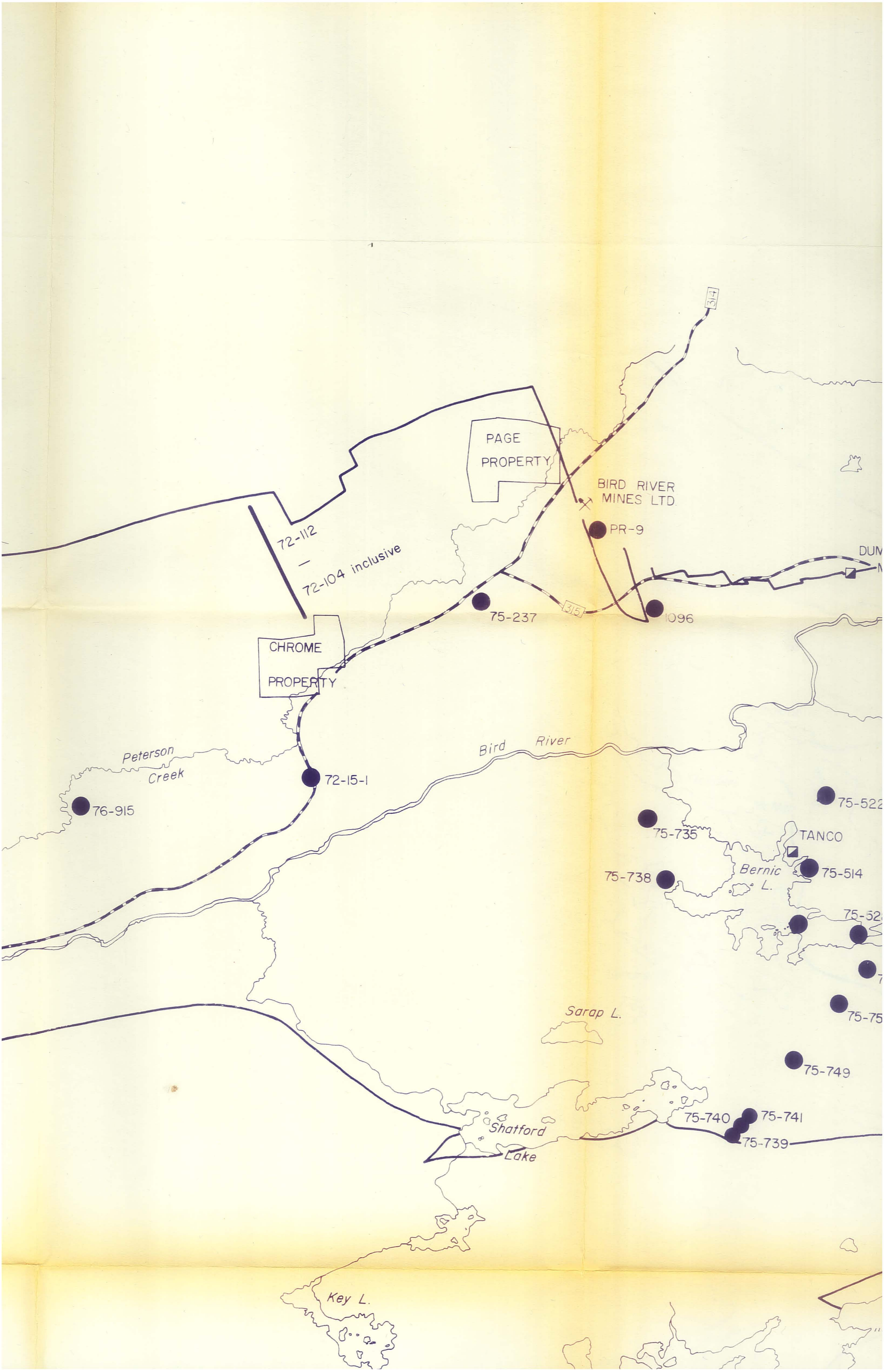
rd Lake
Tulabi L.
Starr L.
Cassiar L.
D-70
74-19
74-97
Davidson L.
Kingston L.
Booster Lake
Flanders L.
McNab L.
Marijane L.
Mud L.
Osis L.
75-8-1
Blue L.
75-605
Birse Lake
Kingston L.
Summerhill L.
Tin L.
Ryerson L.

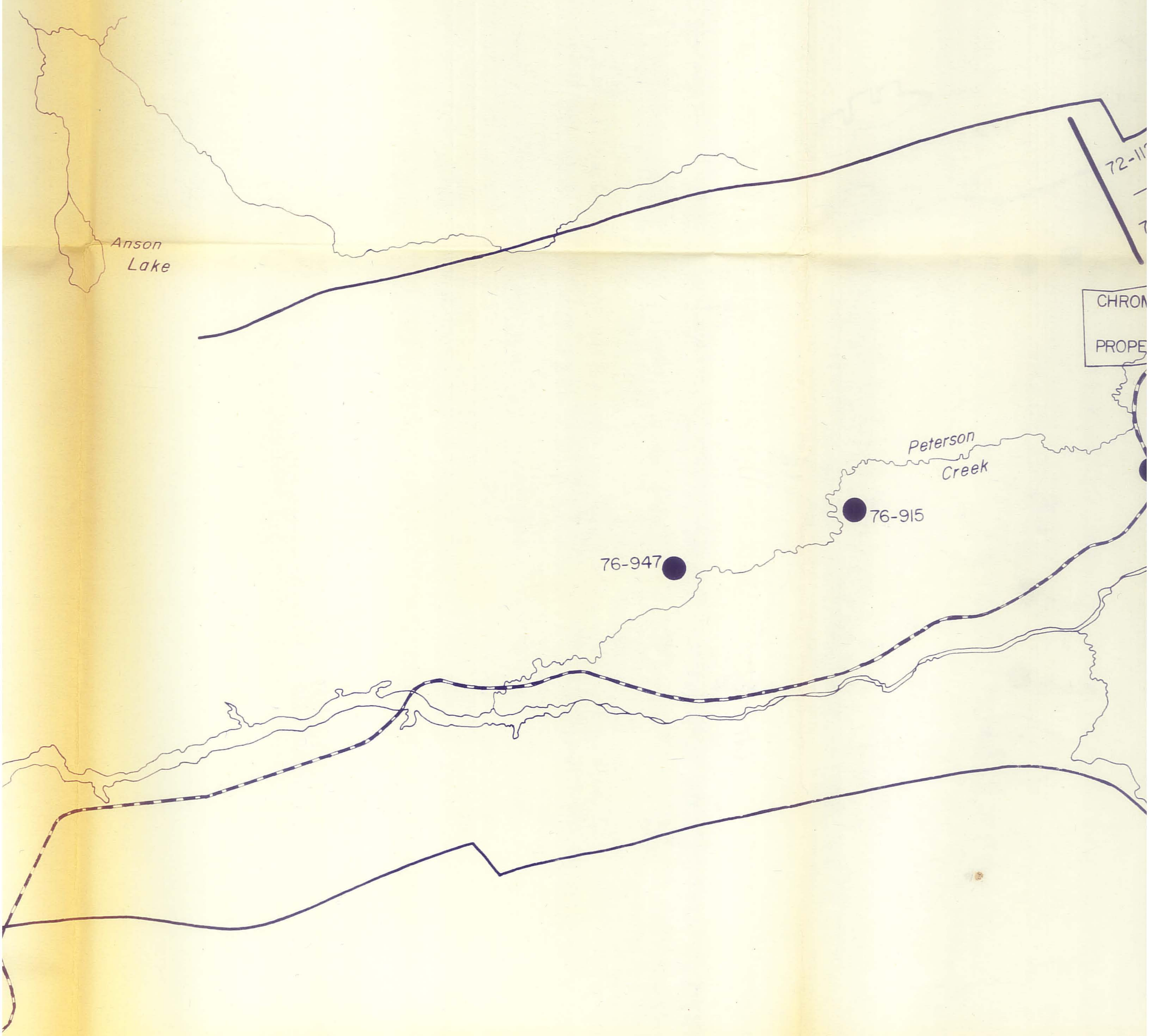


MINES LTD.
096
74-19
74-97
74-8
Rush Lake
Mud L.
Osis L.
75-522
-735
TANCO
Bernic L.
75-514
75-8-1
75-578
75-568
Blue L.
75-528
75-576
75-605
Mugwump L.
75-755
Birse Lake
75-753
75-749
75-740
75-741
75-739
75-429
75-503
75-408
75-504
Lamprey Falls
75-498
75-497
75-496
Greer L.
River

314
D RIVER
NES LTD.
PR-9
DUMBARTON
MINES LTD.
Bird Lake
1096
74-19
74-97
74-8
Rush Lake
Osis
L.
75-522
75-735
TANCO
Bernic
L.
75-514
5-738
75-578
75-528
75-568
75-576
75-8-1
Blue L.
Mugwump
L.
75-605
Birse
Lake
75-755
75-753
75-749
75-740
75-741
75-739
75-429
75-503
75-408
75-504
Lamprey Falls


72-104 inclusive
DUMBARTO
MINES
75-237
315
1096
CHROME
PROPERTY
Peterson
Creek
Bird River
72-15-1
76-915
75-522
75-735
TANCO
Bernic L.
75-514
75-738
75-528
75-755
Sarap L.
75-753
75-749
75-740
75-741
75-739
Shatford
Lake
Key L.
River
Winnipeg


314
PAGE
PROPERTY
BIRD RIVER
MINES LTD
PR-9
72-112
—
72-104 inclusive
75-237
315
1096
CHROME
PROPERTY
Peterson
Creek
Bird River
72-15-1
76-915
75-735
TANCO
Bernic
L.
75-514
75-738
Sarap L.
75-749
75-740
75-741
75-739
Shatford
Lake
Key L.


Anson
Lake
CHROM
PROPE
Peterson
Creek
76-915
76-947


CHROME
PROPERTY
72-15-
Peterson
Creek
76-915
76-947
Anson
Lake
Key


Anson Lake
Coppermine Bay
Lac du Bonnet
Poplar Bay
315
313


Anson Lake
Coppermine Bay
Lac du Bonnet
Poplar Bay

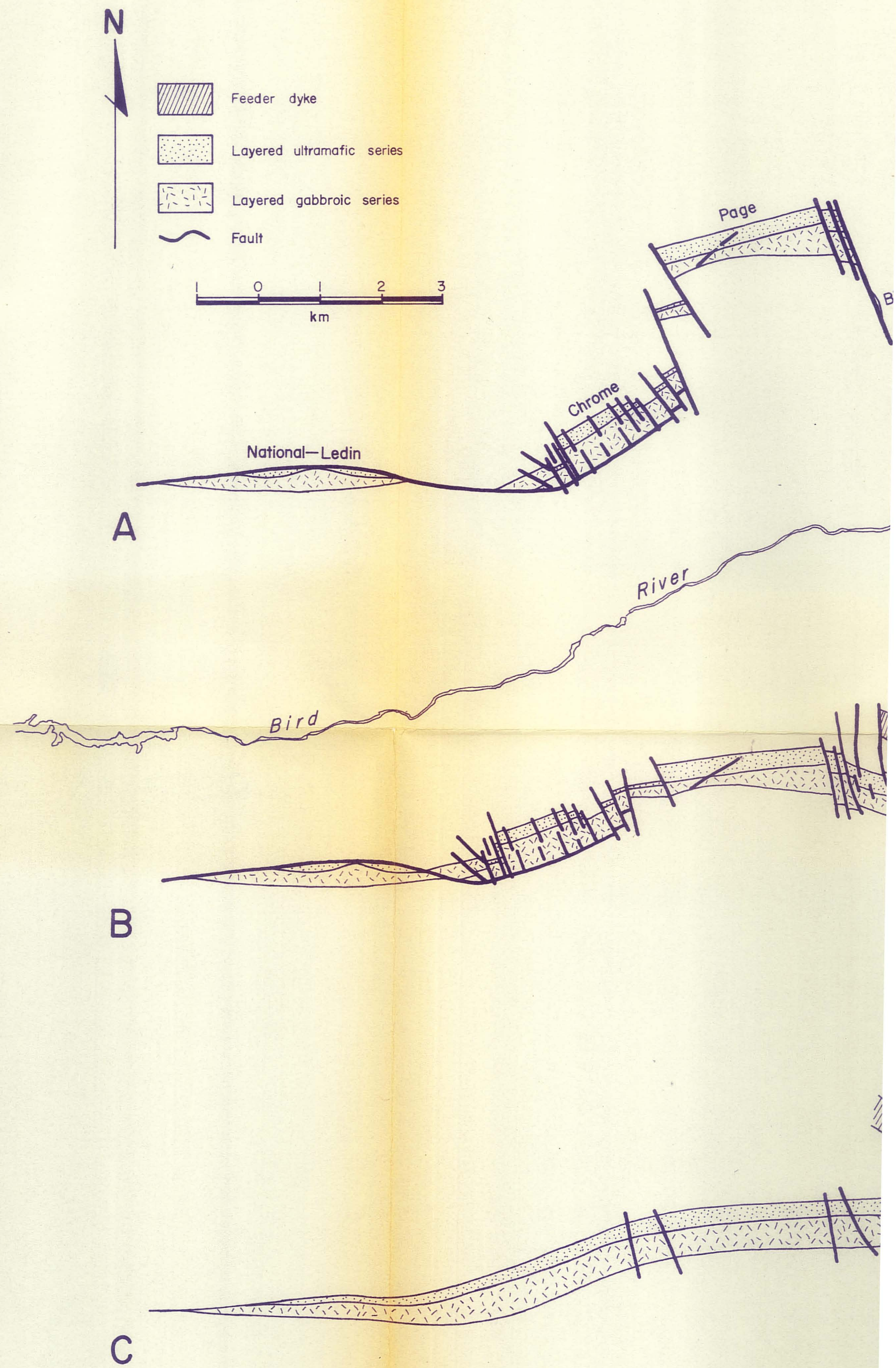
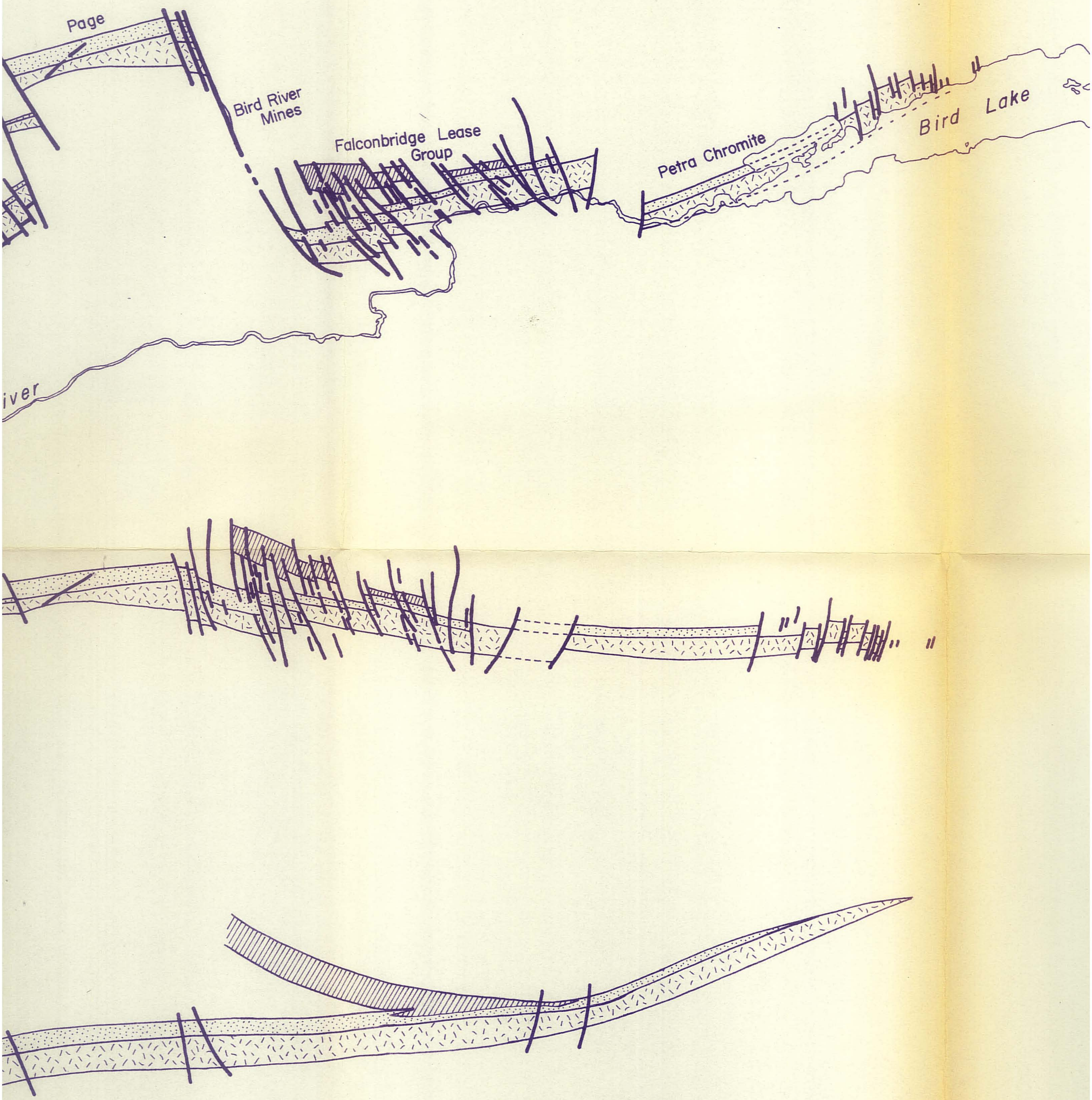
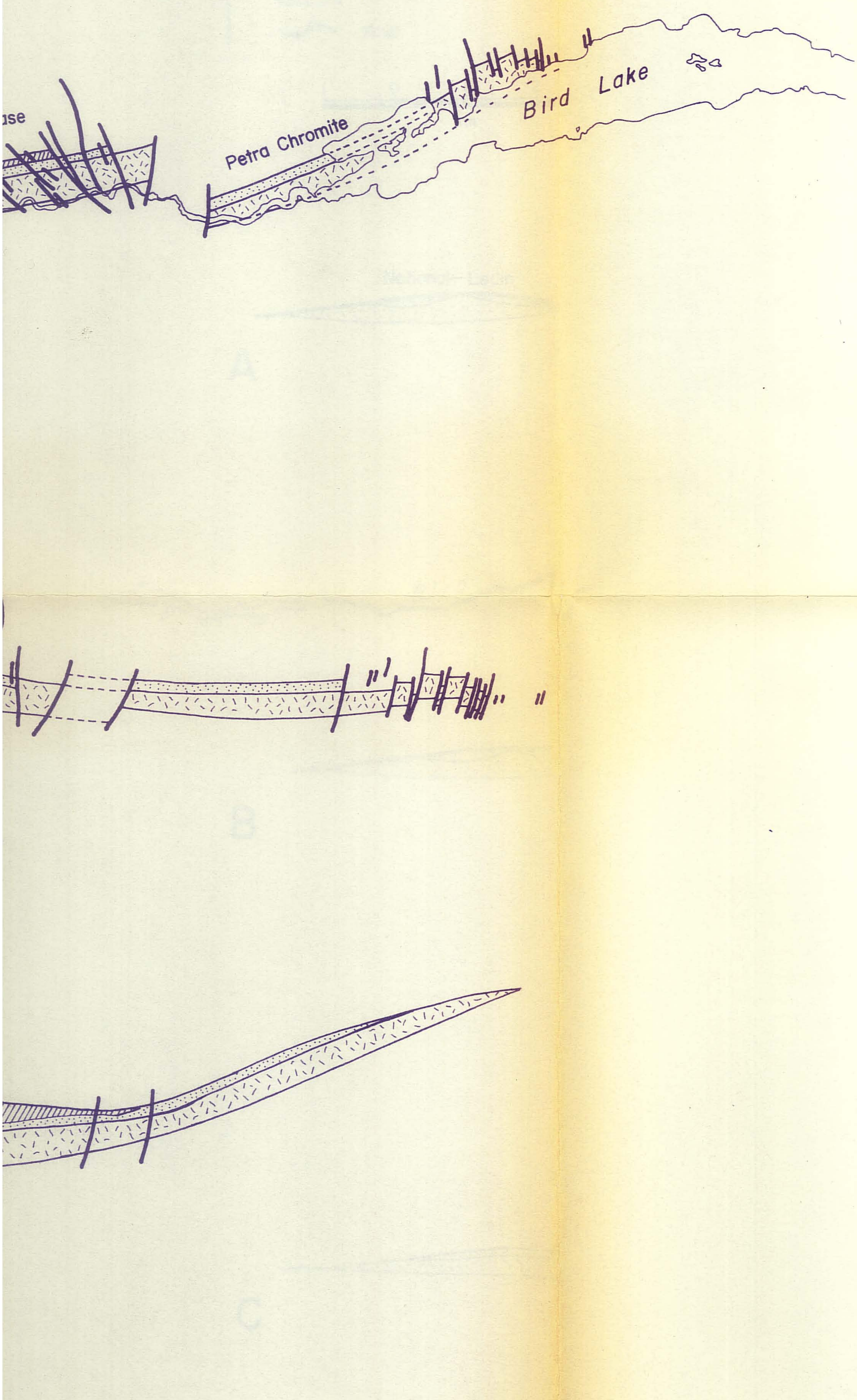
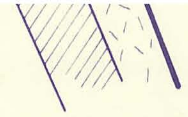


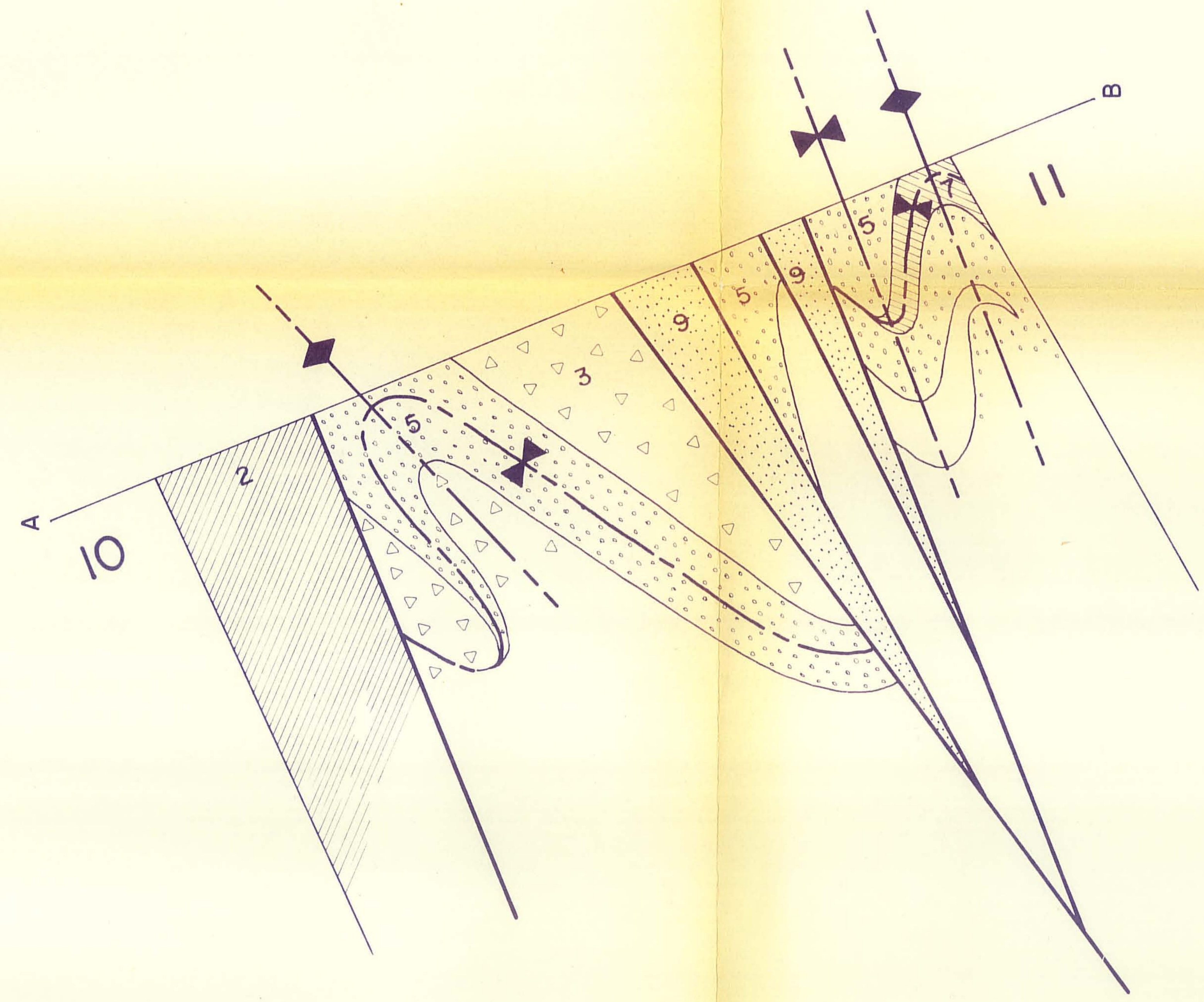
FIGURE 53: Palinspastic reconstruction of the Bird River



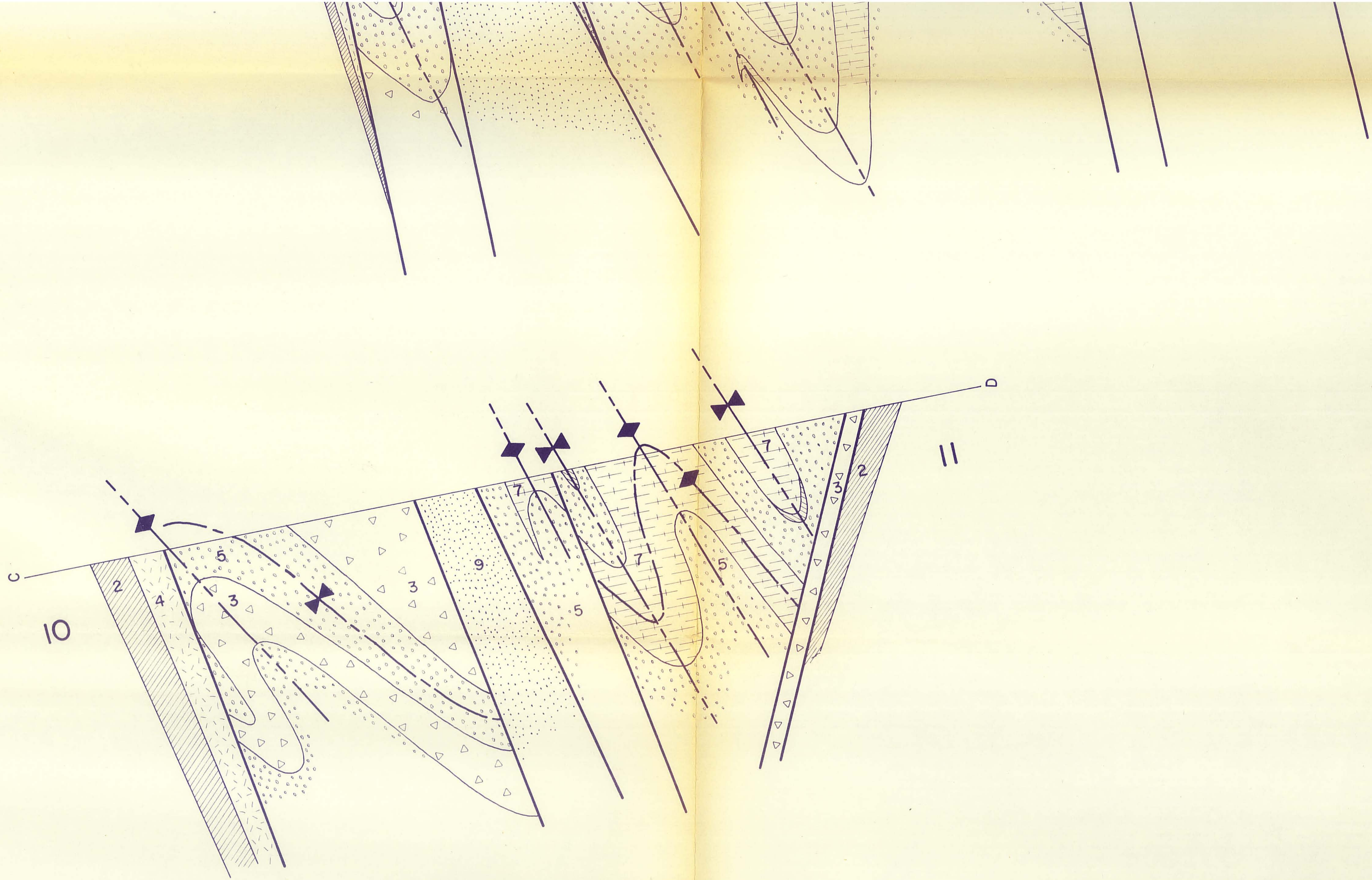
of the Bird River Sill.


ase
Petra Chromite
Bird Lake





10
A
2
5
3
9
5
9
5
7
11
B


C
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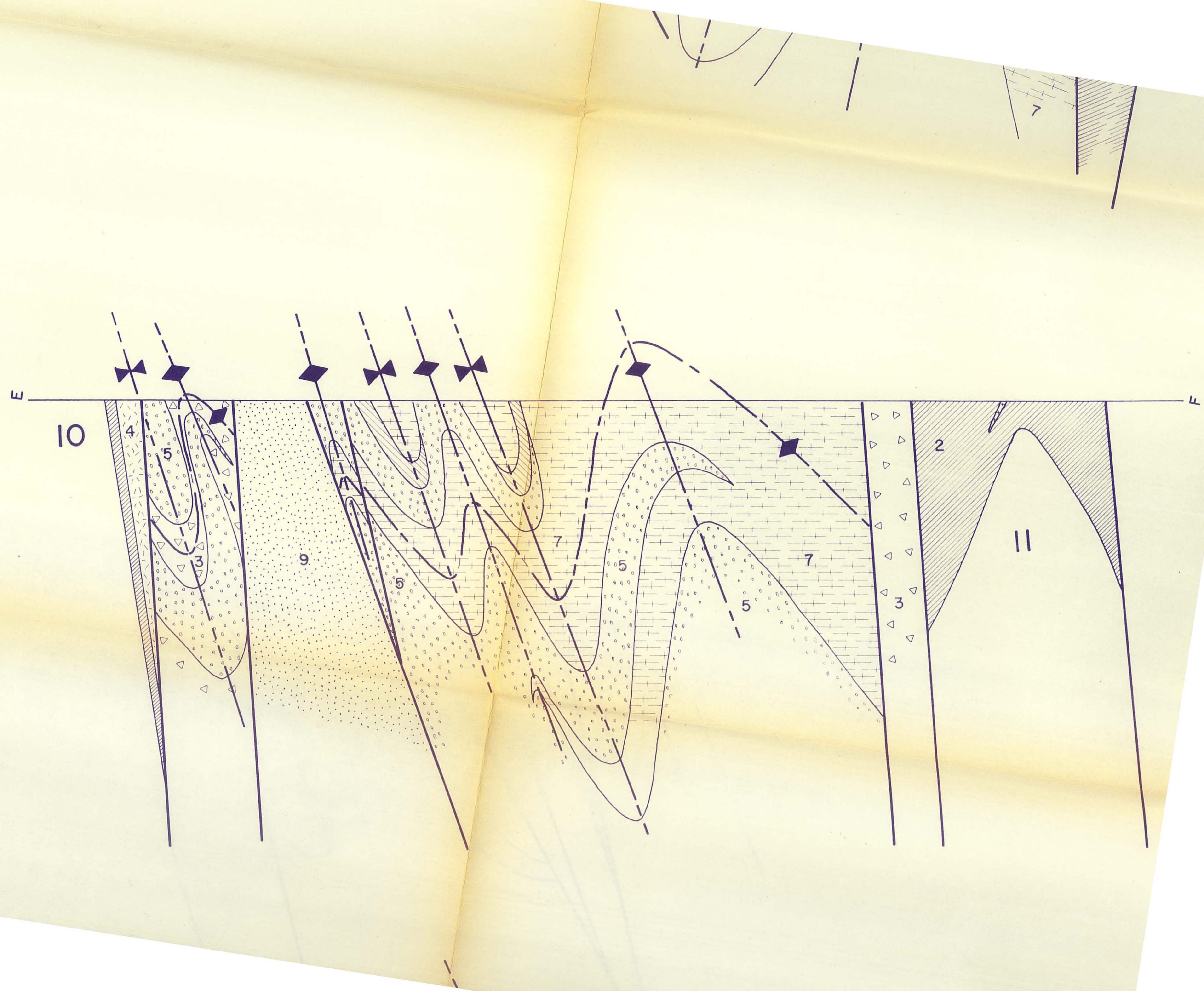
3
3
9
7
5
7
5
7
3
2


E
F
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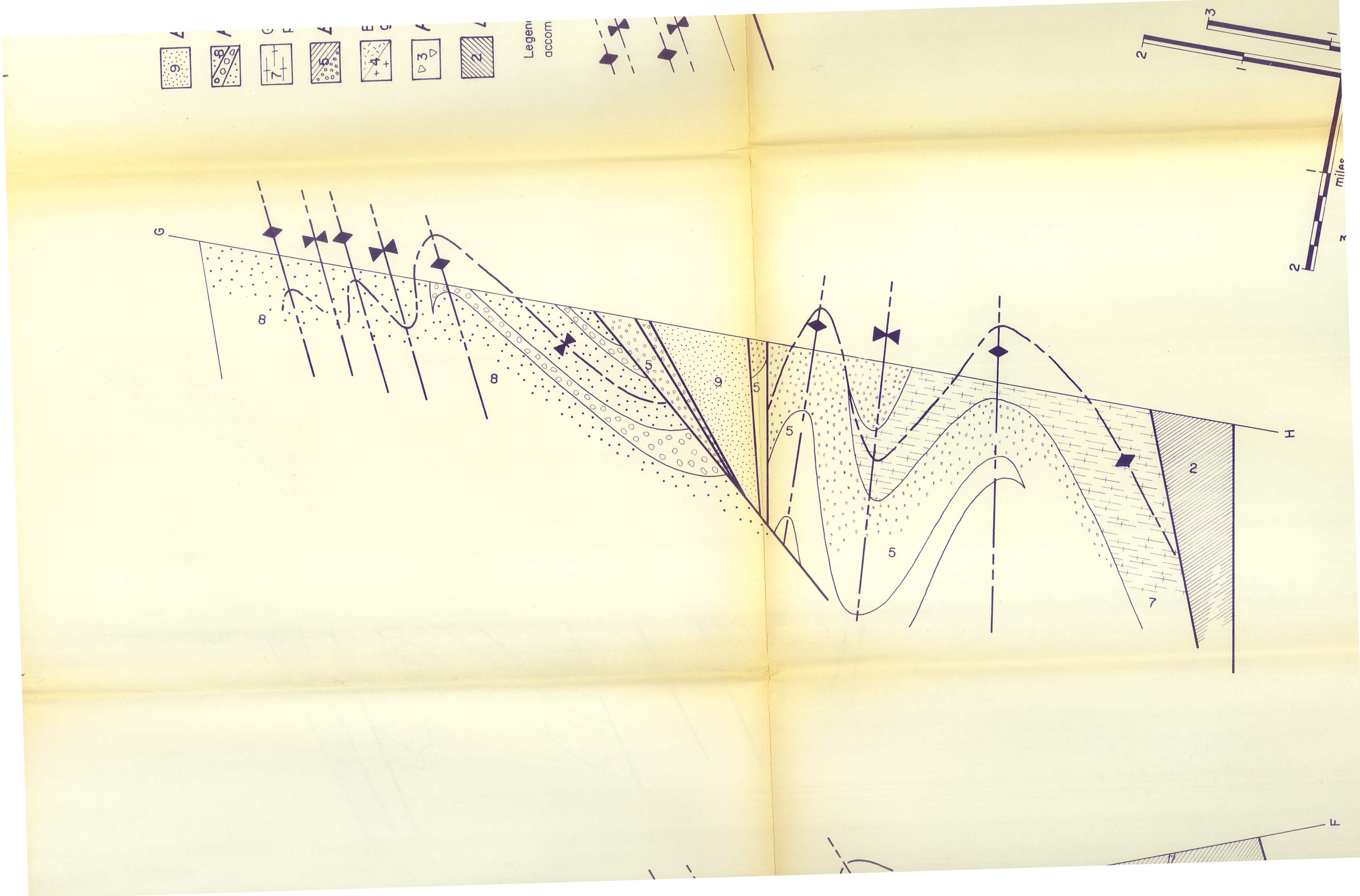
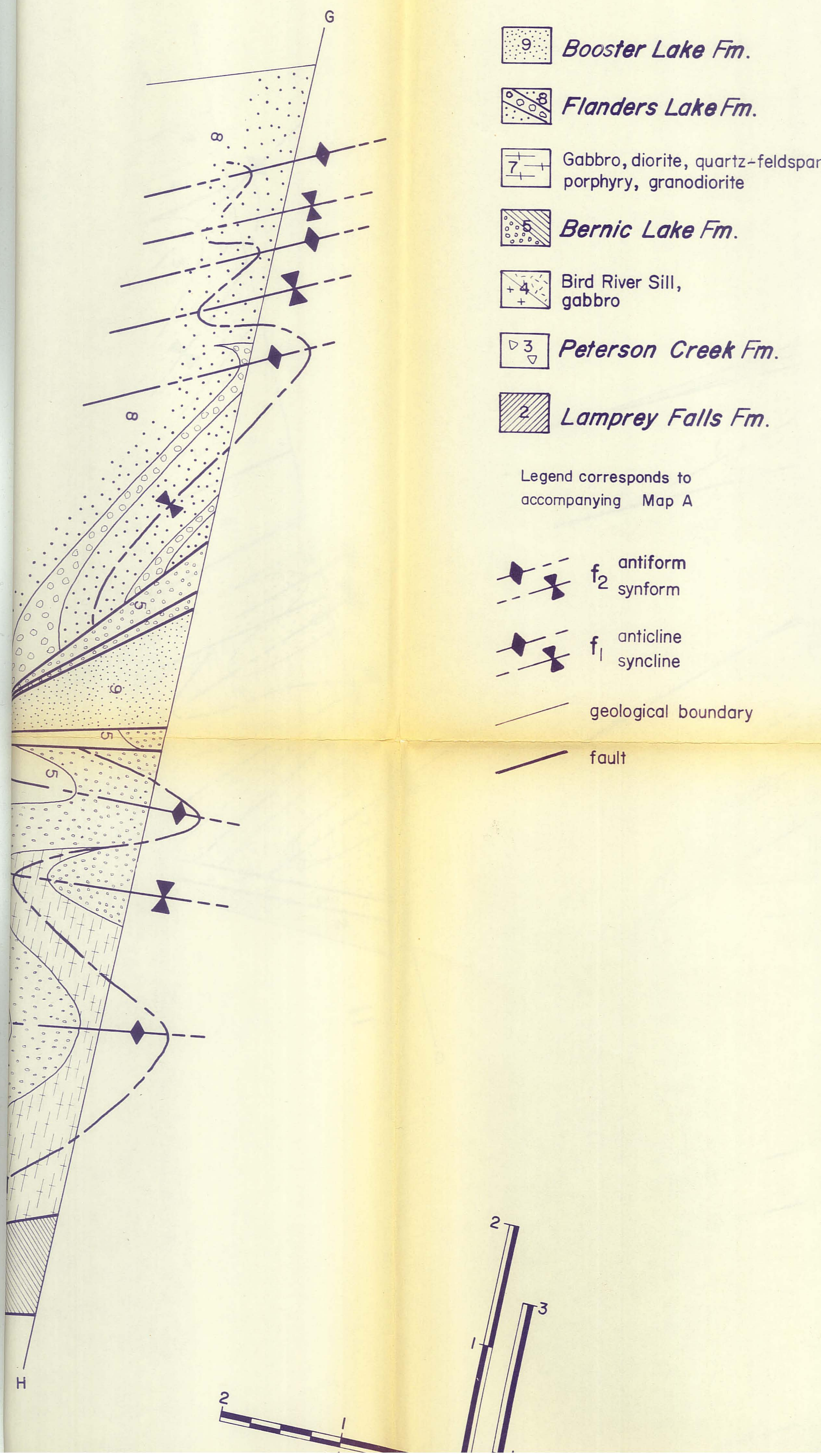
5
7
5
7
5
3
2
11
7



G
H
F
2
5
7
8
9
miles
Legen
accom


G
H
9
Booster Lake Fm.
8
Flanders Lake Fm.
7
Gabbro, diorite, quartz-feldspar porphyry, granodiorite
5
Bernic Lake Fm.
4
Bird River Sill, gabbro
3
Peterson Creek Fm.
2
Lamprey Falls Fm.
Legend corresponds to accompanying Map A
f2 antiform
synform
f1 anticline
syncline
geological boundary
fault
2
1
3

70 strike and dip of schistosity — dip unknown, vertical

70 strike and dip of bedding, tops known — dip unknown, vertical

strike and dip of igneous layering

minor fold, plunge indicated

lineation

f_1 anticlinal trace

f_1 synclinal trace

f_2 anticlinal trace

f_2 synclinal trace

A B reference line for geologic cross sections: Figure 68

MAP B

Structural elements of the Bird River area

To accompany the Ph.D.
dissertation of
D. L. Trueman

geologic boundary

fault

photo - lineament

70 strike and dip of schistosity dip unknown, vertical

70 strike and dip of bedding, tops known dip unknown, vertical

strike and dip of igneous layering

minor fold, plunge indicated

lineation

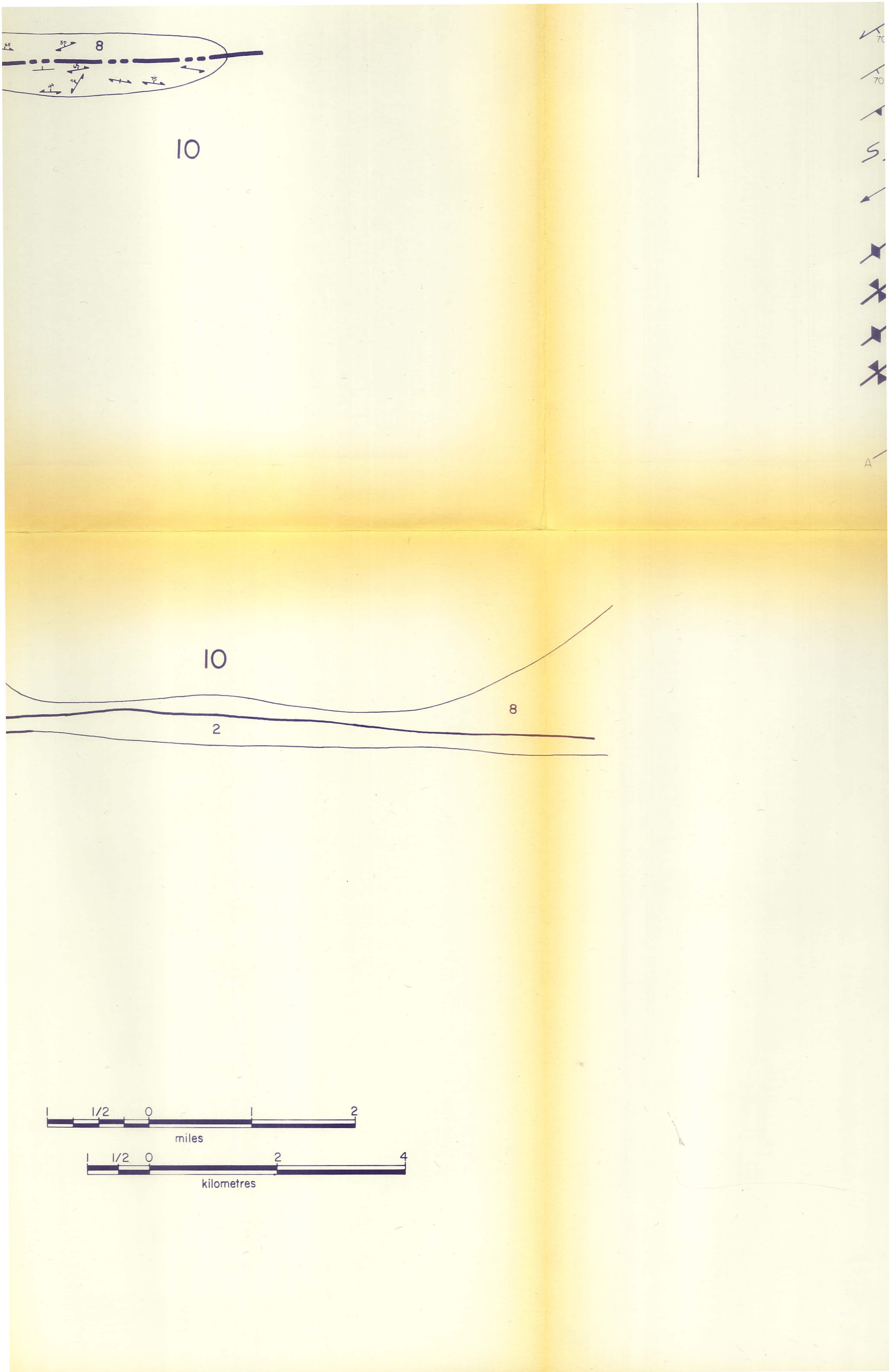
f_1 anticlinal trace

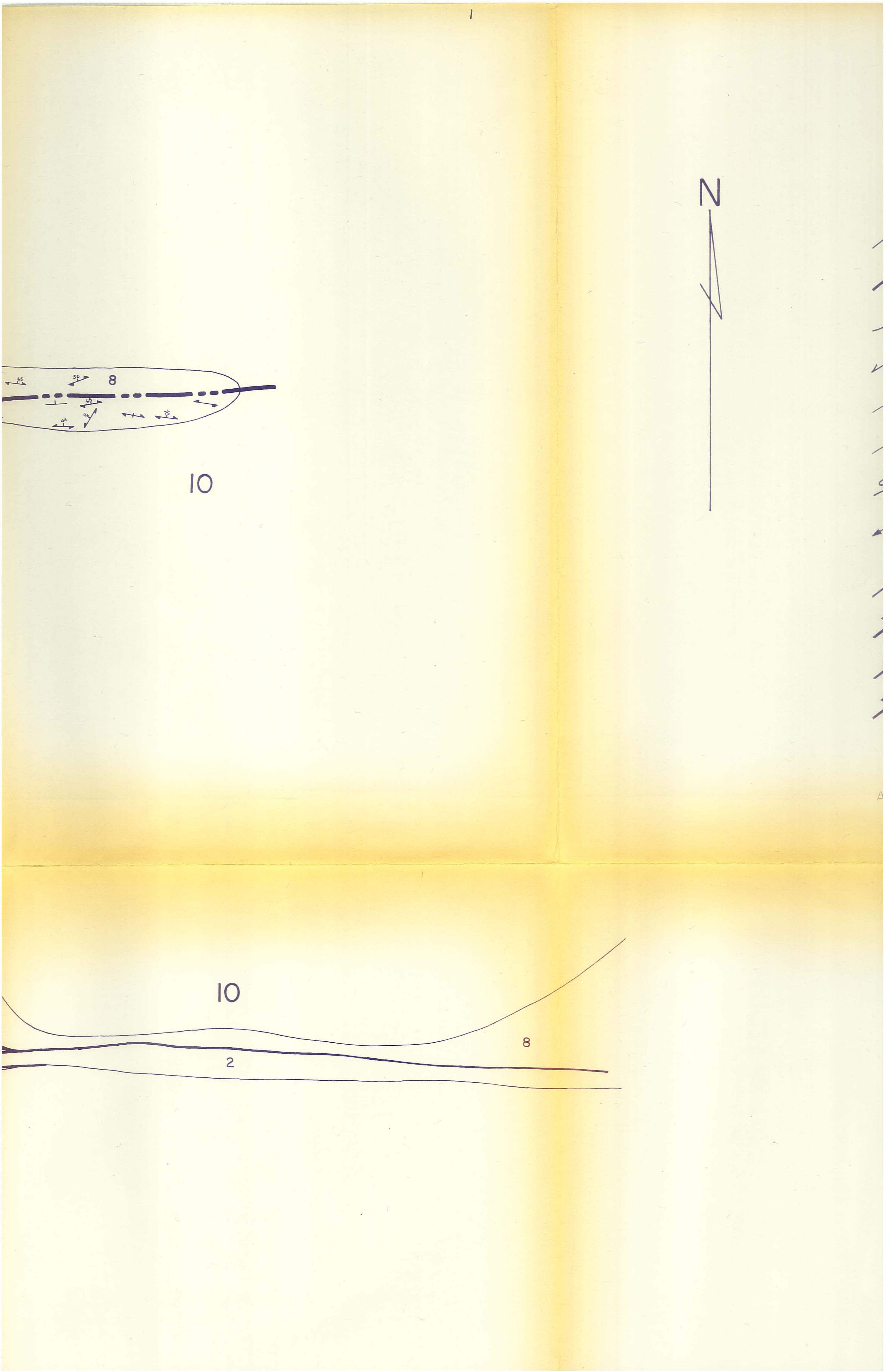
f_1 synclinal trace

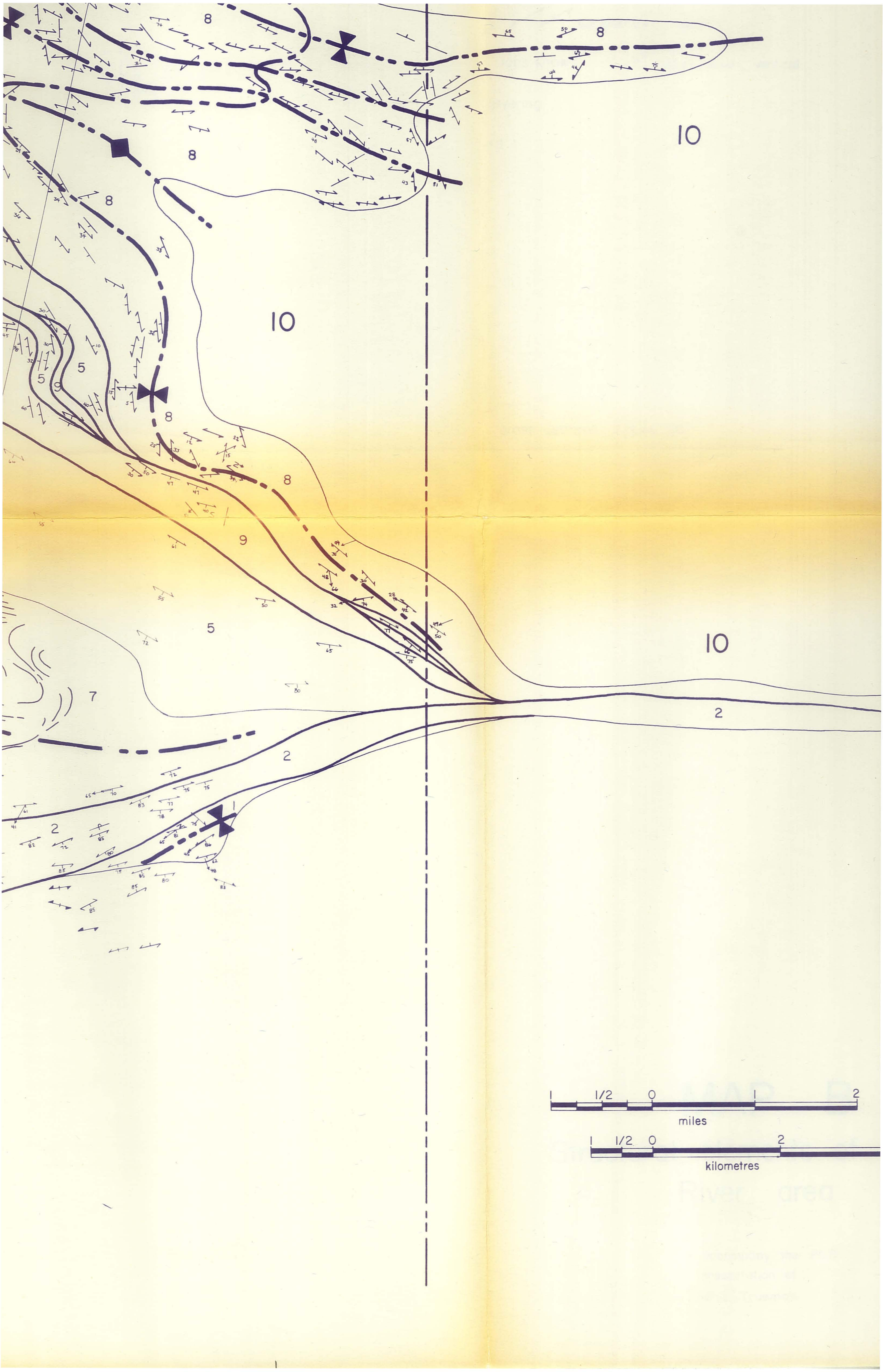
f_2 anticlinal trace

f_2 synclinal trace

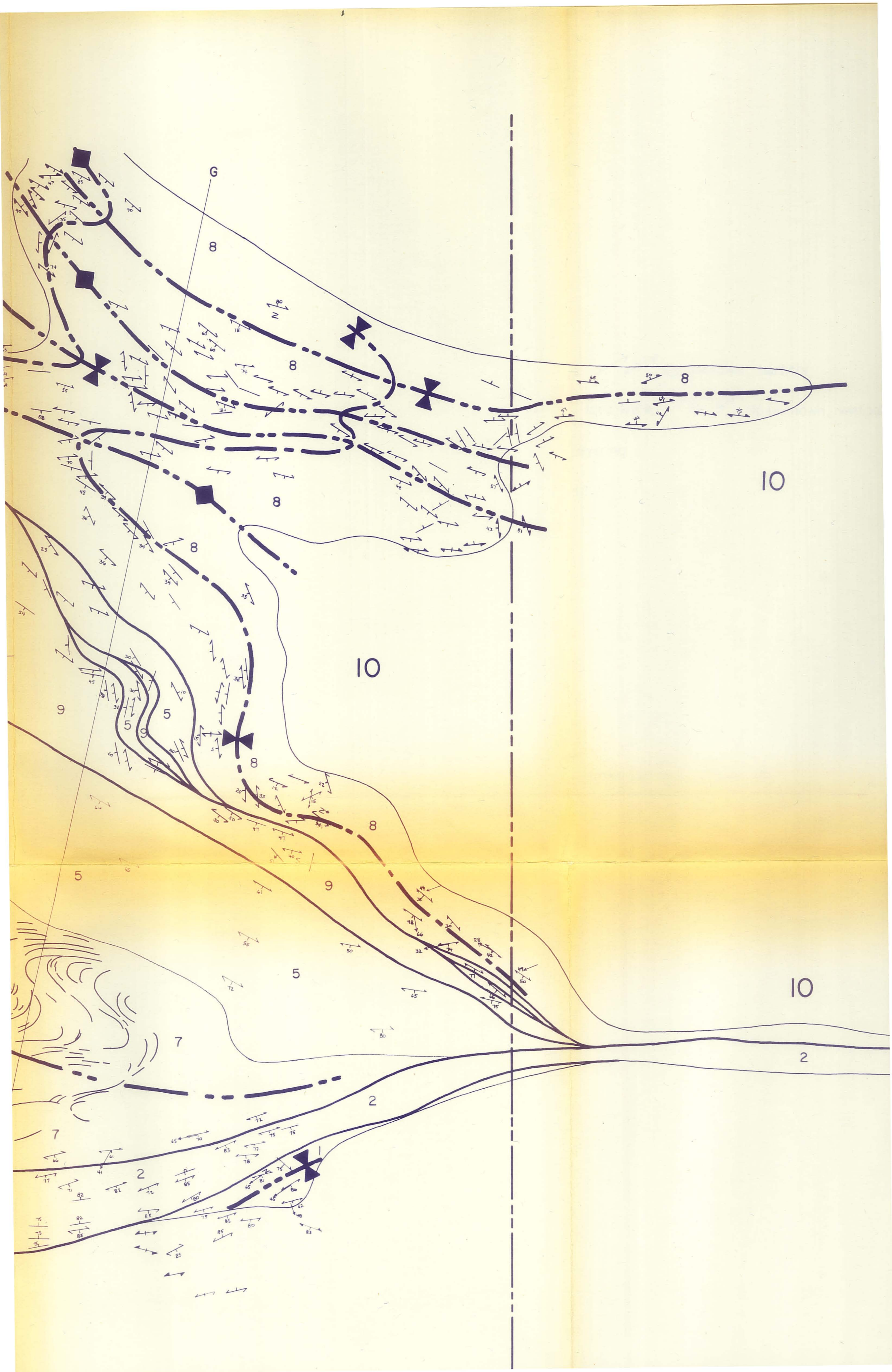
A B reference line for geologic cross sections: Figure 68


8
10
10
8
2
1 1/2 0 1 2
miles
1 1/2 0 2 4
kilometres


N
8
10
10
8
2



10
8
5
9
7
2
1/2 0 1 2
miles
1/2 0 2
kilometres



G
8
8
8
8
8
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9
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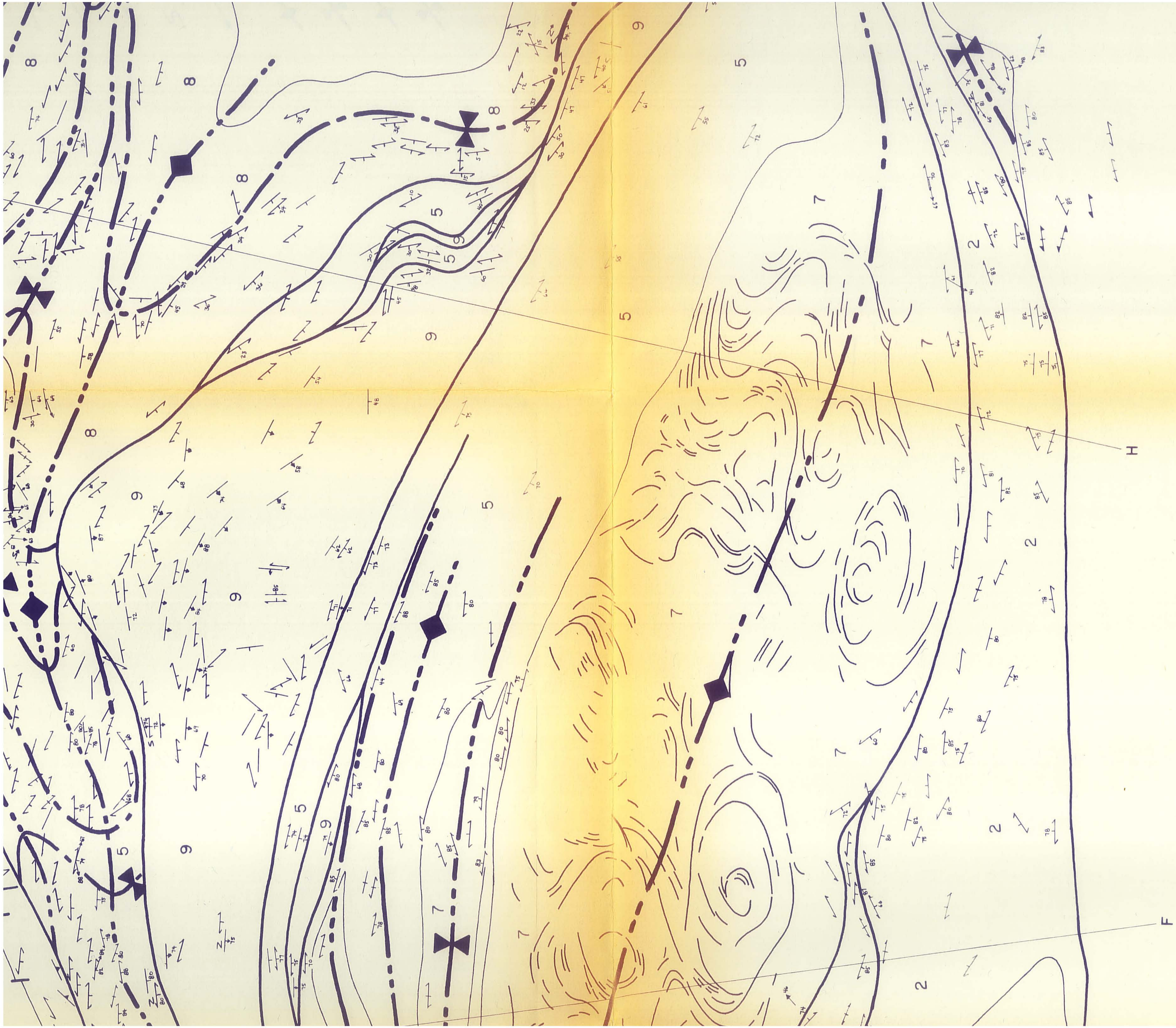
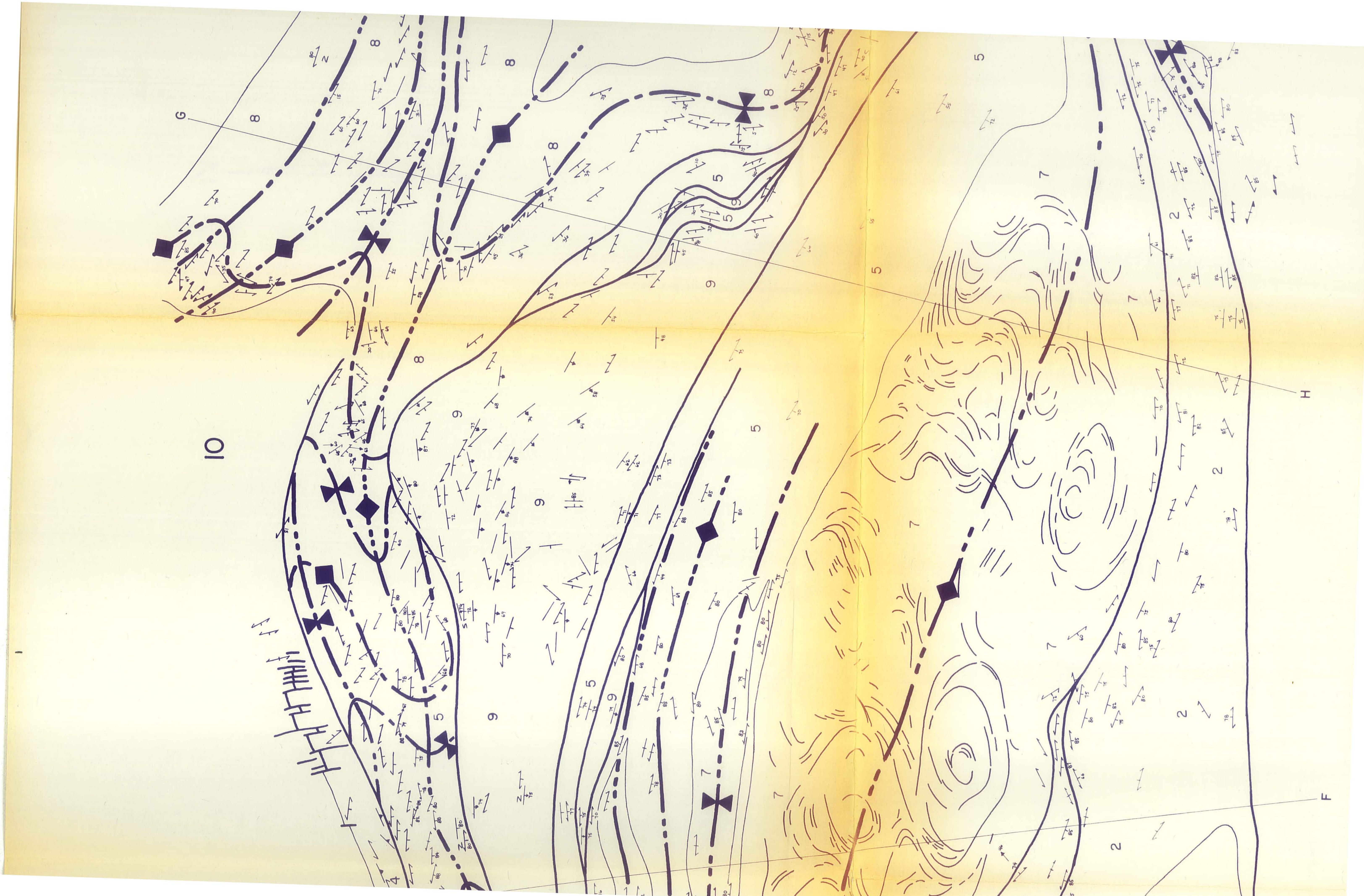
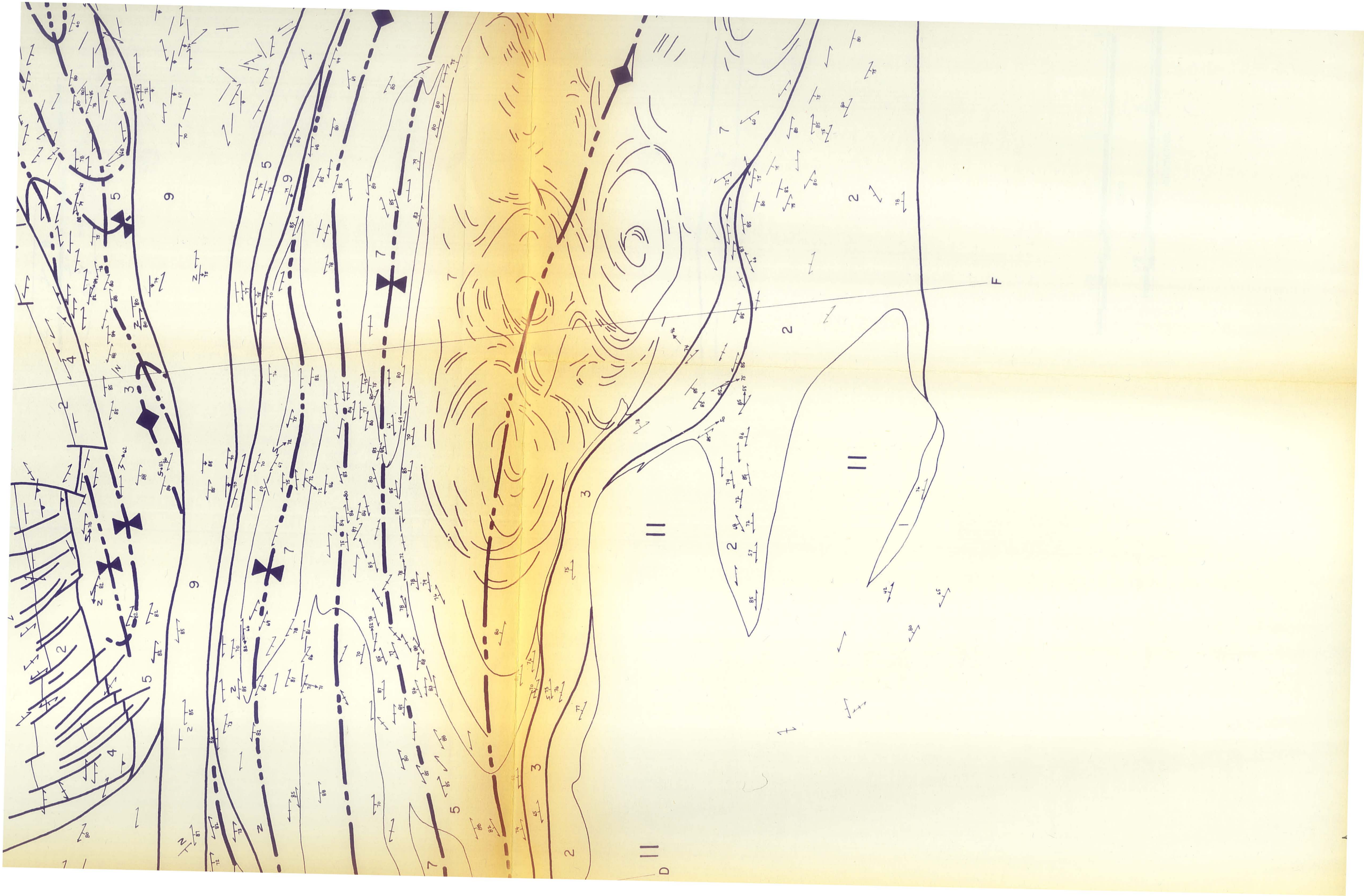
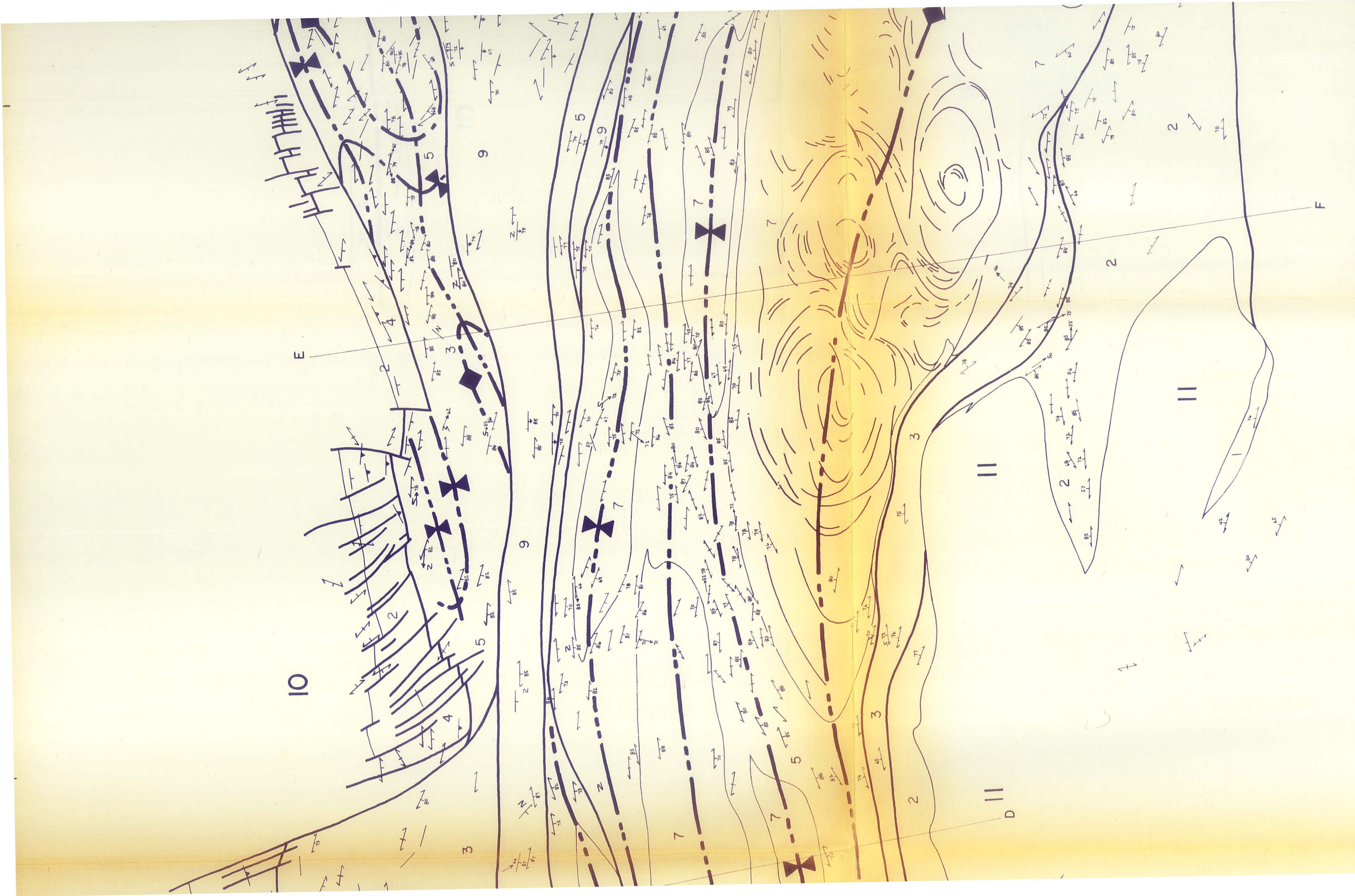
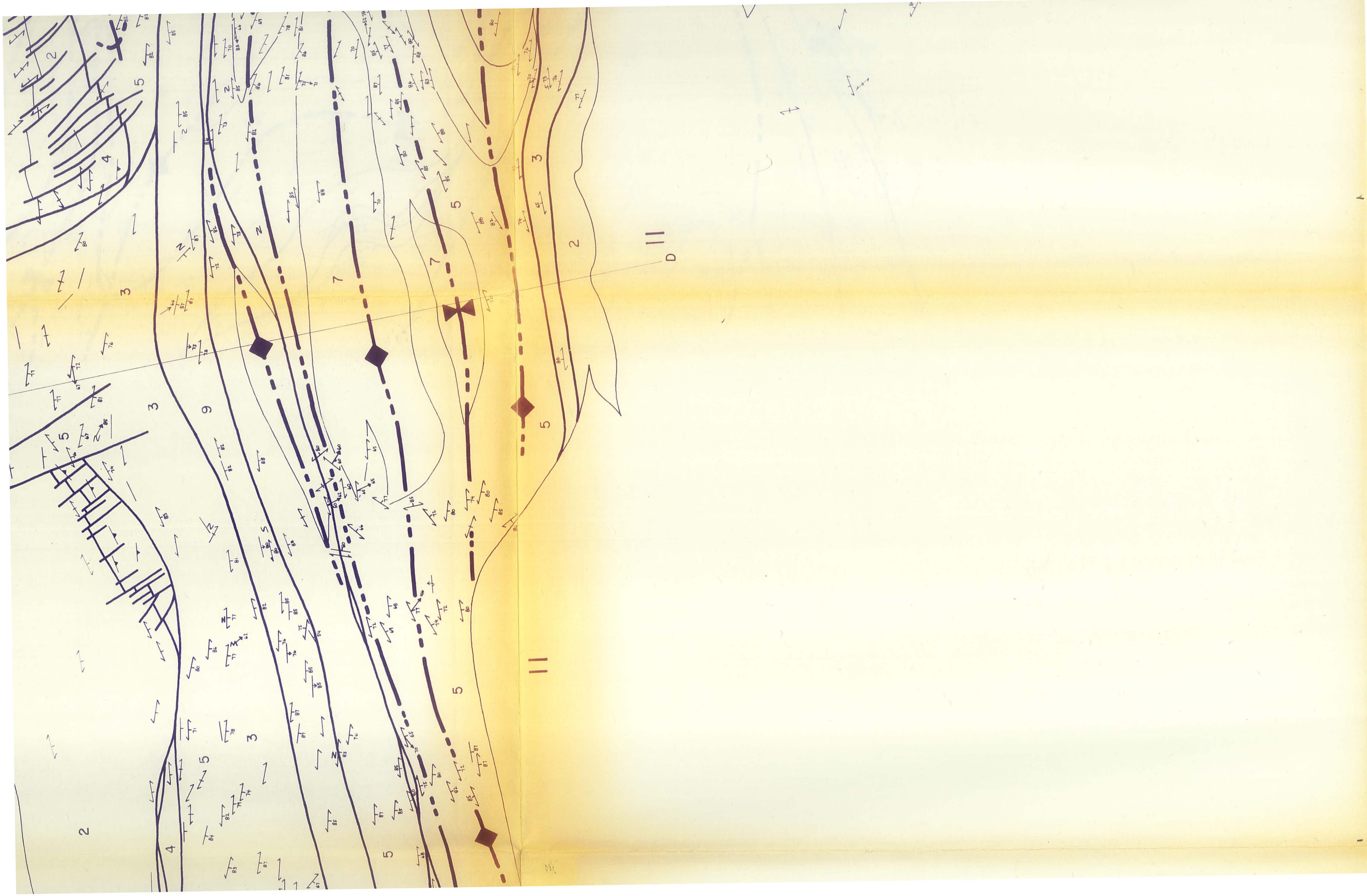
5
7
7
2
2

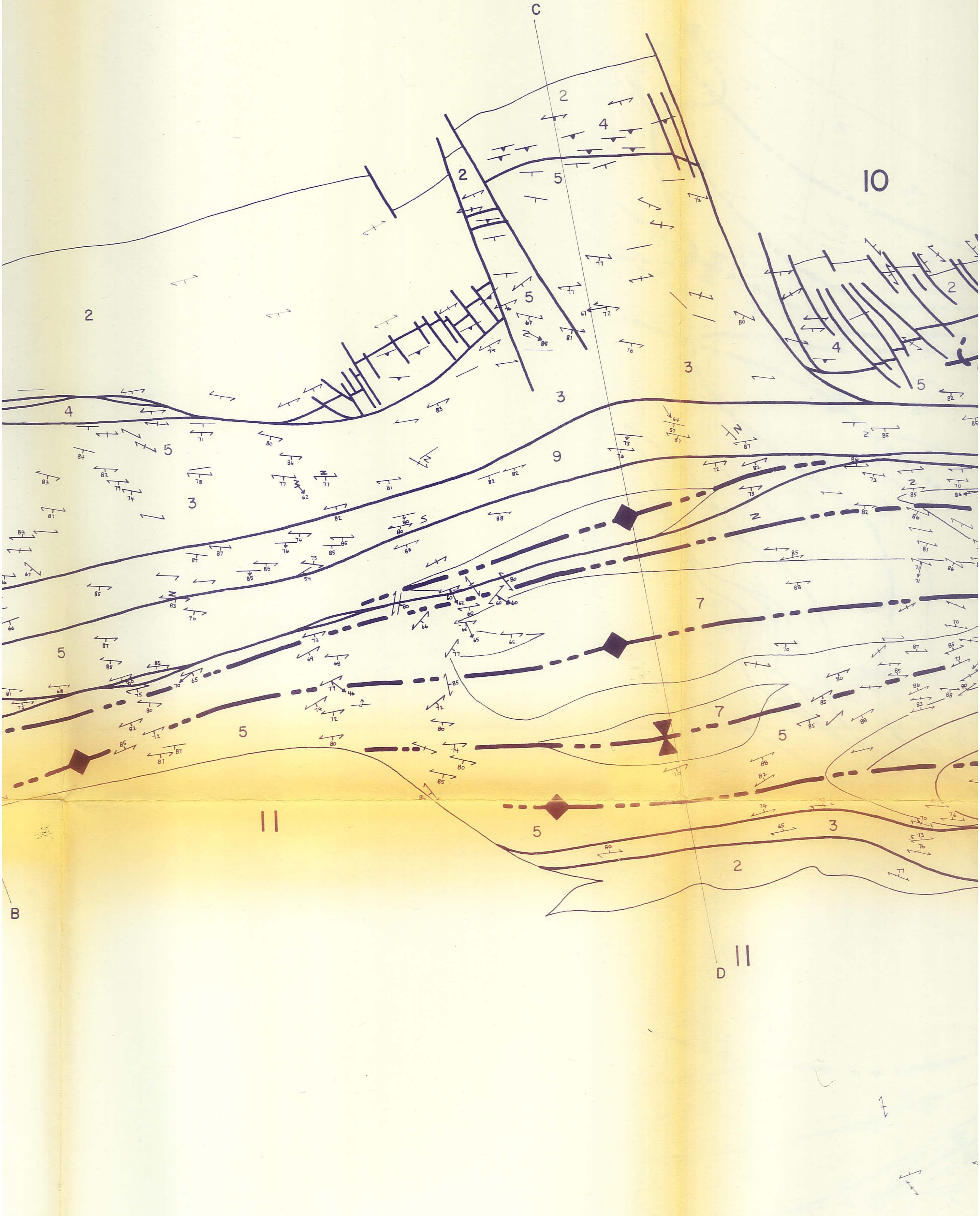

H
F



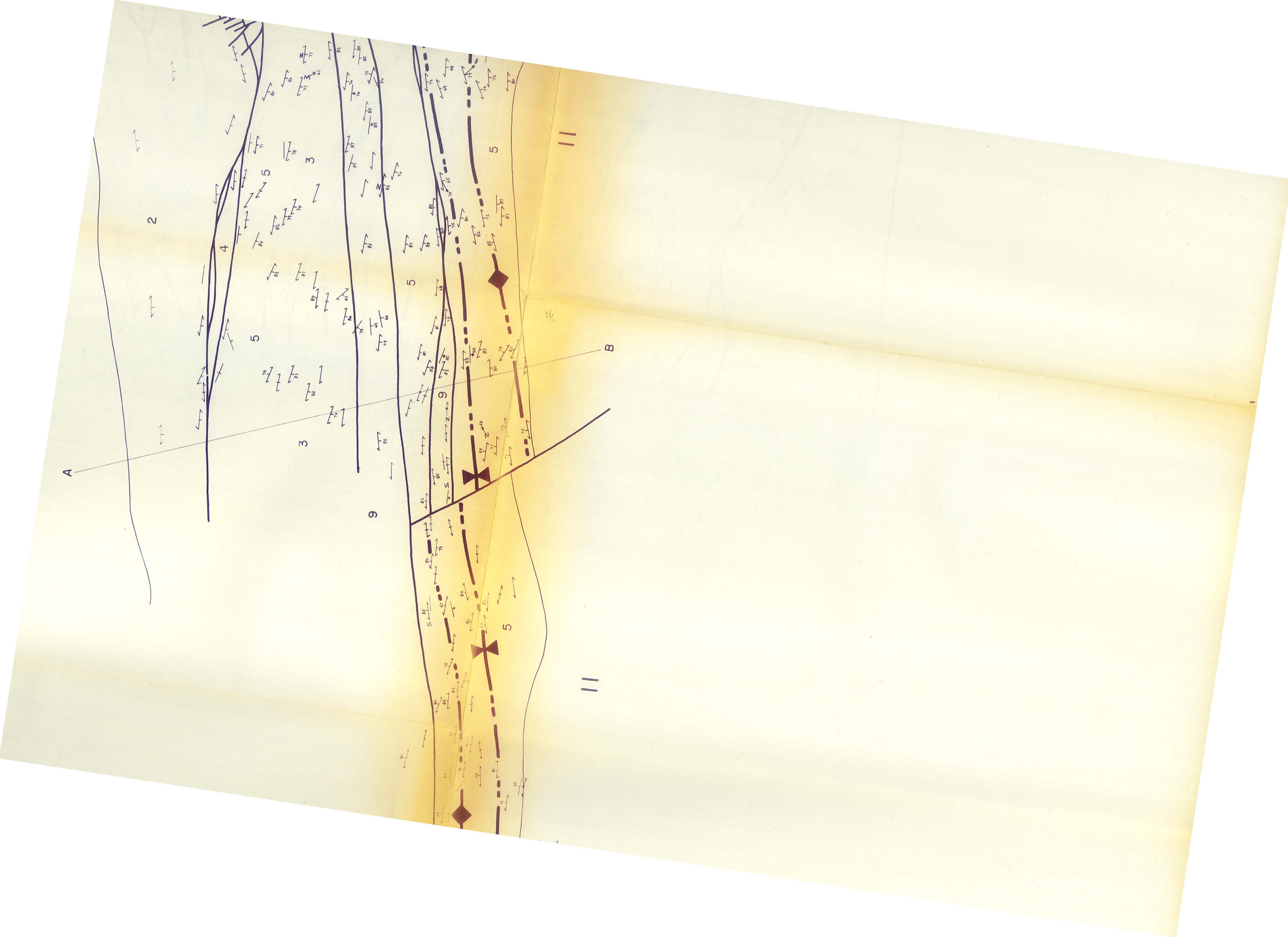


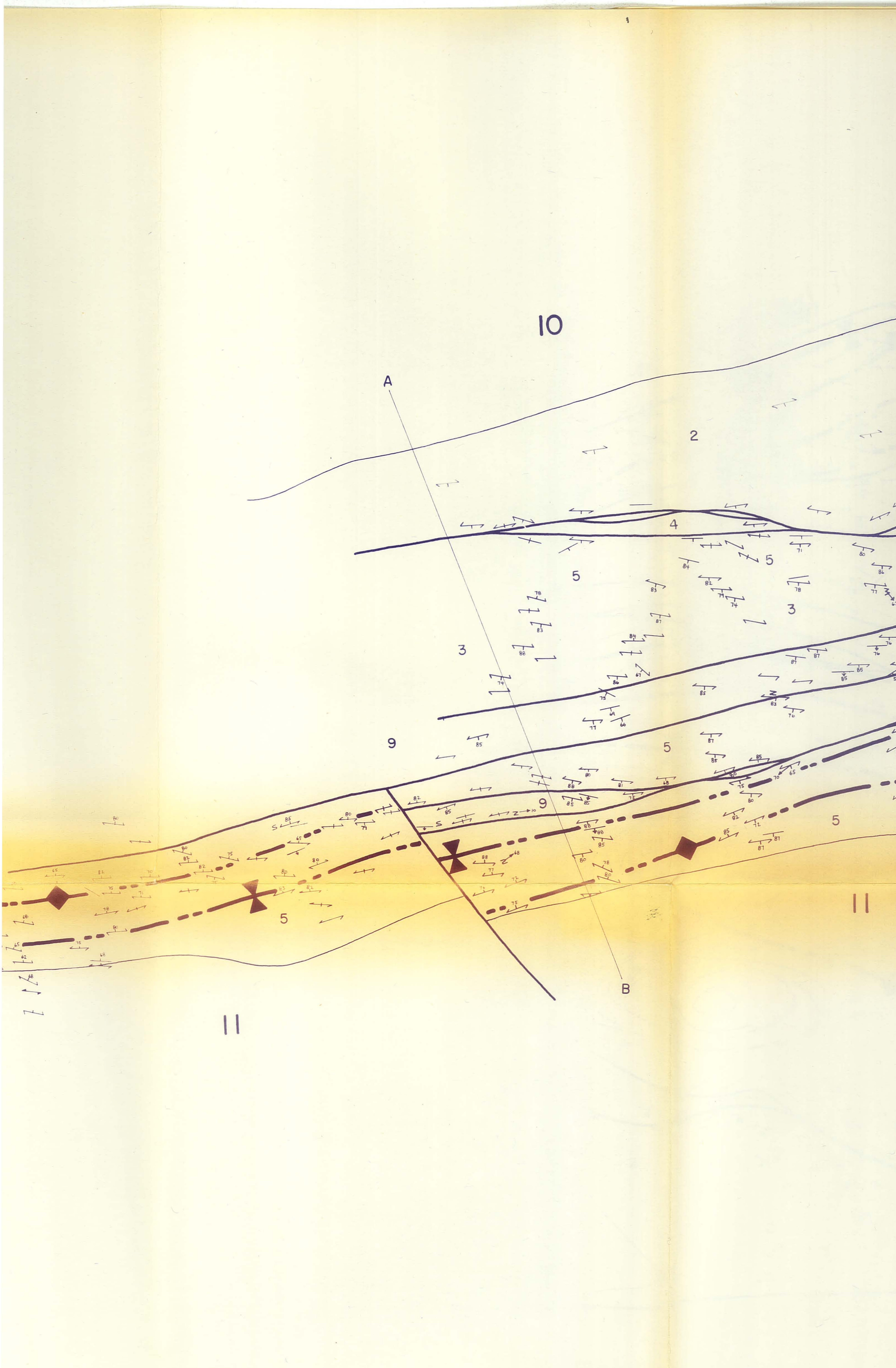

E
F
D
10
11





C
10
11
D
B


A
B
II



10
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B
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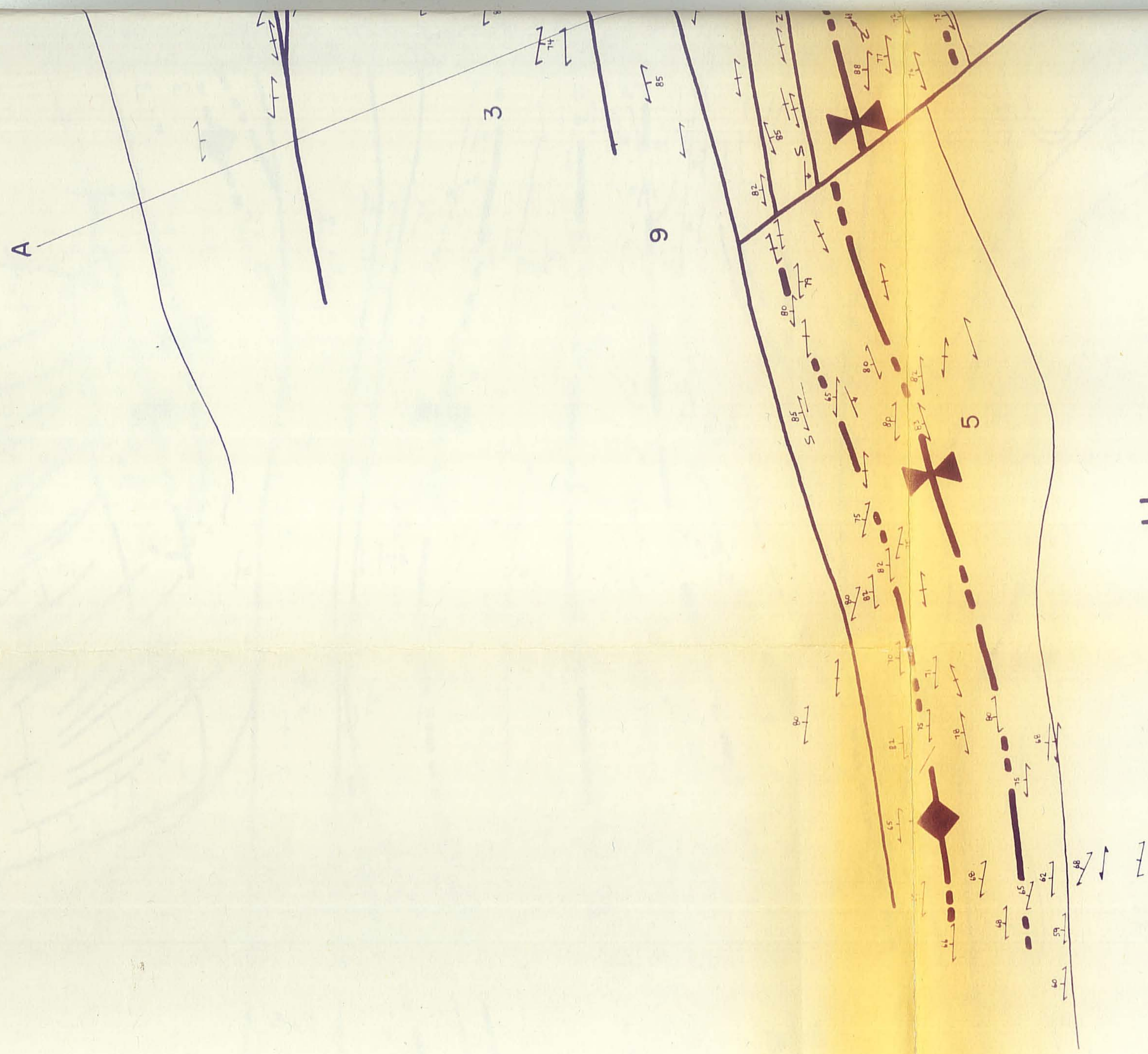
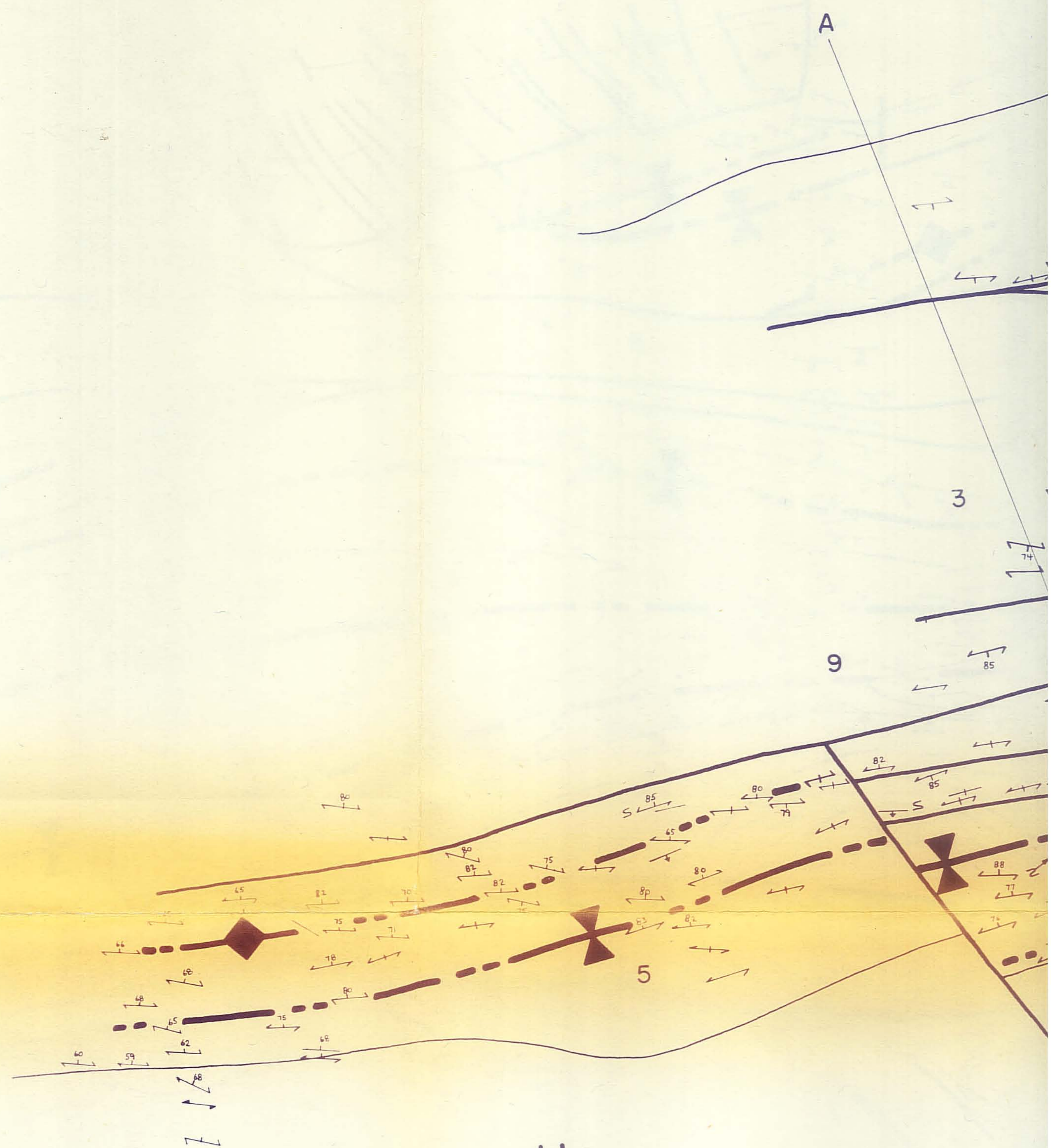



A
3
9
5
11

11 Lac du Bonnet quartz monzonite
b, related dykes

10 Great Falls quartz diorite – granite
a, Maskwa Lake batholith b, Marijane Lake batholith
c, related dykes

9 *Booster Lake Fm.* a, greywacke – mudstone
b, conglomerate / metamorphic equivalents

Unconformity

8 *Flanders Lake Fm.* a, lithic arenite
b, polymict conglomerate / metamorphic equivalents

Unconformity

7 a, gabbro b, diorite c, quartz-feldspar porphyry
d, granodiorite / metamorphic equivalents

6 quartz – feldspar porphyry

5 *Bernic Lake Fm.* a, basalt b, andesite c, dacite d, rhyolite
e, polymict conglomerate f, oligomict conglomerate / metamorphic
equivalents g, cordierite schist h, garnet – biotite schist

Unconformity

4 a, Bird River Sill b, gabbro
/ metamorphic equivalents

3 *Peterson Creek Fm.* a, rhyolite b, breccia
c, lapillistone d, lapilli tuff e, tuff
f, volcanic sandstone / metamorphic equivalents

2 *Lamprey Falls Fm.* a, pillow basalt b, porphyritic basalt
c, amygdaloidal basalt d, megacrystic basalt e, hyaloclastite-
aquagene breccia / metamorphic equivalents

1 *Eaglenest Lake Fm.* volcanic wacke, pebbly wacke,
volcanic sandstone / metamorphic equivalents

Geologic boundary
Iron formation
Fault
Road
Mine
C Geology compiled
Powerline

MAP A

Metavolcanic, metasedimentary, and intrusive rocks of the Bird River area

To accompany the Ph.D.
dissertation of
D. L. Trueman

ARCHEAN

RICE LAKE GROUP

INTRUSIVE ROCKS

12 pegmatite
b, pegmatitic granite

11 Lac du Bonnet quartz monzonite
b, related dykes

10 Great Falls quartz diorite – granite
a, Maskwa Lake batholith b, Marijane Lake batholith
c, related dykes

9 *Booster Lake Fm.* a, greywacke – mudstone
b, conglomerate / metamorphic equivalents

Unconformity

8 *Flanders Lake Fm.* a, lithic arenite
b, polymict conglomerate / metamorphic equivalents

Unconformity

7 a, gabbro b, diorite c, quartz-feldspar porphyry
d, granodiorite / metamorphic equivalents

6 quartz – feldspar porphyry

5 *Bernic Lake Fm.* a, basalt b, andesite c, dacite d, rhyolite
e, polymict conglomerate f, oligomict conglomerate / metamorphic equivalents g, cordierite schist h, garnet – biotite schist

Unconformity

4 a, Bird River Sill b, gabbro
/ metamorphic equivalents

3 *Peterson Creek Fm.* a, rhyolite b, breccia
c, lapillistone d, lapilli tuff e, tuff
f, volcanic sandstone / metamorphic equivalents

2 *Lamprey Falls Fm.* a, pillow basalt b, porphyritic basalt
c, amygdaloidal basalt d, megacrystic basalt e, hyaloclastite-aquagene breccia / metamorphic equivalents

1 *Eaglenest Lake Fm.* volcanic wacke, pebbly wacke,
volcanic sandstone / metamorphic equivalents

Geologic boundary

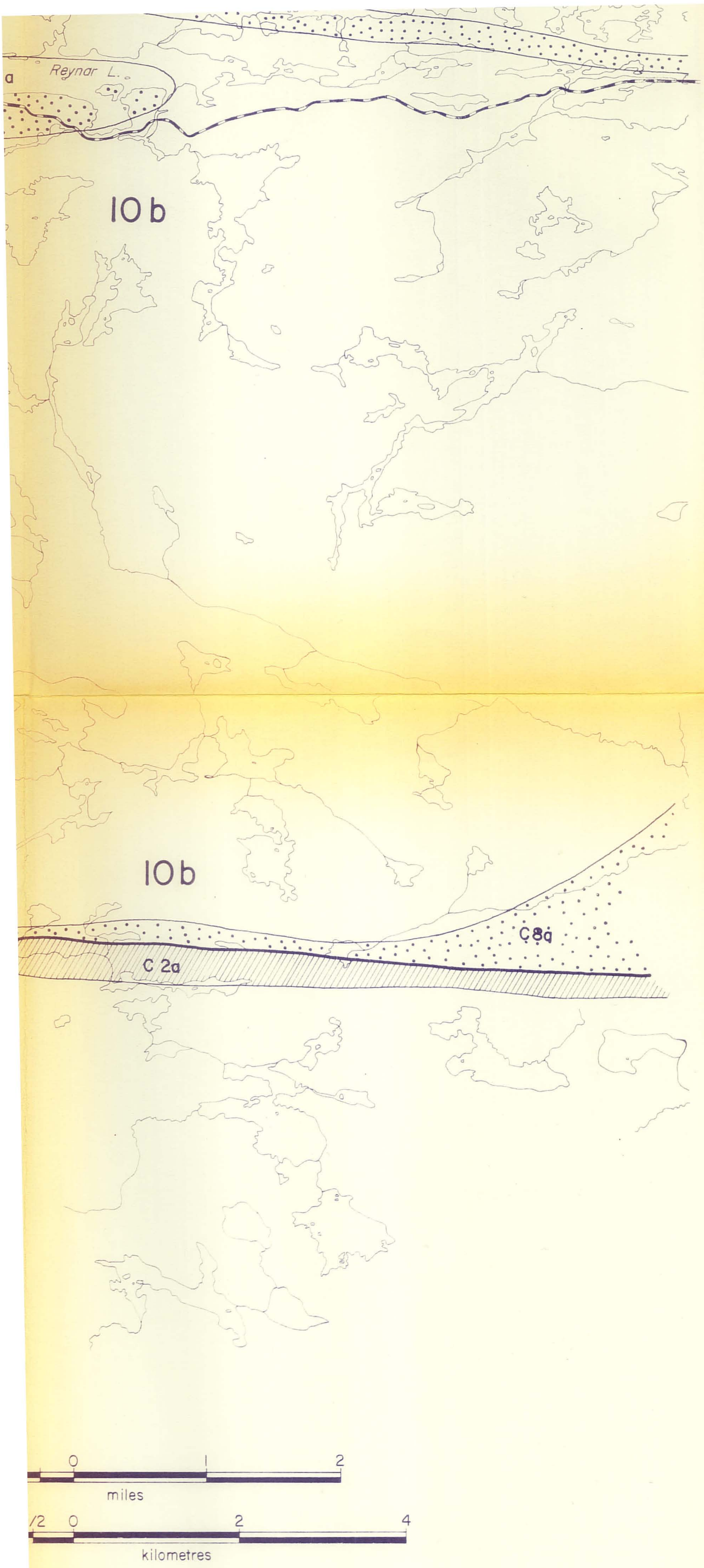
Iron formation

Fault

Road

Mine

C Geology compiled



Booster La
b, conglomer

Unconformity

Flanders L
b, polymict c

Unconformity

Bernic Lake
e, polymict co
equivalents

Unconformity

Peterson Cr
c, lapillistone
f, volcanic sa

Lamprey Fa
c, amygdaloida
aquagene b

Eaglenest L
volcanic sand

Geologic boun

Iron formation

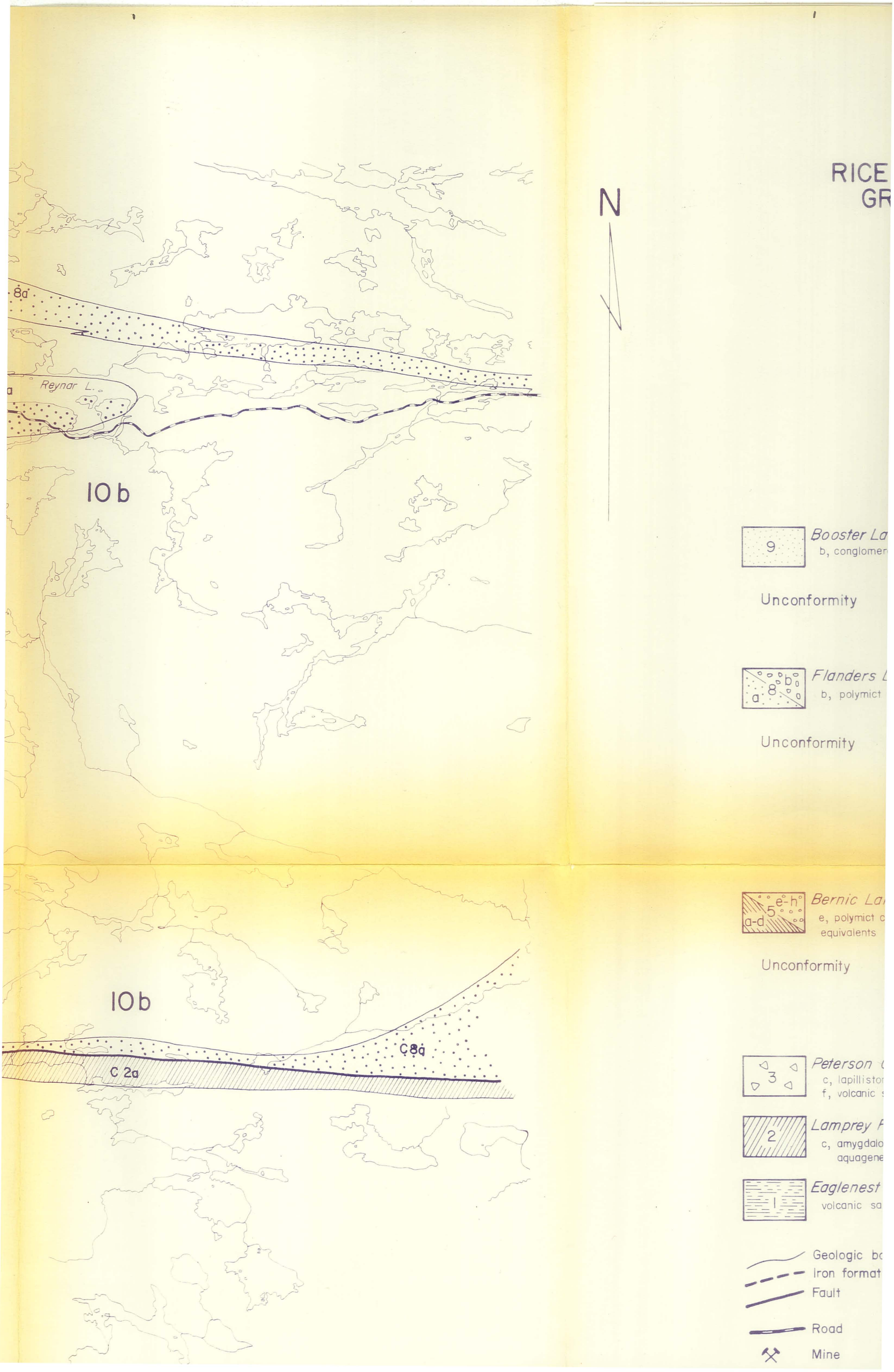
Fault

Road

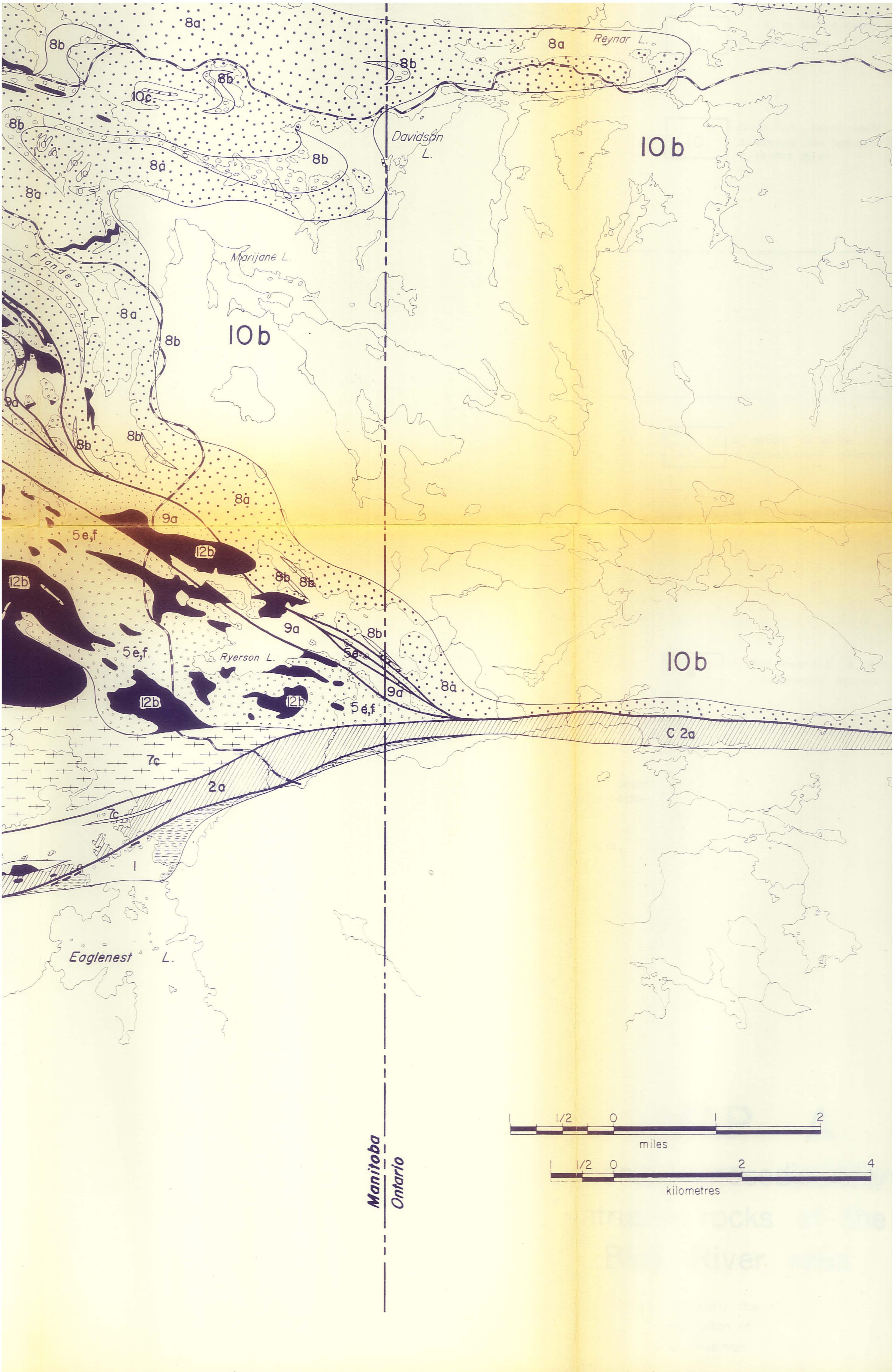
Mine

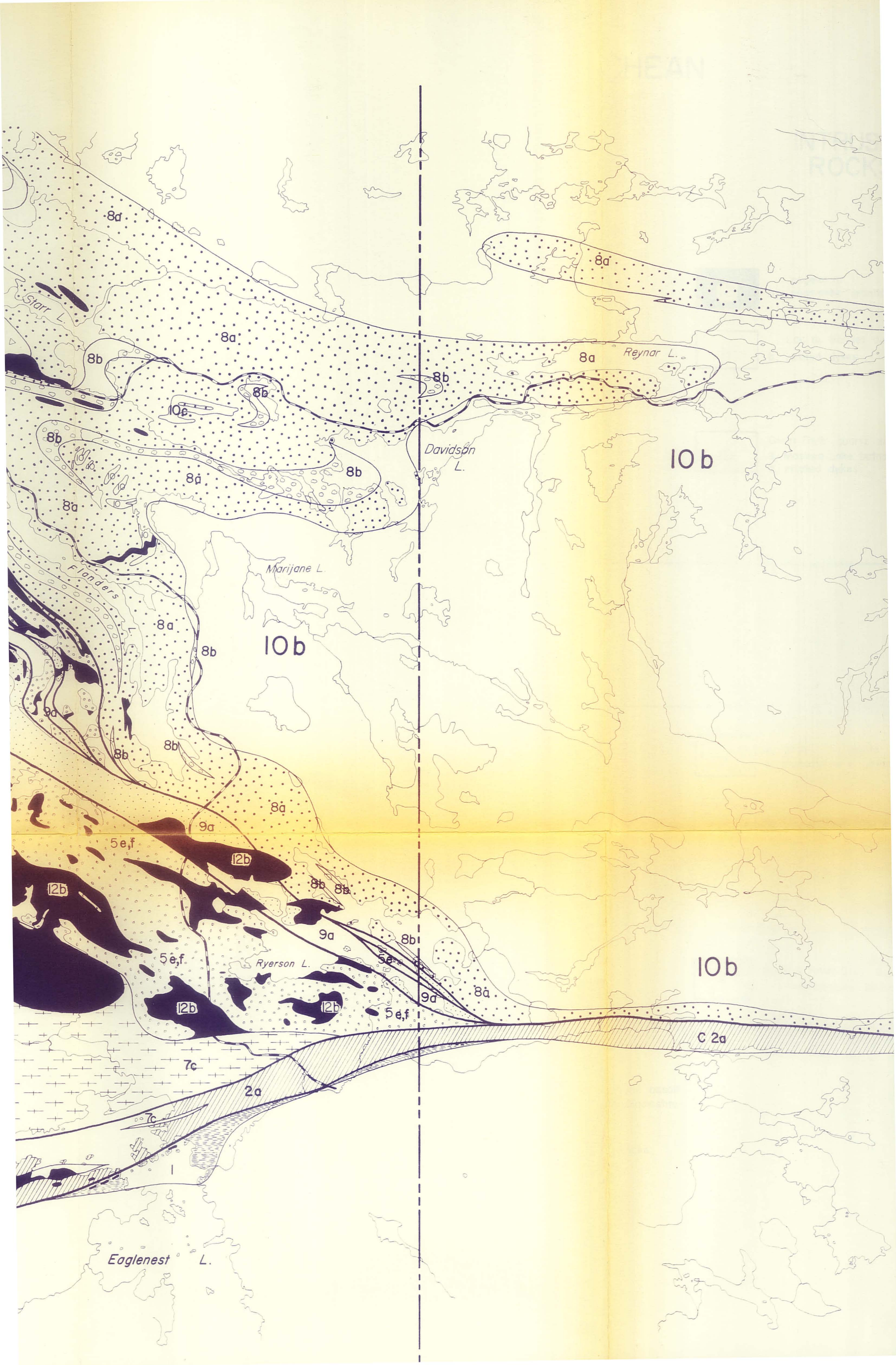
C Geology compi

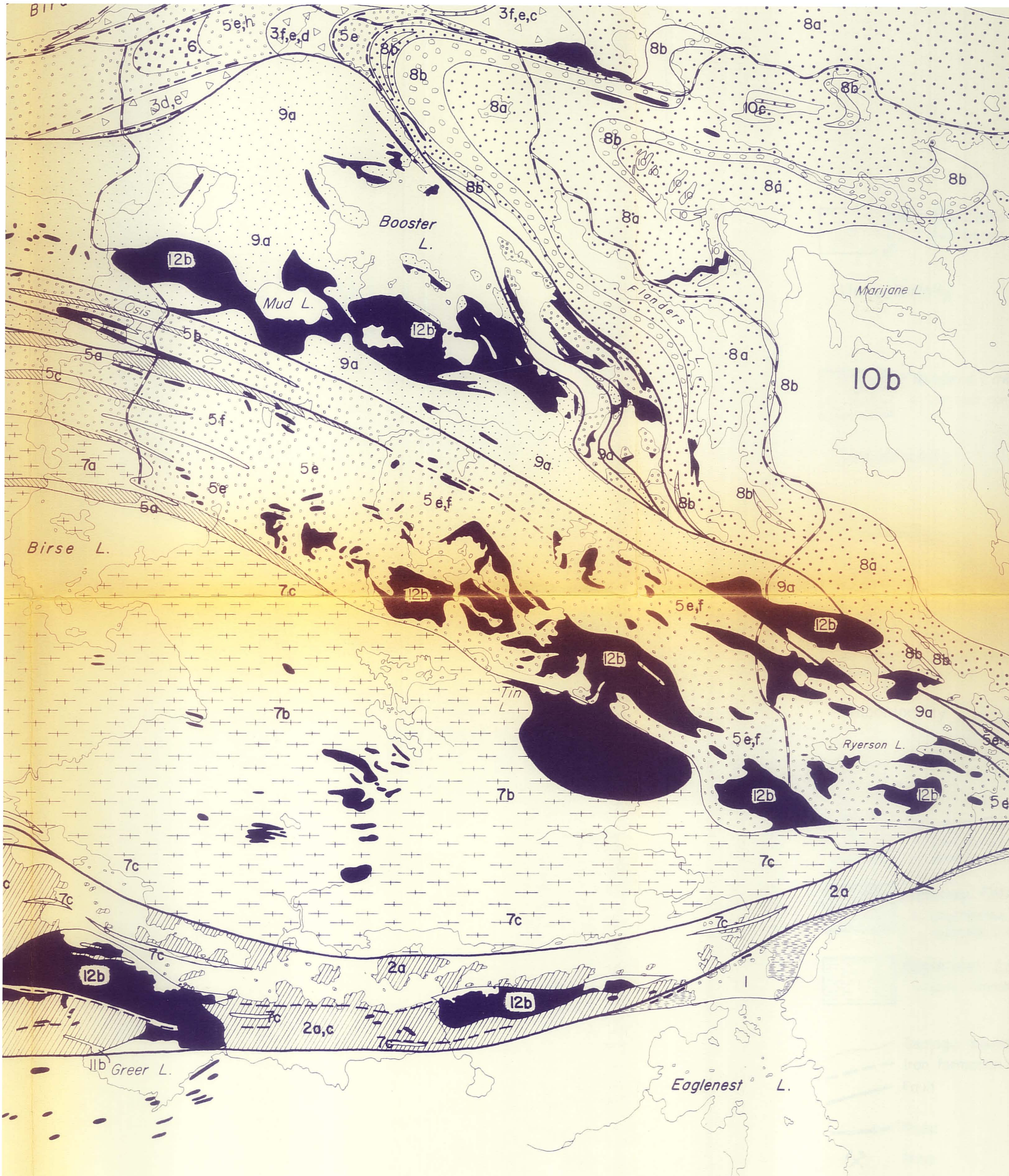
Powerline



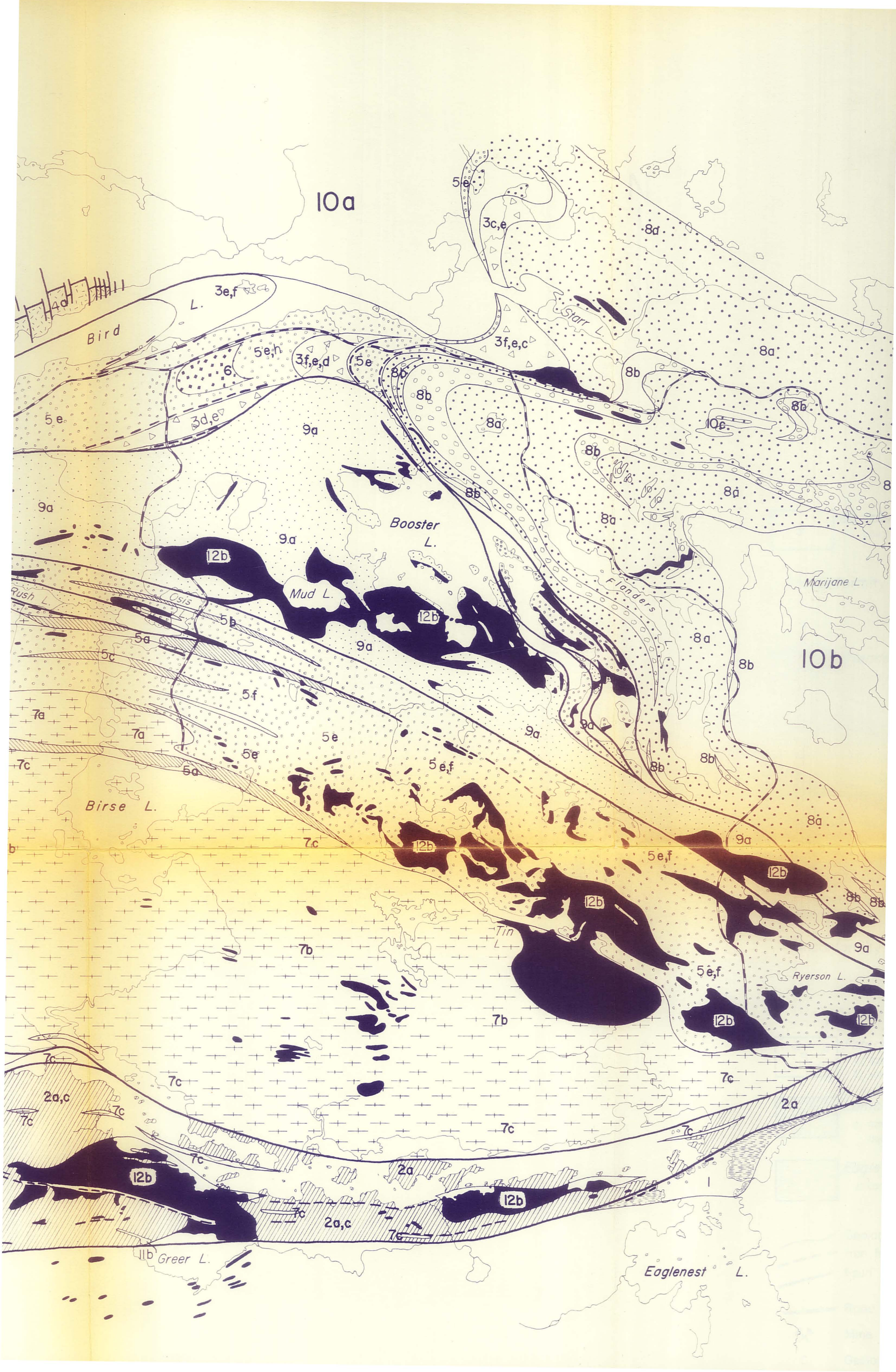
RICE
GR
N
8a
Reynar L.
a
10b
10b
C8a
C 2a
9
Booster La
b, conglomer
Unconformity
a 8 b
Flanders L
b, polymict
Unconformity
a-d 5 e-h
Bernic La
e, polymict c
equivalents
Unconformity
3
Peterson
c, lapillisto
f, volcanic
2
Lamprey
c, amygdalo
aquagene
1
Eaglenest
volcanic sa
Geologic bo
Iron format
Fault
Road
Mine

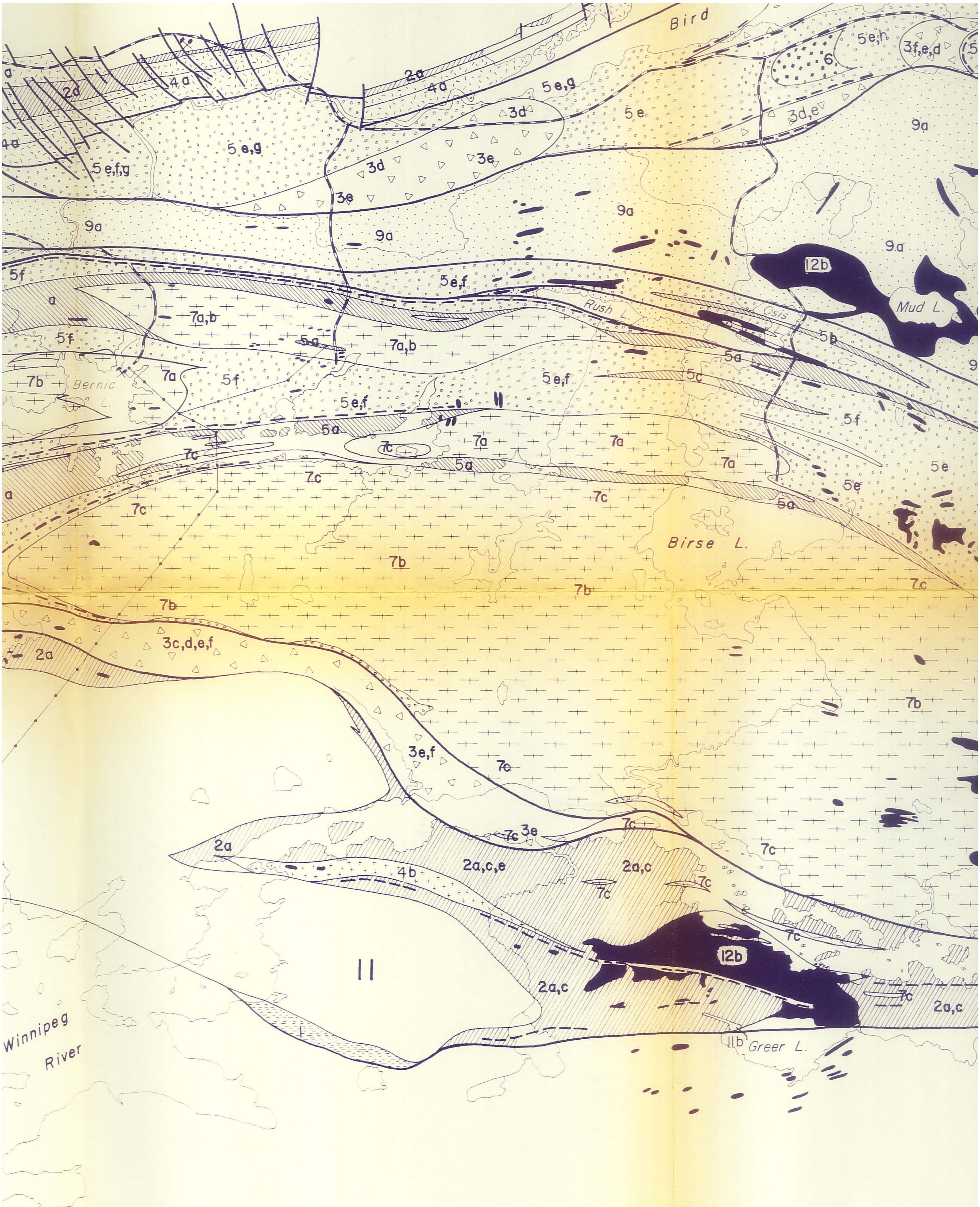

Reynar L.
Davidson L.
Marijane L.
Flanders L.
Ryerson L.
Eaglenest L.
10b
10b
10b
10c
8a
8b
9a
5e,f
12b
7c
2a
C 2a
1
Manitoba
Ontario
1/2 0 1 2
miles
1/2 0 2 4
kilometres


10b
10b
10b
8a
8b
8a
9a
5e,f
12b
7c
2a
C 2a
10e
1
Reynar L.
Davidson L.
Marijane L.
Ryerson L.
Flanders L.
Starr L.
Eaglenest L.

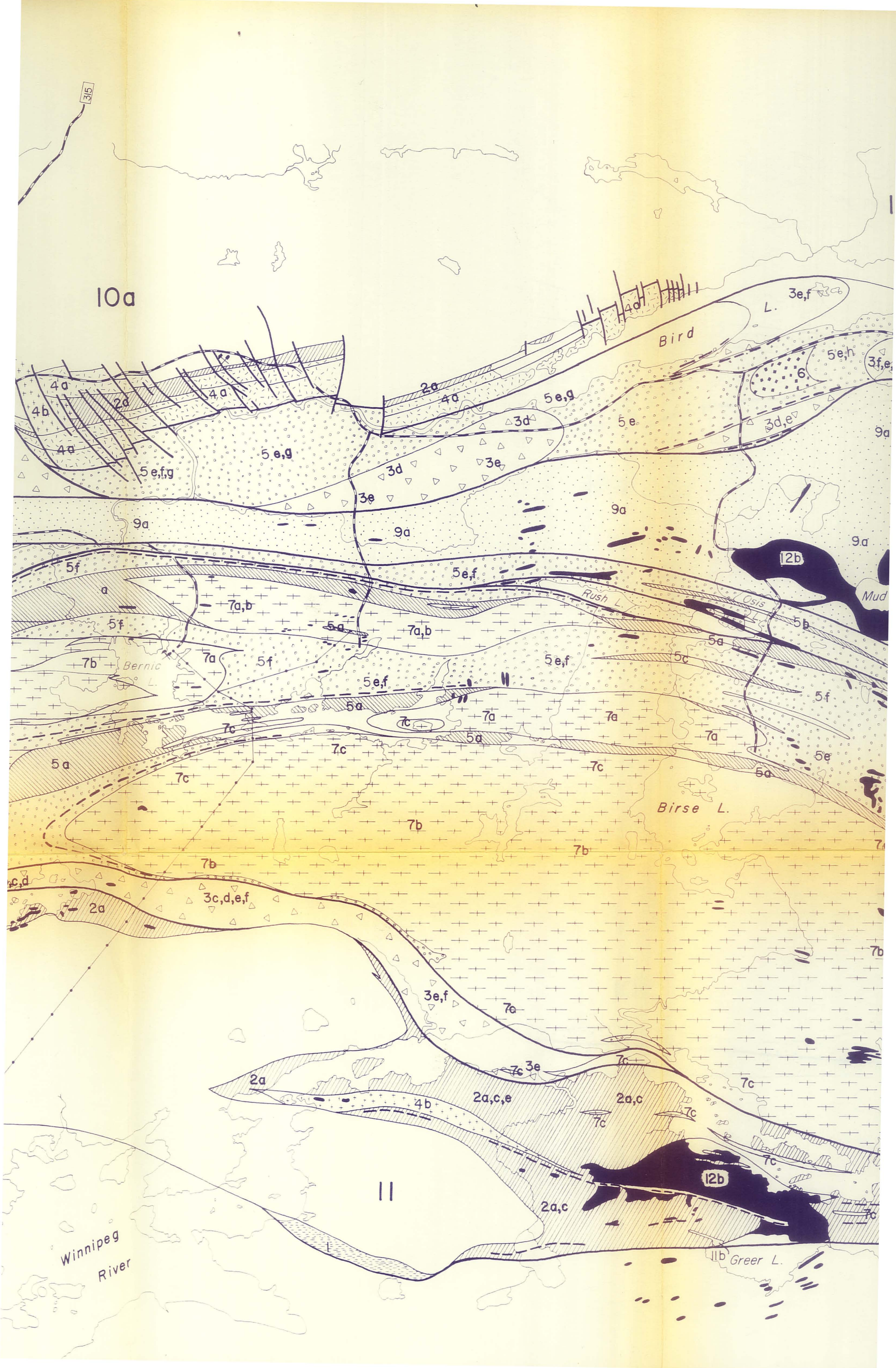


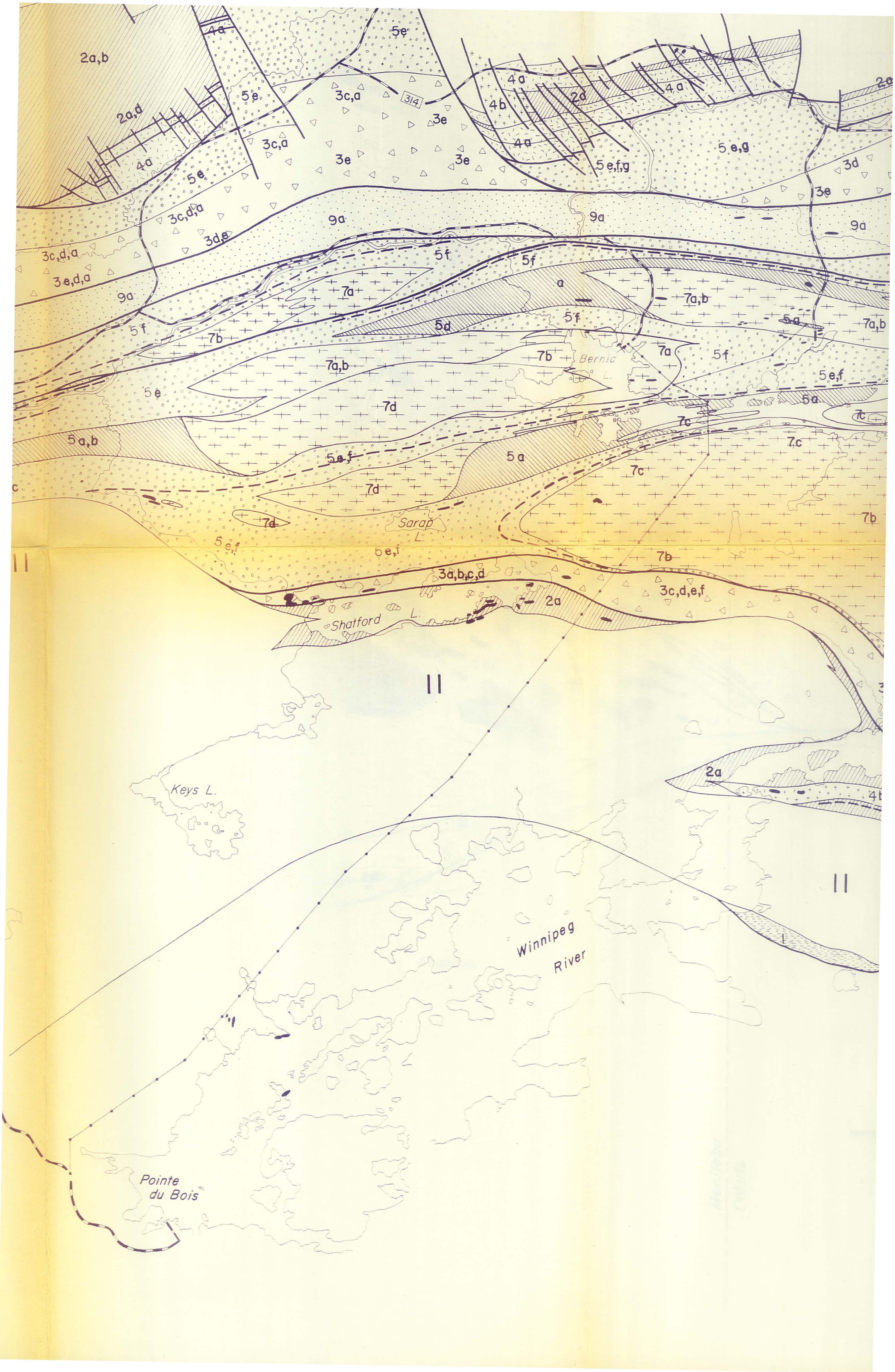
Marijane L.
10b
Ryerson L.
Eaglenest L.
Flanders L.
Booster L.
Mud L.
Tin L.
Osis L.
Birse L.
Greer L.
8a
8b
10c
3f,e,c
3f,e,d
5e,h
3d,e
5e
6
9a
12b
5e,f
5b
5a
5c
5f
7a
7b
7c
2a
2a,c
11b


10a
10b
Marijane L.
Ryerson L.
Eaglenest L.
Starr L.
Flanders L.
Booster L.
Mud L.
Tin L.
Birse L.
Bird L.
Osis L.
Rush L.
Greer L.
12b
2a
2a,c
7a
7b
7c
8a
8b
9a
5a
5b
5c
5e
5f
5e,f
5e,h
3c,e
3e,f
3f,e,c
3f,e,d
3d,e
4d
6
10c
11b

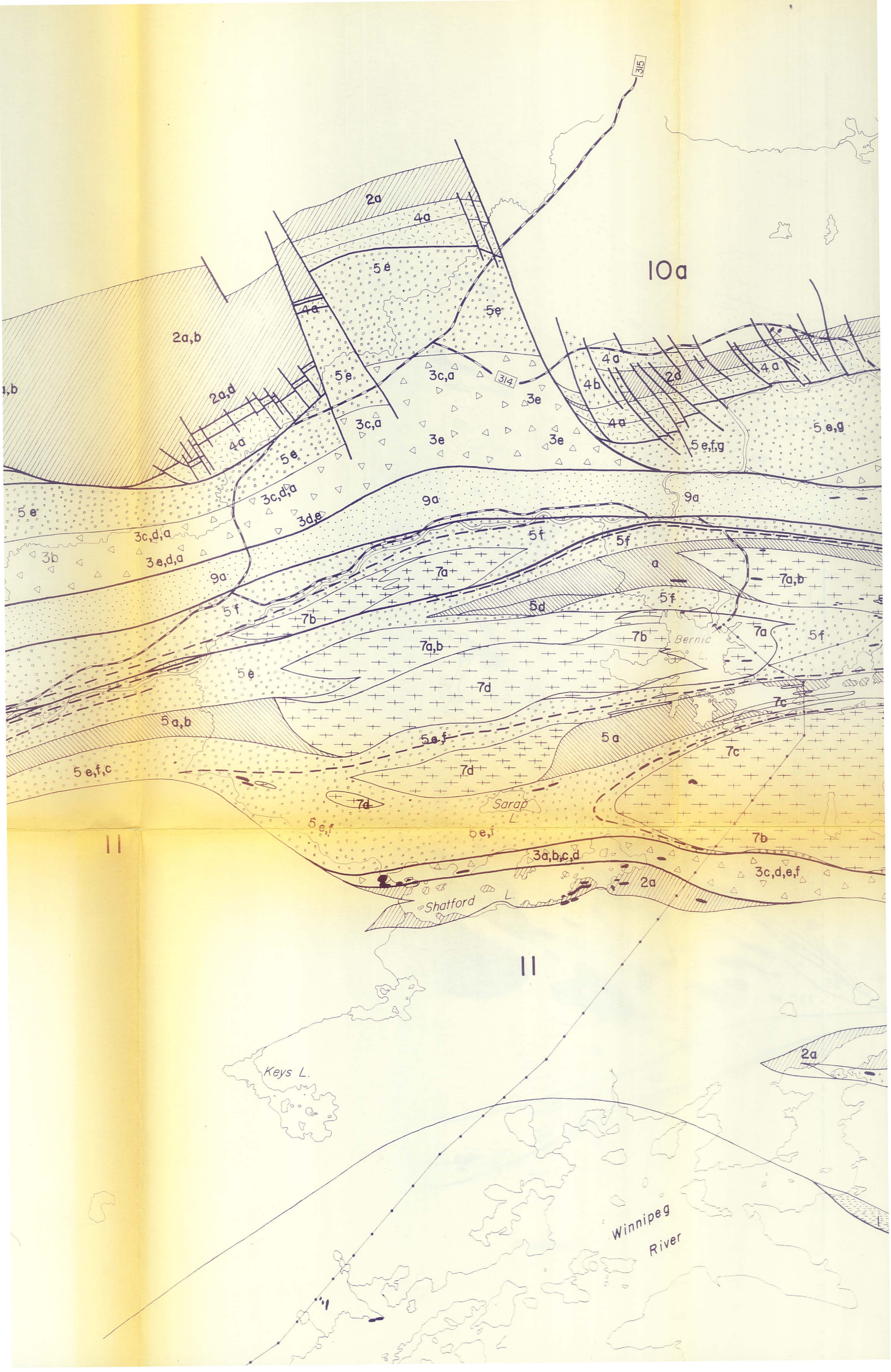


Bird
Mud L.
Rush L.
Osis L.
Bernic L.
Birse L.
Greer L.
Winnipeg River

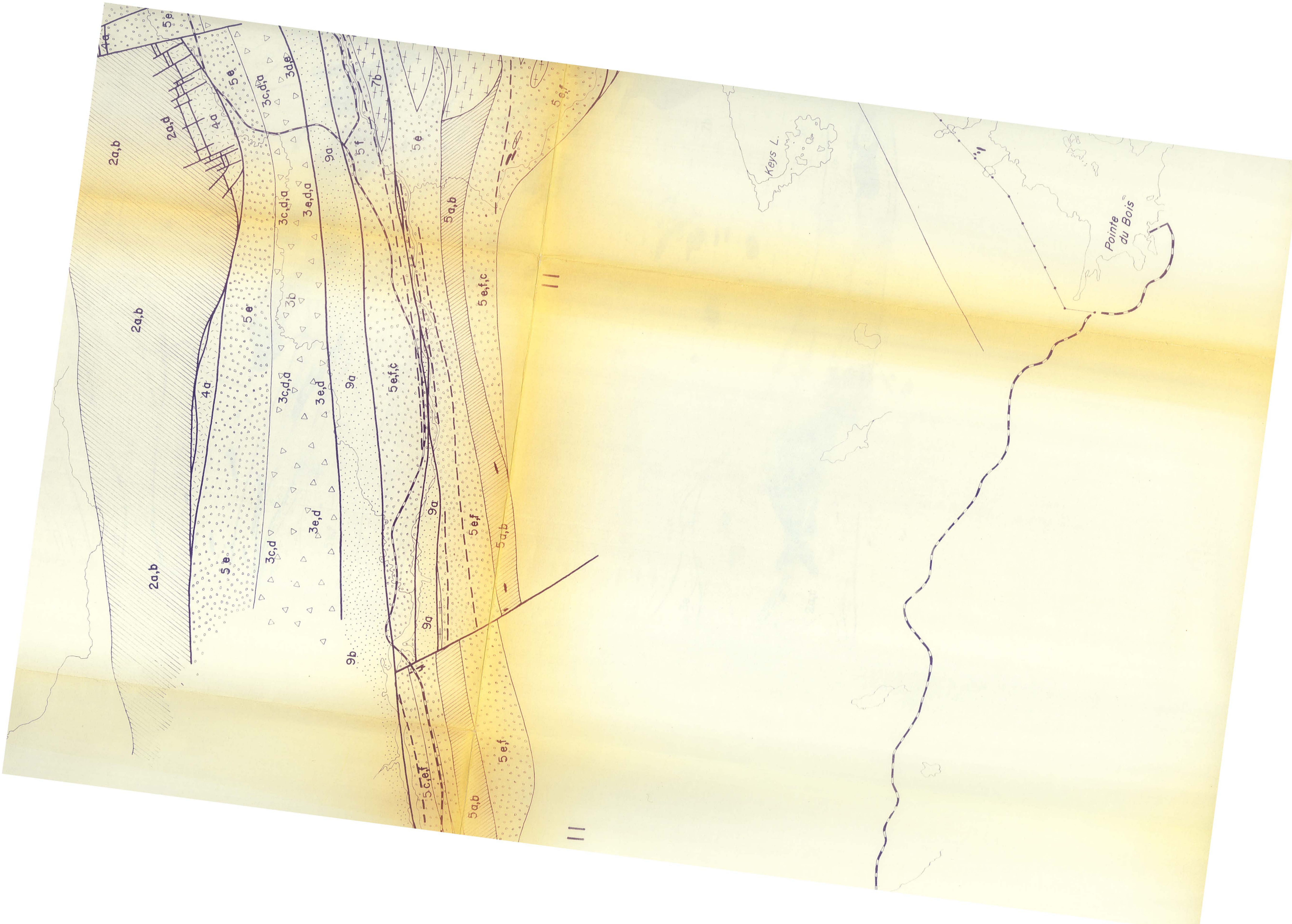

10a
Bird L.
Rush L.
Osis L.
Mud
Bernic L.
Birse L.
Greer L.
Winnipeg River
11
12b
315

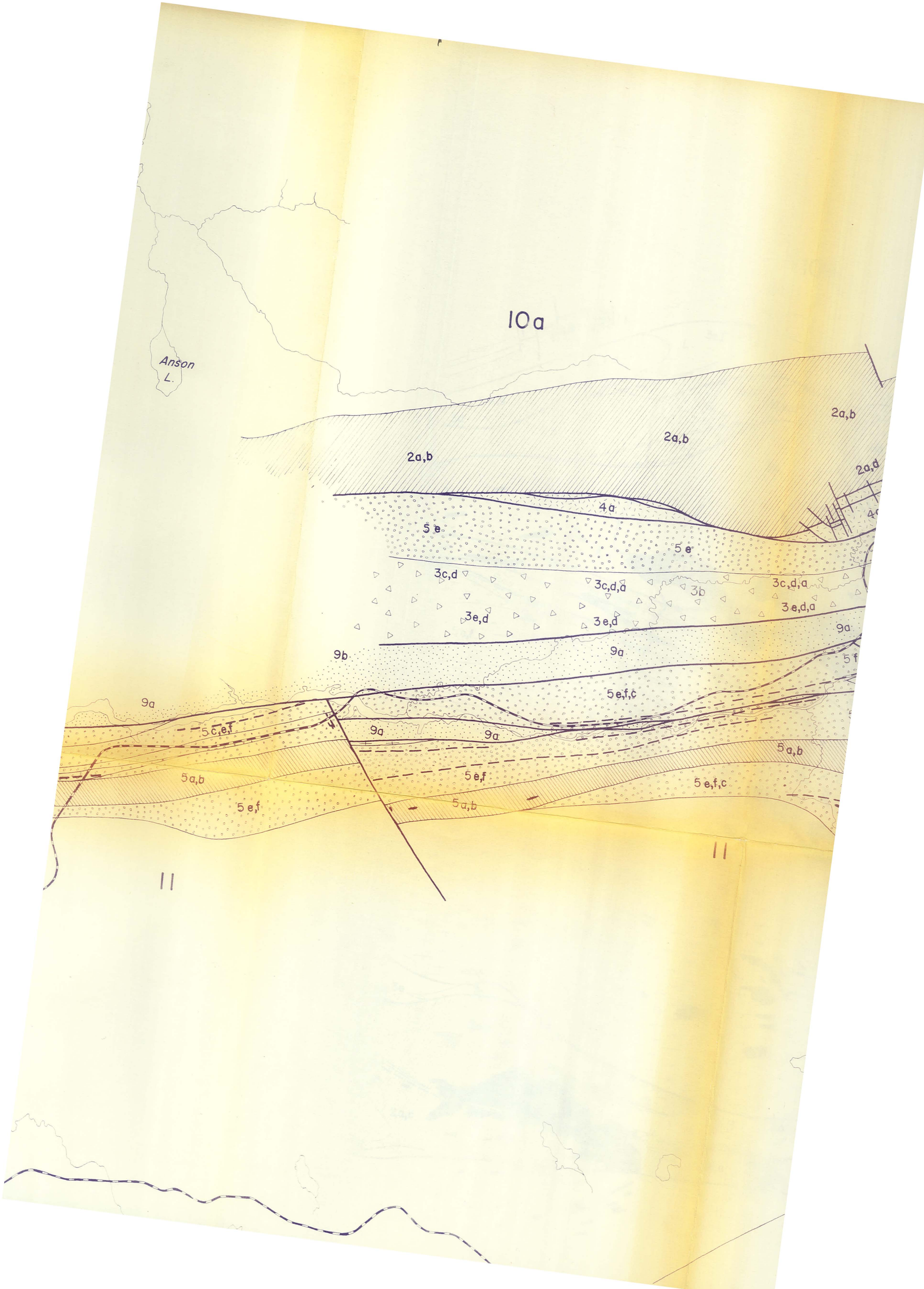


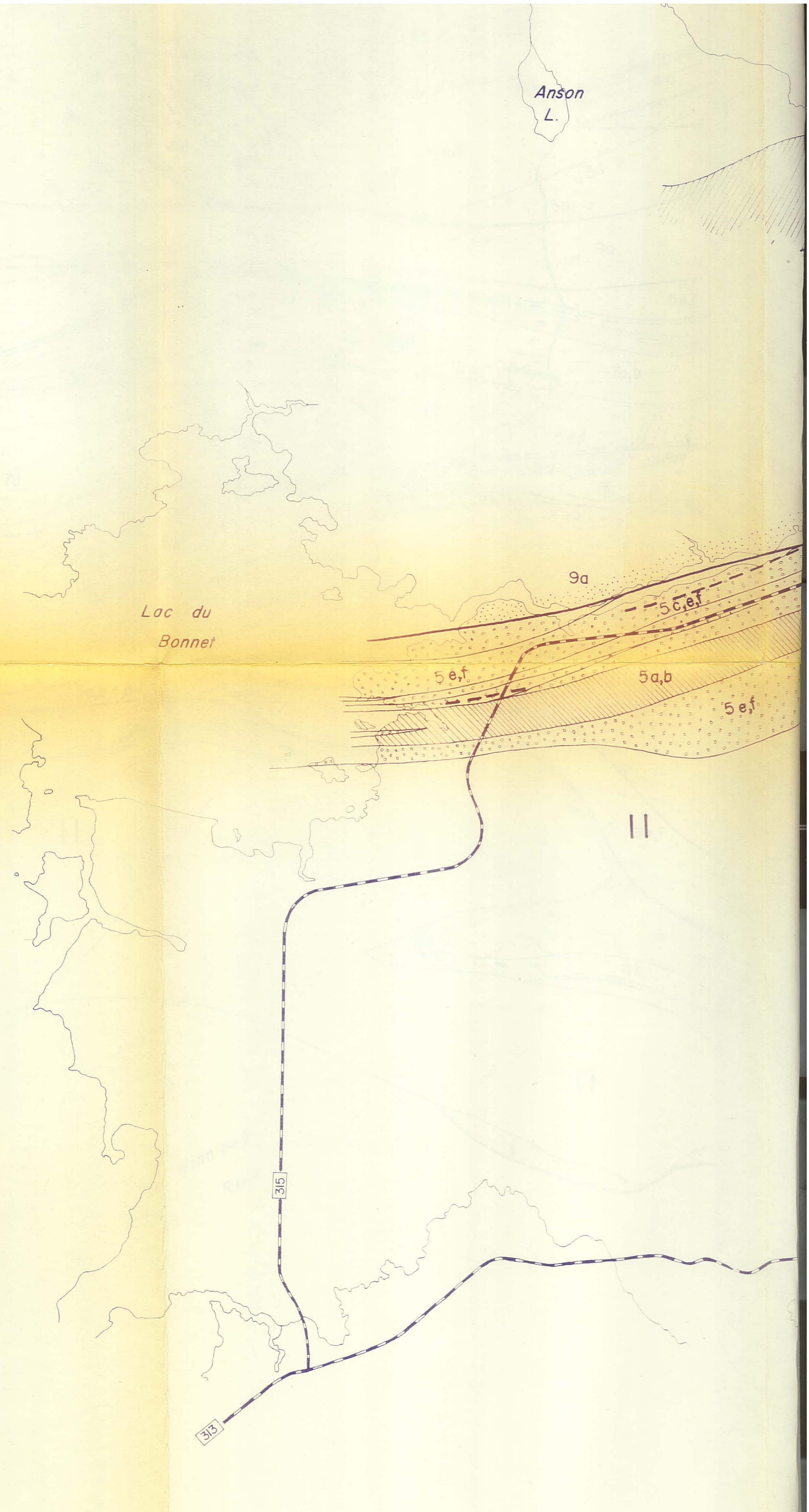
Bernic L.
Sarap L.
Shatford L.
Keys L.
Winnipeg River
Pointe du Bois
314



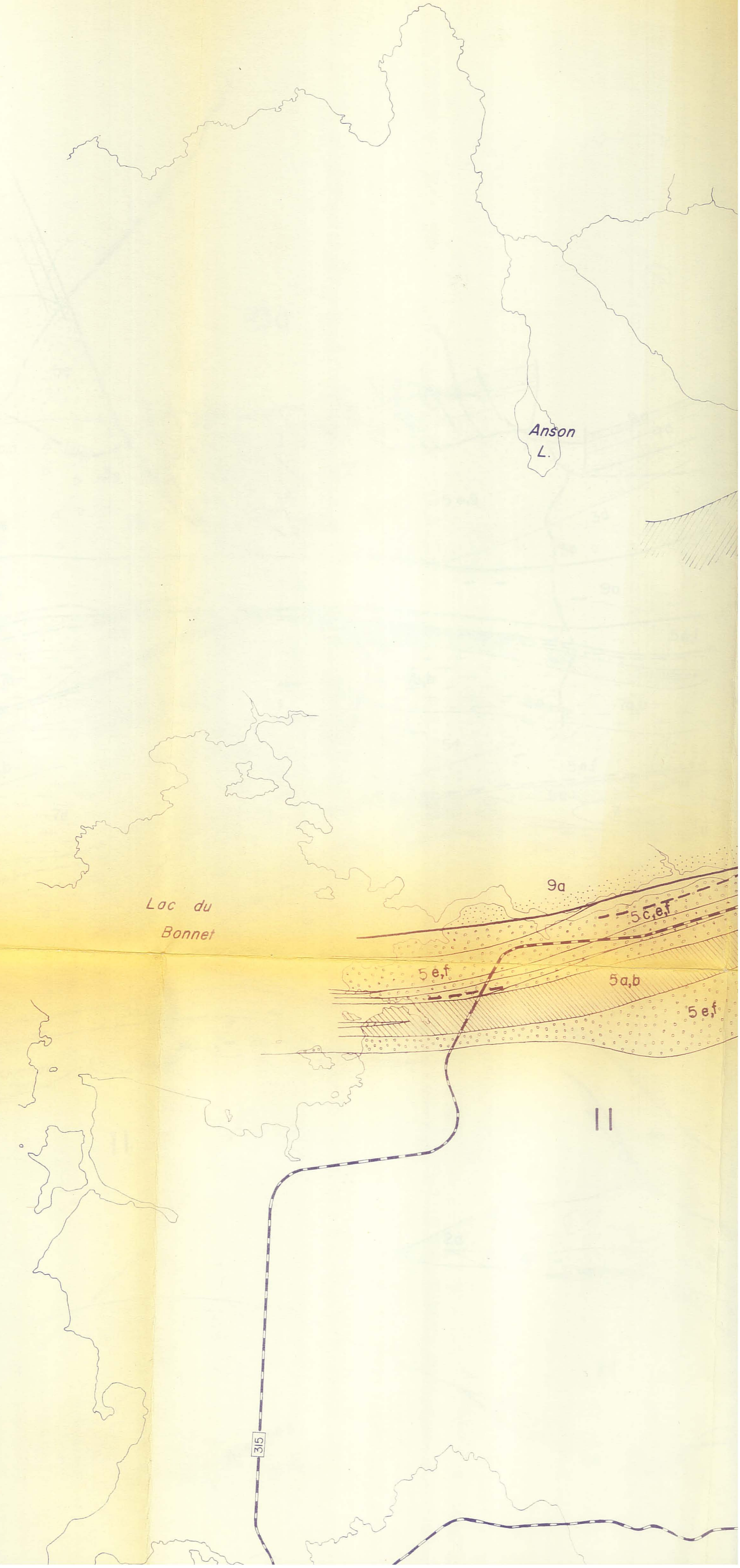
315
314
10a
11
11
2a
4a
5e
5e
4a
2a,b
2a,d
4a
5e
3c,a
3e
3e
3c,a
3e
4a
4b
2d
4a
4a
5 e,f,g
5 e,g
5e
3c,d,a
3d,e
9a
9a
3b
3c,d,a
3e,d,a
9a
5f
5f
7a
a
7a,b
5d
5f
7b
7b
7a
5f
Bernic L.
7a,b
5e
7d
7c
5a,b
5e,f
5a
7c
5 e,f,c
7d
7d
Sarap L.
5 e,f
5 e,f
7b
3a,b,c,d
3c,d,e,f
2a
Shatford L.
Keys L.
2a
Winnipeg River


2a,b
2a,d
4a
5e
3c,d,a
3d,e
7b
5f
9a
5e
5e,f
3c,d,a
3e,d,a
5a,b
5e,f,c
3b
5e
2a,b
4a
3c,d,a
3e,d
9a
5e,f,c
3c,d
3e,d
5e
9a
5e,f
5a,b
2a,b
9b
9a
5c,e,f
5a,b
5e,f
Keys L.
Pointe du Bois


10a
Anson L.
2a,b
2a,b
2a,b
2a,d
4a
5 e
5 e
3c,d
3c,d,a
3b
3c,d,a
3e,d
3e,d
3e,d,a
9a
9b
9a
5 e,f,c
9a
5 c,e,f
9a
9a
5 a,b
5 e,f
5 e,f,c
5 a,b
5 e,f
5 a,b
11
11



TRUEMAN, D.L.



TRUEMAN, D.L.