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A STRUCTURAL ANALYSIS OF AN ANTICLINE-SYNCLINE

PAIR IN THE LABRADOR TROUGH

NEAR SCHEFFERVILLE, P. Q.

A STRUCTURAL ANALYSIS OF AN ANTICLINE-SYNCLINE PAIR IN THE LABRADOR TROUGH NEAR SCHEFFERVILLE, P.Q.

By

B. TERRENCE HENNESSEY

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AUTHOR: B. Terrence Hennessey

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SCOPE AND CONTENTS:

A syncline-anticline pair in miogeosynclinal sediments of the western margin of the Labrador Trough was mapped. Samples were taken of each rock unit and a structural analysis was performed. The structure determined was compared in an elementary fashion to geophysics completed over the mapping area.

The folds in the pair are highly variable along their length changing from an open to tight folding style and with a rolling plunge varying from 3° NW to 12° SE.

The beds of the folds show no internal deformation except for drag folding in the shaly units. The rocks were folded by a flexural slip mechanism.

The gravity and ground magnetics successfully outlined the structure of the fold, dipping of the beds and in one instance located a fault. Typical gravity values (signatures) for a number of rock units are easily determined.

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CHAPTER I

INTRODUCTION

The Labrador Trough is a Proterozoic basin which has been studied in great detail in the area of Schefferville, P. Q. Most of this work was completed by the Iron Ore Company of Canada (hereafter called I. O. C.) because of their open pit iron mines located there.

A study of a syncline-anticline pair located in the miogeosynclinal sediments of the basin near Schefferville was undertaken to

1) outline and analyse the structure of the folds
2) compare, in an elementary fashion, the structure determined to geophysics completed on the area.

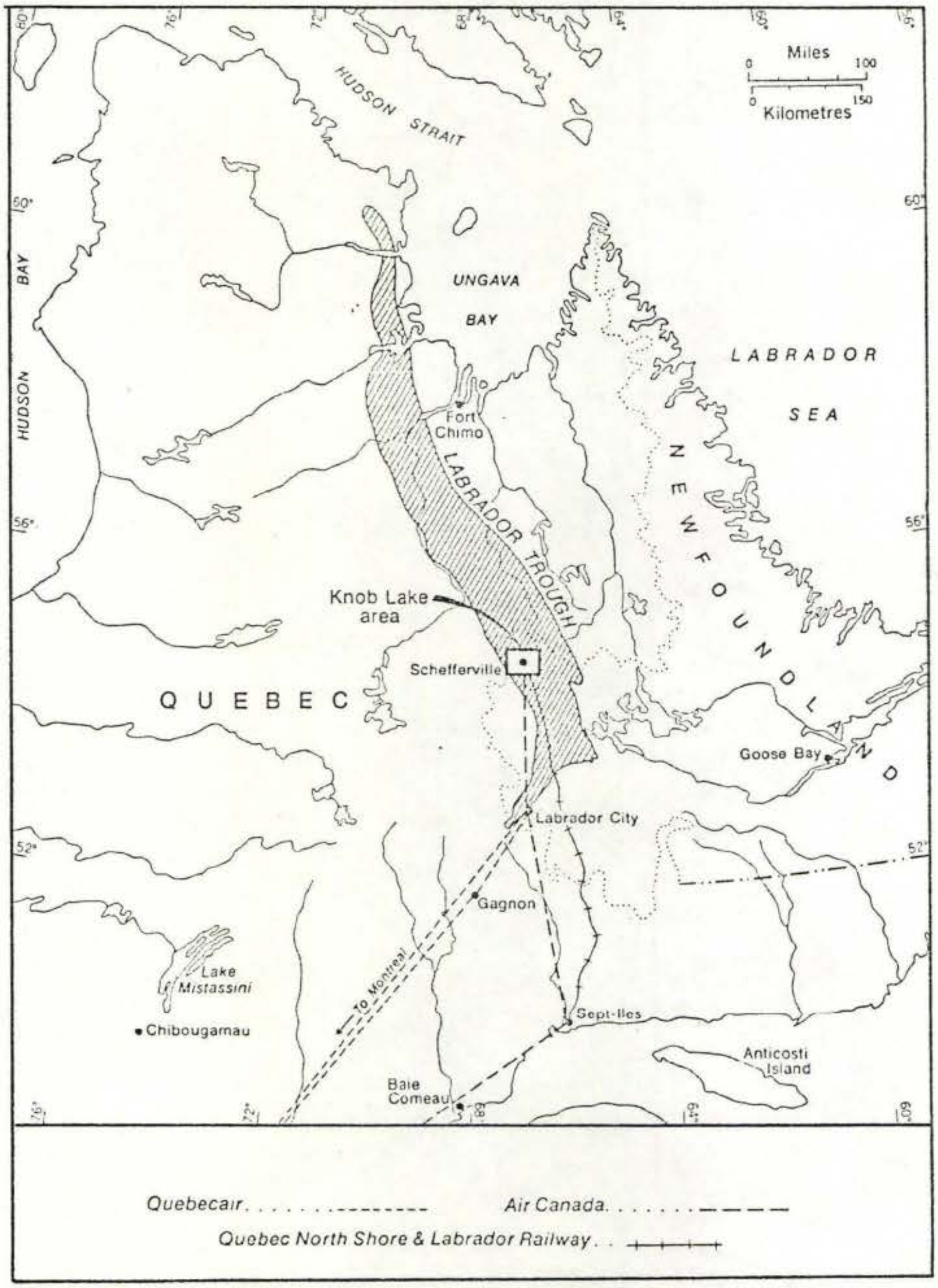
LOCATION AND ACCESSIBILITY:

The town of Schefferville, Quebec, is located in the central segment of the Labrador Trough (see Figure 1) on the Quebec-Labrador border. Schefferville is accessible by daily jetliner service or by a twice weekly passenger train. The train runs from the ore shipping port of Sept Isles, P. Q., north for 580 kilometers to Schefferville. There is no road access to the town.

FIGURE 1

Location of Shefferville

(after Zajac, 1972)



Miles
0
100
0
150
Kilometres
HUDSON STRAIT
UNGAVA
BAY
HUDSON
BAY
LABRADOR
SEA
Fort Chimo
LABRADOR TROUGH
NEWFOUNDLAND
Knob Lake
area
Schefferville
QUEBEC
Goose Bay
Labrador City
Gagnon
Lake
Mistassini
Chibougamau
To Montreal
Sept-Iles
Anticosti
Island
Baie
Comeau
60°
56°
52°
76°
72°
68°
64°
60°
Quebecair
Air Canada
Quebec North Shore & Labrador Railway

The thesis area is located approximately 26 kilometers northwest of the town and is easily accessible from the townsite by mine and drag roads (see Figure 2).

PREVIOUS WORK:

During the mid to late 19th century a number of explorers and missionaries passed through the Schefferville area, some mentioning having seen iron in the rocks. The first geologist to arrive was A. P. Low of the Canadian Geological Survey doing reconnaissance mapping. His work was followed up in 1929 by J. E. Gill who discovered direct shipping soft iron ore, arousing the interest of the Labrador Mining and Exploration Company. They began prospecting in 1936.

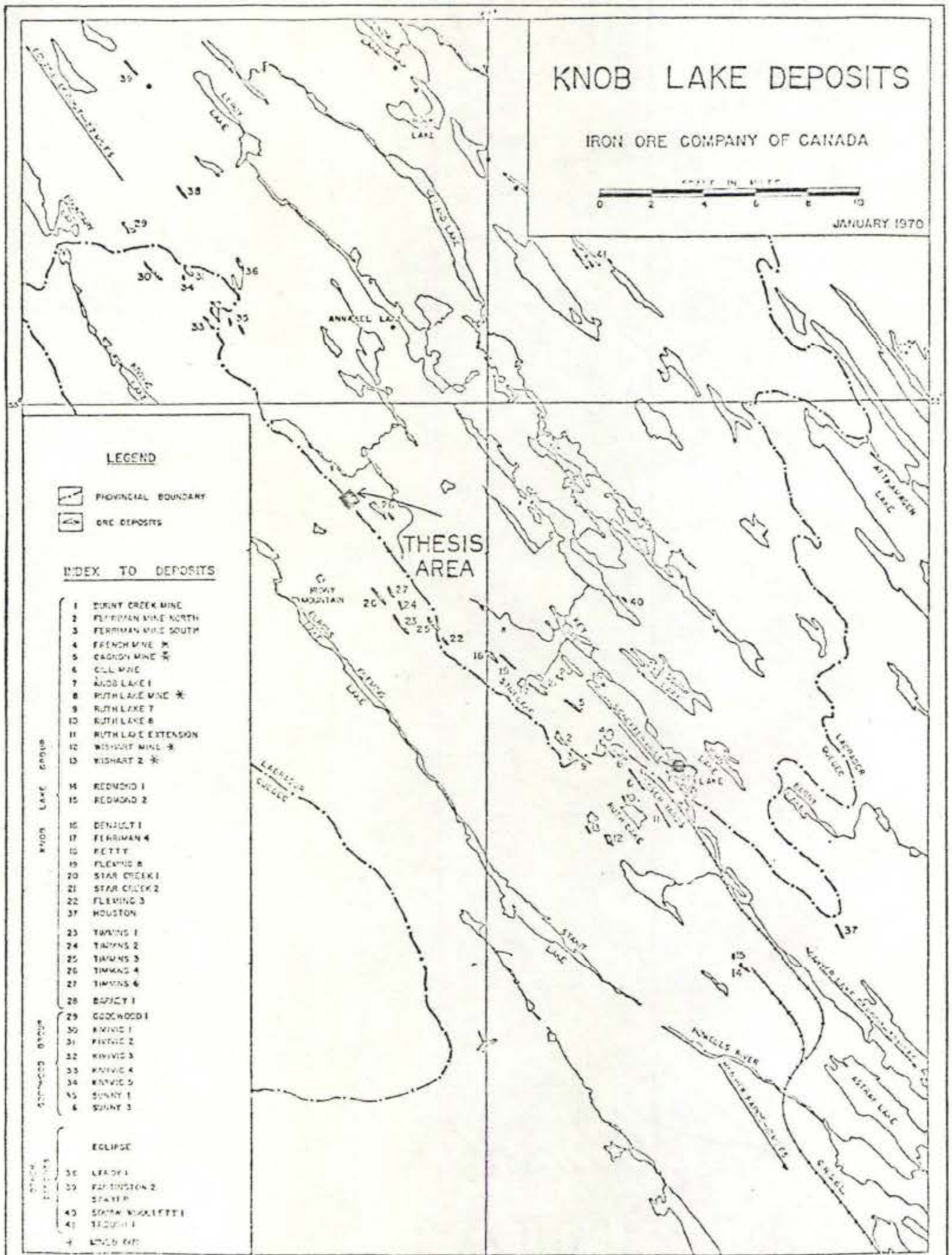
The beginning of World War II brought about increased demand for steel so L. M. & E. and Hollinger North Shore Exploration Company (H. N. S.) began intensive exploration and mapping programs resulting in the discovery of many economic soft ore deposits and frequent showings of ore.

In 1949 L. M & E. , H. N. S. , Hanna Mining, Republic, National, Armco and the Youngstown and Wheeling Steel Companies formed the Iron Ore Company of Canada to exploit the deposits found and explore for new deposits in the immediate vicinity of Schefferville. I. O. C. shipped its first car of ore in 1954 and since then the

FIGURE 2

Map showing the thesis area in relation to the town of Schefferville.

(Iron Ore Co. of Canada)


KNOB LAKE DEPOSITS
IRON ORE COMPANY OF CANADA
0 2 4 6 8 10
JANUARY 1970
THESIS AREA
LEGEND
PROVINCIAL BOUNDARY
ORE DEPOSITS
INDEX TO DEPOSITS
KNOB LAKE GROUP
2 FERRIMAN MINE NORTH
3 FERRIMAN MINE SOUTH
4 FRENCH MINE
5 GAGNON MINE
7 KNOB LAKE I
8 RUTH LAKE MINE
9 RUTH LAKE 7
10 RUTH LAKE 8
11 RUTH LAKE EXTENSION
12 WISHART MINE
13 WISHART 2
14 REDMOND 1
15 REDMOND 2
16 DENAULT I
17 FERRIMAN 4
19 FLEMING 8
20 STAR CREEK I
21 STAR CREEK 2
22 FLEMING 3
37 HOUSTON
23 TIMMINS 1
24 TIMMINS 2
25 TIMMINS 3
26 TIMMINS 4
27 TIMMINS 6
29 GOODWOOD I
ECLIPSE
ANNABEL LAKE
ASTRAY LAKE
STAKIT LAKE

Knob Lake area (Schefferville did not exist at the time) has witnessed extensive growth of mining activities coupled with intensive geological study. These studies done both for economic and purely scientific purposes were conducted by I. O. C.'s staff geologists as well as many distinguished researchers such as Dimroth (1968), Gross (1951, 1960, 1961, 1965, 1968) and Zajac (1972).

I. O. C. and the companies preceding it have been engaged in very detailed geologic mapping and research since the early 1940's and the company has always encouraged students employed by it to do thesis work while in Schefferville. This has created a vast amount of information which was made available to the author.

STRATIGRAPHY

INTRODUCTION:

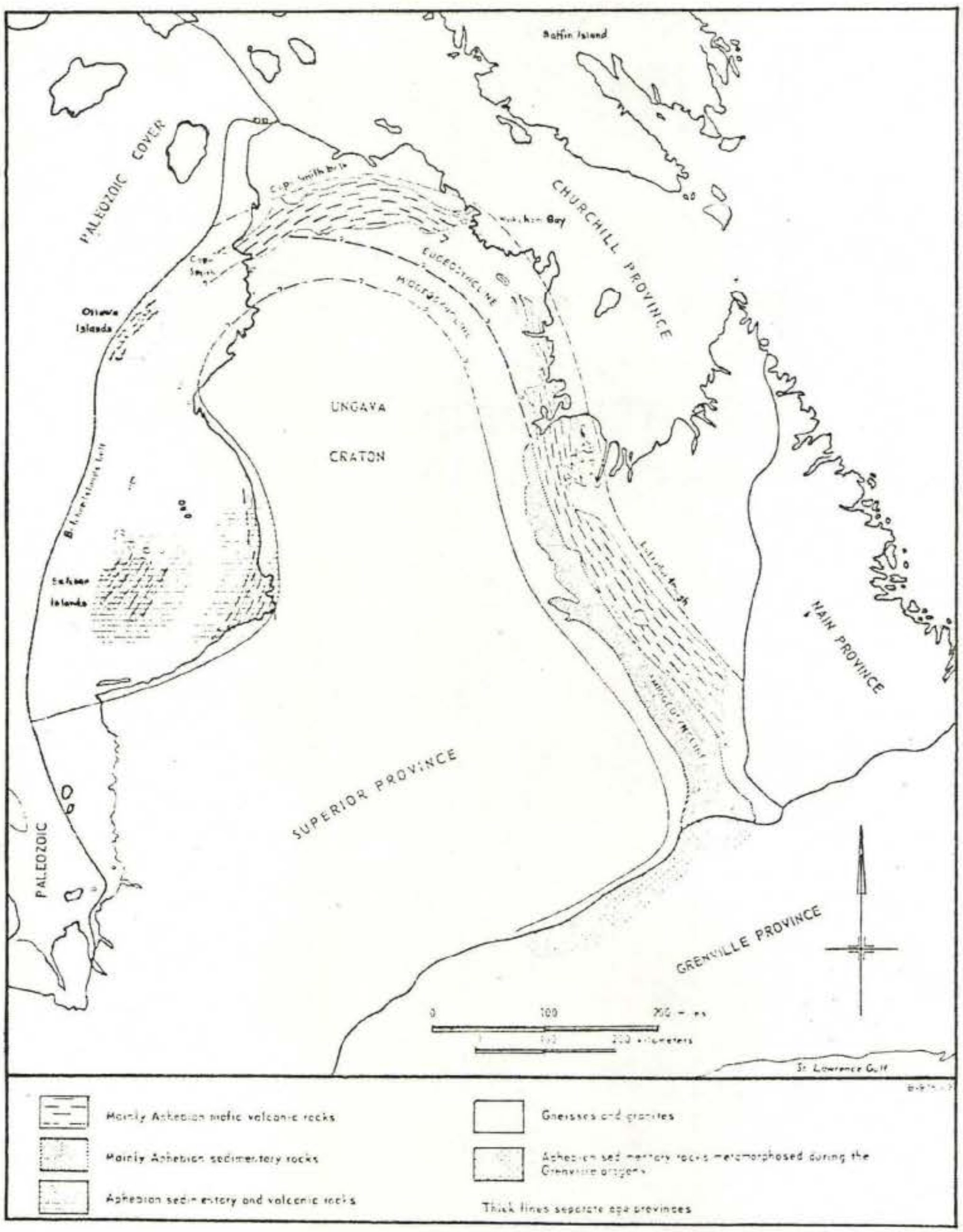
During Aphebian times a large geosyncline existed around what is now known as the Ungava Craton which is the eastern limit of the Canadian Shield. Recent work (e. g., Dimroth 1968 and Fryer 1971) has suggested that part of this Circum-Ungava Geosyncline eventually became what is known today as the Labrador Trough (see Figure 3). The Geosyncline is also preserved in the Belcher Islands, Mistassini and the Smith-Wakeham belts (see Figure 3).

The Labrador Trough extends from the Grenville Front at Labrador City (215 km south of Schefferville) to Payne Bay

FIGURE 3

The Circum-Ungava Geosyncline

(after Dimroth, 1970)


Baffin Island
PALEOZOIC COVER
CHURCHILL PROVINCE
Ottawa Islands
UNGAVA
CRATON
NAIN PROVINCE
SUPERIOR PROVINCE
PALEOZOIC
GRENVILLE PROVINCE
St. Lawrence Gulf
Mainly Aphebian mafic volcanic rocks
Mainly Aphebian sedimentary rocks
Aphebian sedimentary and volcanic rocks
Gneisses and granites
Aphebian sedimentary rocks metamorphosed during the Grenville orogeny
Thick lines separate age provinces

(800 km to the northwest).

It is only in the Schefferville area that both the miogeosynclinal and eugeosynclinal sections are well developed today. The miogeosynclinal area of the trough is found on the western side and is composed almost entirely of sedimentary rocks with little or no volcanic detritus. The eastern or eugeosynclinal side of the trough consists mainly of basic volcanics and intrusive rocks (Zajac 1972). The degree of deformation and metamorphism increases from west to east.

Three cycles of sedimentation have been recognized in the Labrador Trough (Dimroth 1968). Only the second cycle is seen in the Knob Lake area. It is possible that the first cycle of sedimentation is concealed beneath the rocks of the Knob Lake area but this is unlikely. Extensive thrusting has created moderate to steep deeps in Cycle II rocks, and repeated the stratigraphic sequence many times, yet the first cycle is not exposed anywhere around Knob Lake, not even at the unconformity with the Archean basement.

The Schefferville Mining District is surrounded by dominantly miogeosynclinal sediments although a small amount of volcanics and a few diabase dykes are seen. Wherever the base of the Cycle II sediments is seen they unconformably overly Archean basement gneisses and granites directly.

Figure 4 shows the stratigraphic sequence in the Knob Lake area with names and subdivisions as used by I. O. C. in all of its present mapping. Modifications to this sequence have been proposed by others such as Zajac (1972) but have not as yet been implemented. The acronyms for each formation, member and sub-member used on the maps in the appendix as well as geologic sections are found in brackets after the formation name in the text of this report.

The lithologies described here are for unleached, unenriched samples of the various members and sub-members. Leaching and enrichment can alter their appearance considerably.

General lithologic descriptions given here except those referring specifically to the thesis area, are taken from Krishnan (1976), Zajac (1972) and I. O. C. Staff (1970).

The Ashuanipi Complex:

Along the western margin of the Labrador Trough the miogeosynclinal rocks lie unconformably on gneisses and granites of the Ashuanipi Complex. Rocks of this basement group are not seen in the thesis area.

FIGURE 4

Stratigraphic sequence of the Central Labrador Trough in the Knob Lake Area.

(after Krishnan, 1976)

ERA	SUPER GROUP	GROUP	FORMATION	APPROXIMATE THICKNESS (in meters)	DOMINANT LITHOLOGY	
MESOZOIC			REDMOND		Clay, rubble	
UNCONFORMITY						
PROTEROZOIC					Diabase	
	INTRUSIVE CONTACT					
	KANIAPISKAU	KNOB LAKE	MENIHEK	300+	Shale, slate	
			SOKOMAN	90 - 215	"Banded Iron-Formation": Iron-formation	Nimish Formation; 0 - 90m thick: lithology-greenstones
			RUTH	25 - 35	"Banded Iron-Formation": Iron-formation	
			Local (?) Unconformity			
			WISHART	20 - 60	Quartzite	
			Local Unconformity			
			FLEMING	0 - 120	Chert Breccia	
			DENAULT	0 - 180	Dolomite	
			ATTIKAMAGEN	0 - 300+	Shale, slate	Nimish
UNCONFORMITY						
ARCHEAN	ASHUANIPI COMPLEX				Gneisses	

The Kaniapiskau Supergroup:

These miogeosynclinal rocks constitute the Kaniapiskau Supergroup, an assemblage dominated by sedimentary rocks. This Supergroup has been divided into 4 groups, only one of which is seen near Schefferville. The Knob Lake Group is composed of seven formations, four of which outcrop in the area studied.

The Attikamagen Formation (LS):

This rock type occurs mainly as vari-coloured shales and slates having a total thickness of between 300 and 900 meters. They are thin bedded to laminated, fine grained, commonly cherty, silty or dolomitic greenish-grey shales and slates. Beds and lenses of chert, siltstone and quartzite are also present but constitute a very small part of the formation. This Lower Slate (LS) is present in the thesis area but does not outcrop very well. LS is particularly susceptible to frost heaving and dips taken on it are not always accurate.

The Denault Formation:

The Denault Formation is a massive dolomite, containing a stockwork of secondary chert veins. It weathers to a characteristic buff colour. It was deposited as local basin infillings and hence is sporadic in its outcropping. It does not occur in the thesis area. The Denault dolomite conformably overlays the Attikamagen Formation.

The Fleming Formation:

This is a chert breccia conformably overlaying the Denault Dolomite. It, like the Denault, formed by infillings of basins and is also only intermittently present in the stratigraphic column. It does not occur within the thesis area.

The Wishart Formation (QTE):

The Wishart Quartzite unconformably overlays the Fleming Formation and is 20 to 60 meters thick. It is a thickly bedded, light greenish-grey rock. Locally it can be red due to a ferruginous component (this red colour is not seen in the thesis area).

The Wishart can appear as a very pure orthoquartzite or a quartzite with up to 10% argillaceous matrix as in outcrops of the thesis area. It contains almost no feldspar.

The Wishart has at the top a thin marker horizon of black chert (BC on the maps) which is locally present in the mapping area.

The Ruth Formation (RF):

There are two Superior type iron formations recognized by I. O. C. in the Schefferville area, the Ruth being the older. Although this subdivision has been questioned, it is here maintained because of the mappability of the Ruth and the two distinct ore types which come from the two different formations.

The Ruth Formation has two different facies, i) the oxide-silicate-carbonate facies, which appears as an iron rich chert (RC) and ii) the clastic-silicate-carbonate facies, which appears as an iron rich shale (RS). These two cannot always be easily delineated and in that case the formation is mapped as RF.

The Ruth is almost everywhere present in the Schefferville area and has a maximum thickness of 35 meters. The lower part is generally more argillaceous while the upper part is more cherty.

The Shaly Facies: The shales are most commonly red, weathering to a rusty brown. They are finely laminated and non-magnetic (Krishnan 1976). They also are fissile along bedding planes.

The Cherty Facies: The chert is more massively bedded, bluish-grey on fresh surfaces, rusty brown when weathered. Vari-coloured chert lenses are also found within it. In small outcrops it can be mistaken for a sub-member of the Sokoman Formation.

Both the Ruth Chert and Ruth Slate are found in the mapping area.

The top of the Ruth here and in other areas is characterized by alternating thin laminae of blue iron oxides and jasper which are interrupted by thicker lenses of bright red jasper. This rock is known as Jaspilite (JSP). The Jaspilite in the thesis area contains thin (2-10 cm) bands of shale between thicker banded jasper beds.

The Jaspilite where found is an excellent marker horizon and has a sharp contact with the Sokoman Formation (see Plate 1).

The Sokoman Formation:

The Sokoman Formation has been subdivided into three members with numerous sub-members differentiated on the basis of mineralogy, chert colour and textures (see Figure 5). The sub-members are discontinuous and subject to lateral facies changes. The acronyms used for mapping purposes can be seen in Figure 5 also.

The Lower Iron Formation:

This member of the Sokoman has 2 distinct facies for which the sub-members are named. The oxide facies (LIF) is 10 to 30 meters thick. It shows a distinctive "salt and pepper" texture on weathered surfaces due to iron oxide dissemination. It is almost never banded. In the mapping area it also contained corroded oolites. The silicate carbonate facies (SCIF), elsewhere up to 10-15 meters thick is not seen in the map area.

There is also another sub-member called the Lower Grey (LG). This, however, only occurs in the southern part of the Schefferville Mining District.

PLATE 1

View, looking south, of the sharp contact between the Ruth (JSP) and Sokoman Formations (see dotted lines).


JSP
LIF

FIGURE 5

Members and Sub-members of the Sokoman Iron Formation as Used by the Iron Ore Co. of Canada for Mapping.

(after Krishnan, 1976)

FORMATION	MEMBER	SUB-MEMBER	ACRONYM	APPROXIMATE THICKNESS (in meters)	DOMINANT FACIES
SOKOMAN	Upper Iron-Formation (UIF)	Magnetic Shales		0 - 6	oxide-silicate-clastic
		Lean Chert	LC	10 - 25	chert-carbonate-clastic
		Red Upper Iron-Formation	RUIF	0 - 10	oxide-silicate-clastic
		Lower Lean Chert	LLC	0 - 25	oxide-silicate
		Grey Upper Iron-Formation	GUIF	12 - 24	carbonate-oxide-silicate
	Middle Iron-Formation (MIF)	Upper Red Chert	URC	15 - 27	oxide
		Brown Chert	BC	0 - 12	oxide
		Pink Grey Chert	PGC	20 - 35	oxide
		Lower Red Chert	LRC	8 - 12	oxide
	Lower Iron-Formation (LIF)	Lower Iron-Formation; Silicate Carbonate Iron-Formation;Lower Grey	LIF;SCIF;LG	10 - 30	oxide-silicate-carbonate

The Middle Iron Formation:

This member varies in thickness from 60 to 120 meters and contains four sub-members three of which are present in the mapping area.

Lower Red Cherty Sub-member (LRC): LRC is a purplish-red, to deep red thinly bedded rock with a metallic luster due to the high primary iron oxide content. It weathers to a dull bluish, purplish-red. It is oolitic and contains lenticular bodies of jasper. It makes an excellent marker horizon.

Pink Grey Cherty Sub-member (PGC): PGC is 20-35 meters thick, thick bedded and has a distinctive reddish grey colour on fresh faces. Carbonate-rich zones and jasper lenses are common. It has a gradational, conformable contact with LRC marked by changes in colour, texture and bedding thickness. The upper contact is also gradational and is arbitrarily placed below the first appearance of brown chert or bright red chert lenses.

Brown Cherty Sub-member (BC): The brown cherty sub-member, a 4-12 meter thick band of fine-grained brown chert, is not seen in the mapping area.

Upper Red Cherty Sub-member (RC): This is a well bedded unit becoming massive at the top, varying from 15 to 27 meters in thickness. This rock is coarse-grained and granular. On fresh surfaces it is metallic grey with occasional bright red chert lenses but weathers to grey or greyish-white. The most characteristic feature of this sub-member is the chert lenses. Iron carbonates are common minerals at the top of this unit.

In areas of high leaching or limited outcrop it may be difficult to tell URC from PGC and the two may be mapped together as one unit.

The Upper Iron Formation:

In the Upper Iron Formation the predominant facies is a silicate-carbonate one with minor oxide and clastic facies. It tends to have a low iron content and shows a wide variation in mineralogy.

Grey Upper Iron Formation Sub-member (GUIF): The GUIF is 12 to 24 meters thick, thick bedded and bluish to greenish-grey weathering to dull grey and brown. It contains carbonates which leach out to leave pock marks on weathered surfaces. It is a granular rock containing blue magnetite, carbonates, with a grey cherty matrix and minor amounts of green and brown chert. It has a sharp upper contact marked by thin green or yellow beds.

Lower Lean Chert Sub-member (LLC): The LLC is 5 to 10 meters thick and is only locally present. It is seen in the mapping area, however. It looks very much like the Lean Chert Sub-member (LC) but has a waxy luster and a dull purplish-red colour.

Red Upper Iron Formation Sub-member(RUIF): The RUIF is a 3-10 meter thick shaly unit which does not appear in the study area.

Lean Chert Sub-member (LC): This unit is a 10 to 25 meters thick, greenish to pinkish coloured rock which weathers to mauve. It has large amounts of waxy green chert in thick beds with shaly partings up to 12 cm thick in between. Minor amounts of pink chert and carbonates are seen. The primary iron content is very low, the lowest of all the units in the Sokoman Formation. This is the last unit of the stratigraphic sequence seen outcropping in the mapping area. The Sokoman Formation sometimes does have a capping layer of Magnetic Shales (MS) with a 20% magnetite content (Krishnan 1976) which creates a very strong magnetic anomaly. All other units shown in Figure 4 are truncated by a fault interpreted by I. O. C. geologists.

STRUCTURAL HISTORY

The central Labrador Trough near the Schefferville Mining district was subject to at least 2 identified periods of deformation resulting in the intricate folding and faulting seen today. These 2 deformations were connected with the Hudsonian Orogeny and a period of Cretaceous faulting respectively.

The Hudsonian Orogeny:

The Hudsonian Orogeny caused intensive folding and thrust faulting which created a continuous range of hills which form the most prominent topography in Central Labrador. This range of hills follows the general strike of the rocks of the area (NW-SE). The sediments in the hills generally have intermediate easterly dip values.

There was a general shortening of the miogeosynclinal sediments along a northeast-southwest axis, that first results in folding in an en echelon pattern (Krishnan 1976) but which later developed into strike thrust faults dipping steeply to the east. The thrust faults have reverse dip-slip movements commonly less than 160 meters. Thrusts of this type are very common causing repeats of the stratigraphic sequence in whole or in part very many times as one traverses the western margin of the Labrador Trough. The thrusts, however, do not extend to the very edge on the western side. Here for a few kilometers the rocks are almost flat lying and essentially undeformed. This indicates that there is little or no basement involvement in the folding and thrusting. There must be a zone of discontinuity here allowing the folding of the Labrador Trough. Dimroth (1970) calls this a zone of decollement.

Figures 6 and 7 reproduce the schematic profiles across the Labrador Trough according to Dimroth (1970). Figure 7 is an interpreted structural cross-section. Figure 6 is a reconstruction of his lithologic variations, prior to deformation, arrived at by unfolding and unthrusting the structures now visible.

Normal faults are very few in number, but short, steeply dipping cross faults showing very little movement are common. One of these can be seen in the east corner of the geologic map (see appendix).

The metamorphic grade in the trough increases as one moves to the northeast (see Figure 7) which is where the orogenic stresses originated (I. O. C. Staff, 1970). The metamorphic grade in the Schefferville Mining District is lower greenschist facies. Sedimentary structures such as cross bedding oolites and rounded detrital grains are preserved (I. O. C. Staff, 1970).

CRETACEOUS FAULTING:

> "Within the Schefferville Mining District the structures of Hudsonian age in the Labrador Trough have been disrupted by Cretaceous faulting. These faults are common in the southeastern part of the Mining District but have not been recognized in the northwest. Probably the Cretaceous tectonic event affected a fairly large part of both the trough and the adjoining Superior and Churchill Structural Provinces.....
> .... The Cretaceous faults in the Schefferville Mining District are probably related to the Late Mesozoic rift

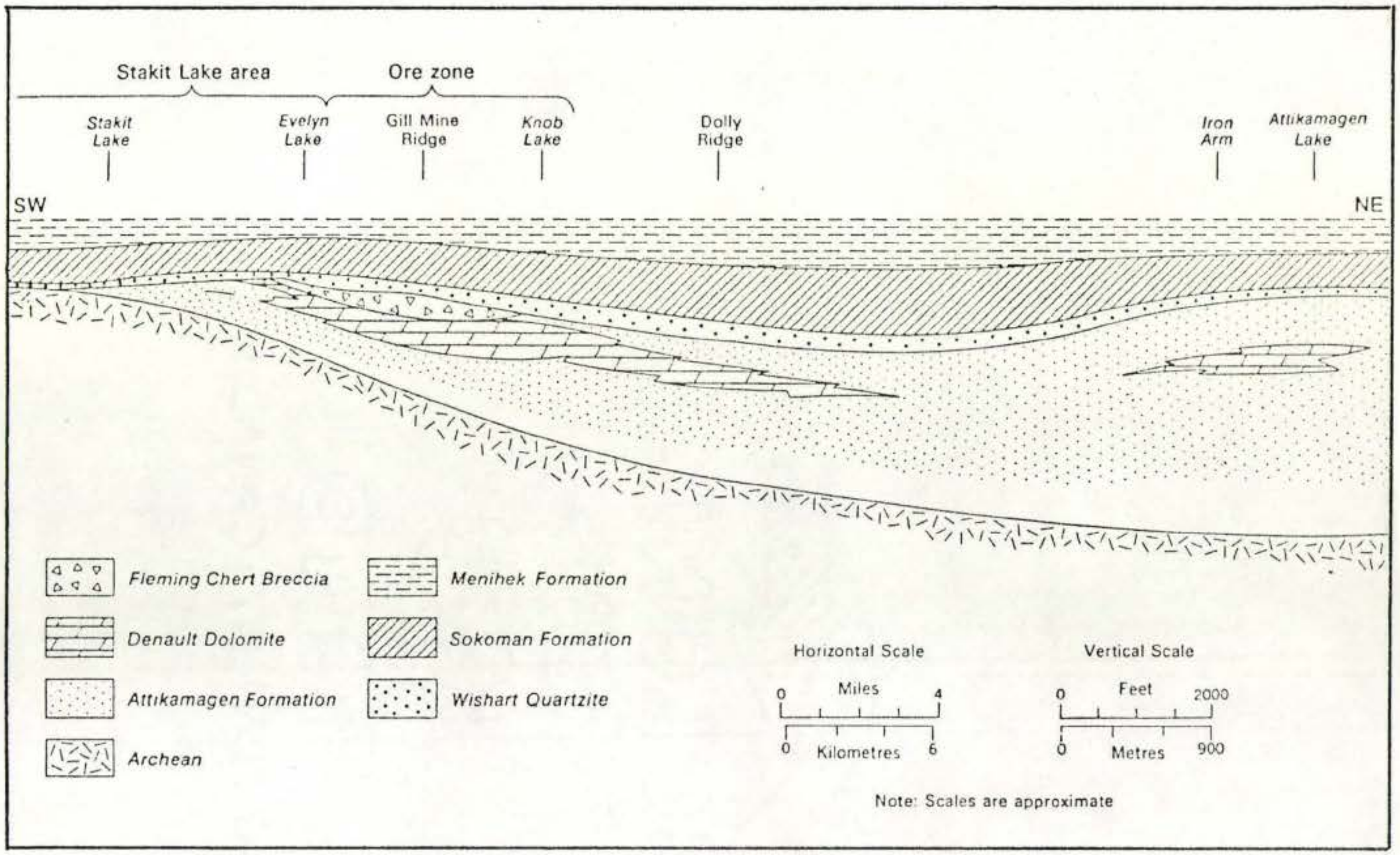
FIGURE 6

Hypothetical Cross Section Through the

Central Part of the Knob Lake Area

Before Deformation.

(after Dimroth, 1970)



Stakit Lake area
Ore zone
Stakit Lake
Evelyn Lake
Gill Mine Ridge
Knob Lake
Dolly Ridge
Iron Arm
Attikamagen Lake
SW
NE
Fleming Chert Breccia
Menihek Formation
Denault Dolomite
Sokoman Formation
Attikamagen Formation
Wishart Quartzite
Archean
Horizontal Scale
0 Miles 4
0 Kilometres 6
Vertical Scale
0 Feet 2000
0 Metres 900
Note: Scales are approximate

FIGURE 7

Hypothetical Cross Section Through the Central Labrador Trough After the Hudsonian Orogeny. Note the Strong Thrusting on the SW Margin in the Schefferville Area.

(after Dimroth, 1970)

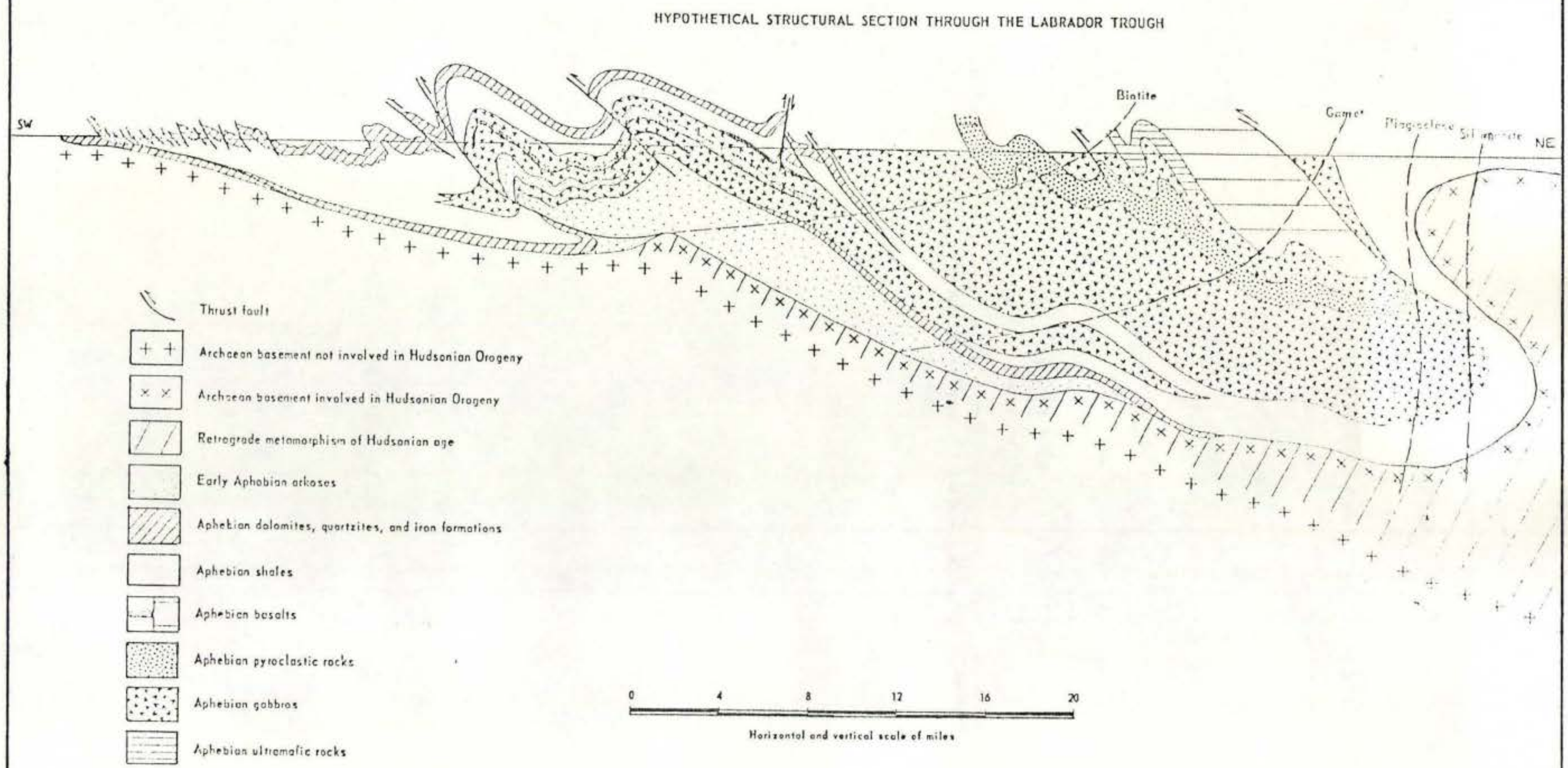


Figure 10. Tectonic section across the Labrador trough.

system in the St. Lawrence region." (Krishnan, 1976)

The Cretaceous faulting created a number of horsts and grabens. The Proterozoic rocks in the grabens were often covered with sequences of unstratified broken material called "rubble" composed of reworked Proterozoic rocks mixed with sand, clay and some organic material. This organic material consists of wood and leaf imprints.

The plant remains have enabled geologists to date the faulting, with a good degree of accuracy, as late Cretaceous (Dorf, 1959). These rubble deposits are often a source of ore grade material due to the ease with which they are leached.

The Cretaceous Faults have never been mapped in the immediate vicinity of the thesis area and no faults of Cretaceous age cross cut the map. It is still possible that the rocks seen in the area are entirely a part of either a horst or a graben of the Cretaceous Fault system as these faults are common only 8 miles to the southeast.

CHAPTER II

INTRODUCTION

The purpose of this report was to outline and analyze the structure of a syncline-anticline pair. When attempting this sort of work in the area of iron formations a unique problem is encountered. Certain members of the Sokoman and Ruth Formations have moderate to high magnetic susceptibilities when in an unleached state. The presence of these members throughout the study area renders a standard compass useless, making collecting of strike data a time consuming laborious process. Strikes must be plotted on air photos by sighting strikes on the ground onto objects that will be visible on the photos.

Raw Mapping data was made available by I. O. C. and was checked in the field by the author where more detailed structural data was accumulated when necessary. There was not enough time available for a joint survey of the map area or for the mapping to be done again. For this reason no discussion of joint patterns will appear here. All structural interpretations appearing here are based on mapping data by I. O. C. and the author and geophysics completed I. O. C.

STRUCTURE OF THE FOLDS:

The anticline-syncline pair is incomplete within the map area due to glacial removal. The Wisconsinian period of glaciation eroded much of the fold pair away to the point that almost all of the Sokoman Formation is missing from the syncline. The stratigraphy is much better preserved on the NE limb of the anticline because there is not another fold immediately beside this one, instead the Iron Formation appears to continue down dip in planar beds for some distance (see geophysical interpretations).

At first glance on the map, from the way in which the Whishart (QTE), Ruth (RF) and Lower Iron Formation (LIF) outcrop, it appears that the fold pair has a significant plunge to the SE. Plunges measured on the map locally are as high as 20° and almost never below 10°.

To confirm these measurements a stereonet analysis was carried out. Seven sub-areas were defined (see Map B in Appendix C) each of which had all the strike and dip data within it plotted on a stereonet. The strikes and dips were plotted as s-poles and where possible a β pole was determined from these to yield an average plunge for each sub-area of the map.

β analysis cannot be performed on a non-cylindrical fold and this fold pair is not cylindrical. It is, however, reasonable to assume that within each sub-area the folds are close to a cylindroidal nature.

Areas I, VI and VII, in the northwestern half of the map, showed plunges of 2° SE, 2° SE and 3°NW respectively. Areas III and IV in the southeastern half of the map showed plunges of 12° SE and 10°SE. Areas II and V did not have well-defined β poles because of a lack of dip values on one fold limb.

This data shows that for much of their outcrop the folds are essentially of horizontal plunge but began to have an overall southeasterly plunge as one proceeds to the southeast. Because of the 10° to 20° SE plunges measured, it must be concluded that along the fold axes of the two folds they must rise and fall in a series of domes of very small amplitude and relatively long wavelength. Part of the outcrop plunge may be due to topography. The elevation of the land decreases steadily as one proceeds SE along the axial traces of the folds at the surface.

Six structural cross-sections were constructed approximately normal to strike at intervals along the fold pair. (Section lines G'-G and H'-H are essentially the same as A'-A and D'-D but were constructed slightly off normal to coincide with magnetometer traverses.) These sections were constructed using only dips, outcrop locations and elevations. No drilling data are available. These sections are in Appendix C.

From these sections and the map it is apparent that the axial traces of the major syncline and anticline converge as one travels to the southeast. This indicates the folding changes from a broad open style in the northwest to a tight fold in the southeast. The axial planes of both the syncline and anticline are not vertical but dip to the northeast. A precise dip value is difficult to assess because the cross-sections are based only on surface data.

DEFORMATIONAL MECHANISMS:

The beds in the thesis area show no pervasive internal deformation or development of an internal fabric. This can be seen clearly in the photomicrographs of Appendix B. These photos clearly show undeformed oolites, original sedimentary structures and quartz grains with no signs of internal strain or development of a preferred c-axis orientation. There has been no internal flow within beds. Therefore, the limbs of the fold underwent rigid body rotations. (This has been shown by Krishnan, 1976 to have occurred in other nearby folds of similar type.) Therefore, during folding deformation must have occurred by flexural slip with deformation occurring in the beds only found in the hinge areas of the folds.

While it is true that the massive, cherty formations, members and sub-members exhibited rigid body rotations, the shaly units showed extensive development of second and third order folding.

These folds are confined almost exclusively to the Ruth (RF) and Jaspilite (JSP) units. These second and third order folds do not develop very far into the LIF or QTE units. They simply fade out.

Examples of these folds can be seen in Plates 2 and 3. These folds are essentially all "drag" folds that occur on the limbs of both the anticline and syncline.

FOLD CLASSIFICATION:

Ramsay (1967) developed a system for the classification of folds based on the patterns dip isogons form when constructed on the right section of a fold. The structural cross-sections of Appendix C are based only on surface data and are, therefore, not reliable enough to be used for the construction of dip isogons. It is, however, possible in this instance to classify these folds in Ramsay's scheme by another method.

Ramsay's class 1B (parallel) type fold is defined by a fold which maintains its orthogonal thickness throughout. All the photo micrographs of Appendix B indicate there has been no internal deformation fabric developed within most of the units in the fold pair. It is, therefore, safe to assume that the orthogonal thickness of each bed has been maintained during folding. Folding occurred by flexural slip, with the slip occurring on thin planes between bedding. If all beds maintain orthogonal thickness then so must the limbs of a fold. Therefore, these folds can be classified as type 1B

PLATE 2

Plate 2 Shows a Small Drag Fold in the Jaspilite Member of the Ruth Formation.

PLATE 3

Plate 3 Shows a Small Drag Fold in the Ruth Formation.

as defined by Ramsay (1967).

INTERPRETATION USING GEOPHYSICS:

Using geophysics it is possible not only to identify rock units of anomalous density or magnetic contrast from their neighbouring units, but also to outline their structure in either a qualitative or quantitative form. The quantitative aspects will not be covered here although they include, i) removing a regional trend to leave the residuals or effects from bodies near the surface, ii) smoothing techniques on the curves and iii) taking second derivatives of the curves to leave residuals.

One can also obtain an approximate dip value by looking at the shape and skew of a curve obtained either from a gravimeter or magnetometer. This method of analysis can be explained using Figures 8 and 9. Figure 8 shows a vertically dipping bed, A of high density with beds B of lower density on either side of it, where A & B are homogeneous, isotropic rock units. The graph above it shows the gravity curve one would obtain in this situation. Note that the curve is symmetrical about an axis passing through the middle of bed A parallel to dip.

If, however, bed A was dipping as in Figure 9 the curve would be skewed to one side with the gently sloping side of the curve in the same direction as the dip of bed A. This is due to the center

FIGURE 8

Figure 8 Shows a Hypothetical Gravimetric Curve Expected Over Three Homogeneous, Isotropic Beds of Densities A & B where

$$\frac{\rho_A}{\rho_B} > 1$$

and the Beds Dip Vertically.

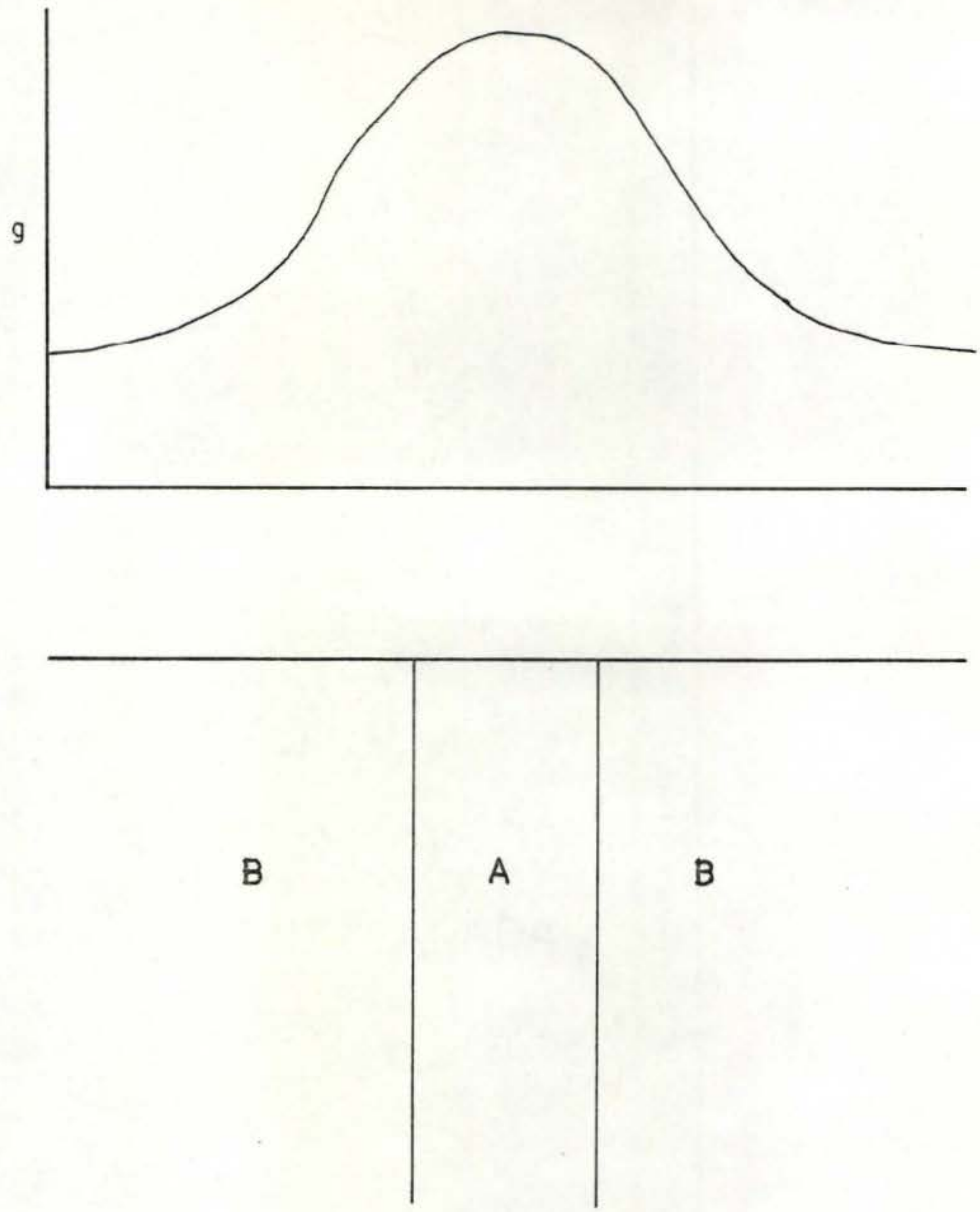

g
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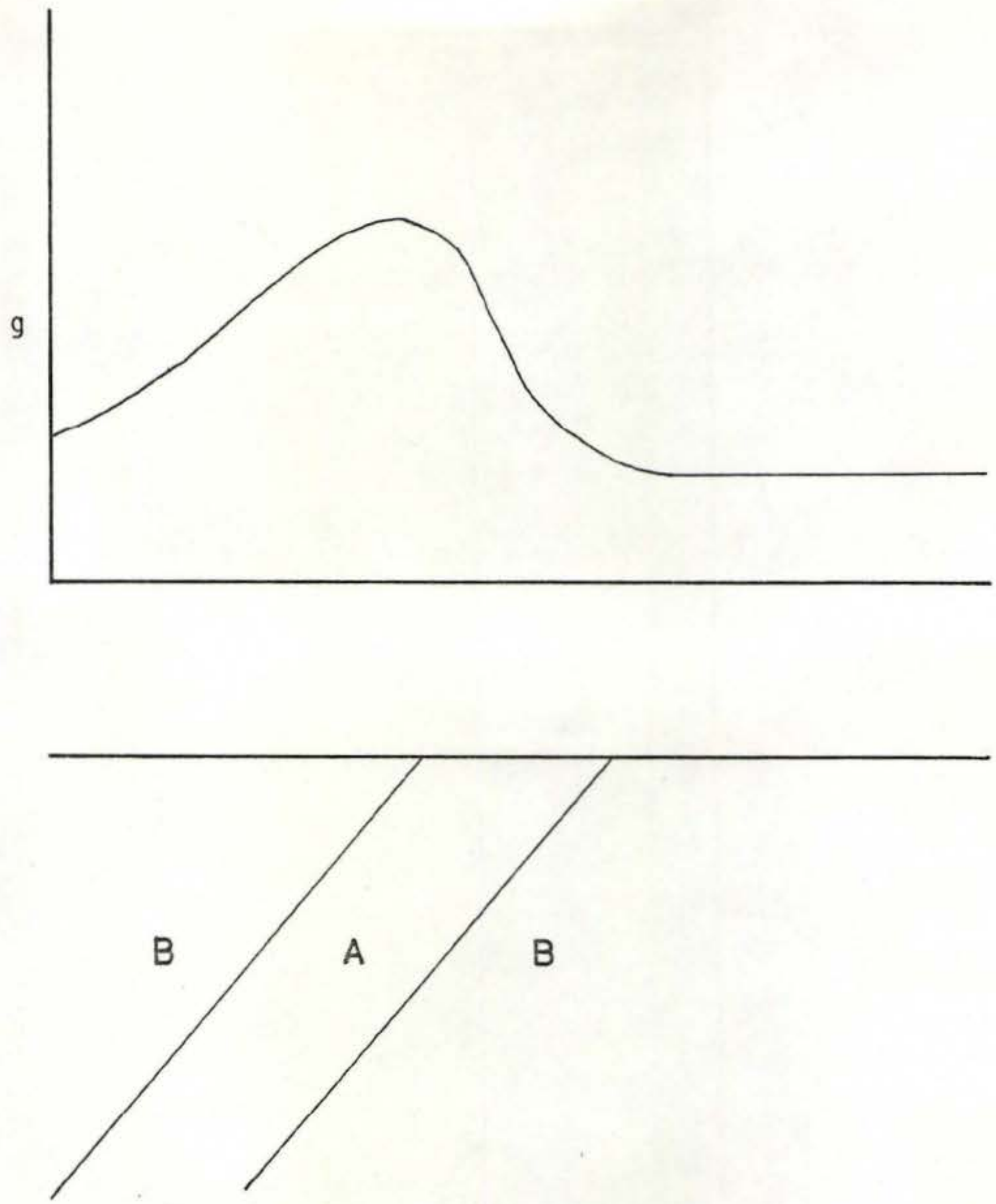
FIGURE 9

Figure 9 Shows a Hypothetical Gravimetric Curve Expected Over Three Homogeneous Isotropic Beds of Densities A & B where

$$\frac{\rho_A}{\rho_B} > 1$$

and the Beds are Dipping at 50°.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of mass of the bed not being located directly underneath the spot on the surface of the ground where the bed outcrops. The shallower the dip of Bed A becomes, the shallower will become the dip of the more gently sloping side of the curve. This allows the interpreter to place a shallow, intermediate or steep value on the dip. Interpreting anything more precise than these three ranges is not justified by the data.

The same ideas can be applied to curves taken from the magnetometer values. Although these curves are more irregular than the gravity curves and normally have lows on either side of a high value, the curves generally have a similar shape. They become skewed in the same manner as the gravity curves. Dips may be read from them, using the same method as for gravity curves.

This is a very useful technique for spotting Iron Formation or ore bodies in areas of limited outcrop and deciding the dip direction for drill hole proposals.

Located in the map pouch on the back cover are eight geologic cross-sections with geophysics along the same line of section. The lines of section can be located by looking at Map A in the map pouch. Section lines A'-A through F'-F have gravimetric data plotted against the geologic section. Section lines G'-G and H'-H have ground magnetic data over the geologic section.

It is important to note the horizontal scale of the sections is the same as that for the maps and that there has been no vertical exaggeration to the topography.

GEOPHYSICAL CROSS-SECTIONS:

Section A'-A shows moderately good agreement with the structural section. A sharp, steeply rising slope, to the anomaly on the left side of the geophysics section indicates moderate to steeply dipping Iron Formation with the dip direction to the left. The anomaly outlines very well the beginning of the Iron Formations on the left side of the section. The low in the middle outlines the QTE outcrop well, with a rise at the beginning of the isolated patch of Ruth Formation. The curve continues to rise with a very shallow slope, however, to the right edge of the section probably indicating more dense rock at depth under the LS.

Section B'-B is very similar to A'-A except for a few points. The RF and JSP Formations at the grounds surface on the left side of the geologic section have shallow dips at first before they begin to dip more steeply into the ground with the other sub-members of the Sokoman Formation. A slight high over the RF in the syncline is also better defined. The curve does indicate a difference in the dip of the syncline limbs because of its asymmetry. The shallow slope is on the right indicating that there is a greater volume of Iron Formation in that direction and that the Iron Formation is tapering slowly in that direction. Given that this is a syncline it means that the more shallowly dipping limb must be on the right side.

In Section C'-C Iron Formation outcrops for most of the distance along the section. This can be seen from the general high value of the gravity curve as far as the QTE outcrop on the right side of the geologic section. The QTE interpreted in the center of the anticline is justified by the low in the gravity curve over the central axis of the fold. QTE is a relatively low density rock being almost devoid of primary iron oxides.

As one traverses southeast across the map and comes to section D'-D, not only does Iron Formation cover most of the surface of the section, it also extends to significant depths. This significant depth of Iron Formation can be seen very obviously in the geophysical sections. They show very high values as far as the QTE outcrop and there are moderately steep slopes on the curves. These indicate an intermediate dip to the rocks at the Iron Formation QTE contact.

The same conditions that existed along section D'-D exist in E'-E. Iron Formation outcrops along most of the section and extends to depth. It creates a large broad high. Two features should be noted. There is a significant and steep drop over the QTE outcrop indicating a dip to the left and outlining the Iron Formation - QTE contact very well. On the left side of the gravity curve the curve begins to drop very steeply but then tapers off slowly. This very steep drop has located the fault directly underneath it which truncated the Sokoman Iron Formation. The low then flattens out over the LS unit. Note that the LS gravity signature is one-half milligal higher than the QTE signature indicating the LS is a denser rock. This is supported from the thin section studies.

In F'-F the faults have not truncated the Iron Formation and the very steep drop in the gravity curve is not seen. The gravity curve does not drop steeply on the right indicating only a moderate dip to the Iron Formation on this side. The left side of the curve drops more steeply than the right hand side indicating a steeper dip to the rocks on this side. All of these features predicted by the gravity curves are seen in the geologic section.

Section G'-G is the first of two Figures with the vertical component of the magnetic field plotted against the geology along the same section. The peak on the left side of the graph has a trailing side to the left indicating a steep dip in that direction. The magnetics curves have outlined the RF and LRC beds very well but the peak on the right shows no definite dip because there is only a small piece of RF present.

Section H'-H is the last line of magnetic data available over the thesis area. This section is much better for outlining the structure than G'-G. The magnetics here show the location and dip of the JSP unit which has a much higher magnetic susceptibility than any other sub-member or formation appearing in this section. The peak on the right has a shallower dip on the left-hand side indicating a dip in that direction which is seen in the structural section below it. The second peak on the graph also shows the same feature indicating at first glance a dip to the left. However, in this second peak there is an almost horizontal portion of the curve directly over the flat lying beds at the fold hinge. The magnetic curve has outlined the anticline but not clearly indicated a dip of either limb. Apparently the magnetic susceptibility has changed from one limb of the anticline to the other. The trailing left-hand side to this second peak may indicate that the JSP continues dipping essentially unchanged to depth.

CHAPTER III

CONCLUSIONS:

The map area has a syncline anticline pair striking northwest-southeast. Limited outcrop suggests that there are no other folds on either side of these two folds and that on the northeast limb of the anticline the beds continue down dip to depth.

The folding style is a broad open one on the northwestern half of the map and becomes progressively tighter as one proceeds to the southeast and the axial traces converge. The axial planes of both the syncline and anticline dip to the northeast.

The folds were formed by a flexural slip mechanism and internal bed deformation is confined to the hinge zones. The limbs of the folds simply underwent rigid body rotations.

Gravity and magnetometer data are useful tools for outlining locations and general structure of beds of anomalous density. In the thesis area faults, location of Iron Formation, location of highly magnetic sub-members of the Sokoman Formation and dips were all identified. Almost invariably the geophysics agreed with the interpreted structural cross-sections.

SUGGESTIONS FOR FURTHER WORK:

The geophysical interpretation is one area which leaves itself open for extensive work. Only a qualitative study of the gravity and magnetics curves was performed here. A number of analytical methods involving statistical smoothing of curves and removal of the density or magnetic effects of bodies at great depth can be applied.

If a significant amount of time for field work is available in the future a joint survey may prove very useful. Because of the unreliability of a magnetic compass over the thesis area this would be a time consuming and laborious process.

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APPENDIX A

The mapping area was broken up into seven smaller areas for the purpose of structural analysis. These areas can be seen in Appendix C on Map B. All the strike and dip data in each area was plotted using s-poles and then a β pole was approximated for each area. The following seven pages show the seven areas plotted on stereograms.

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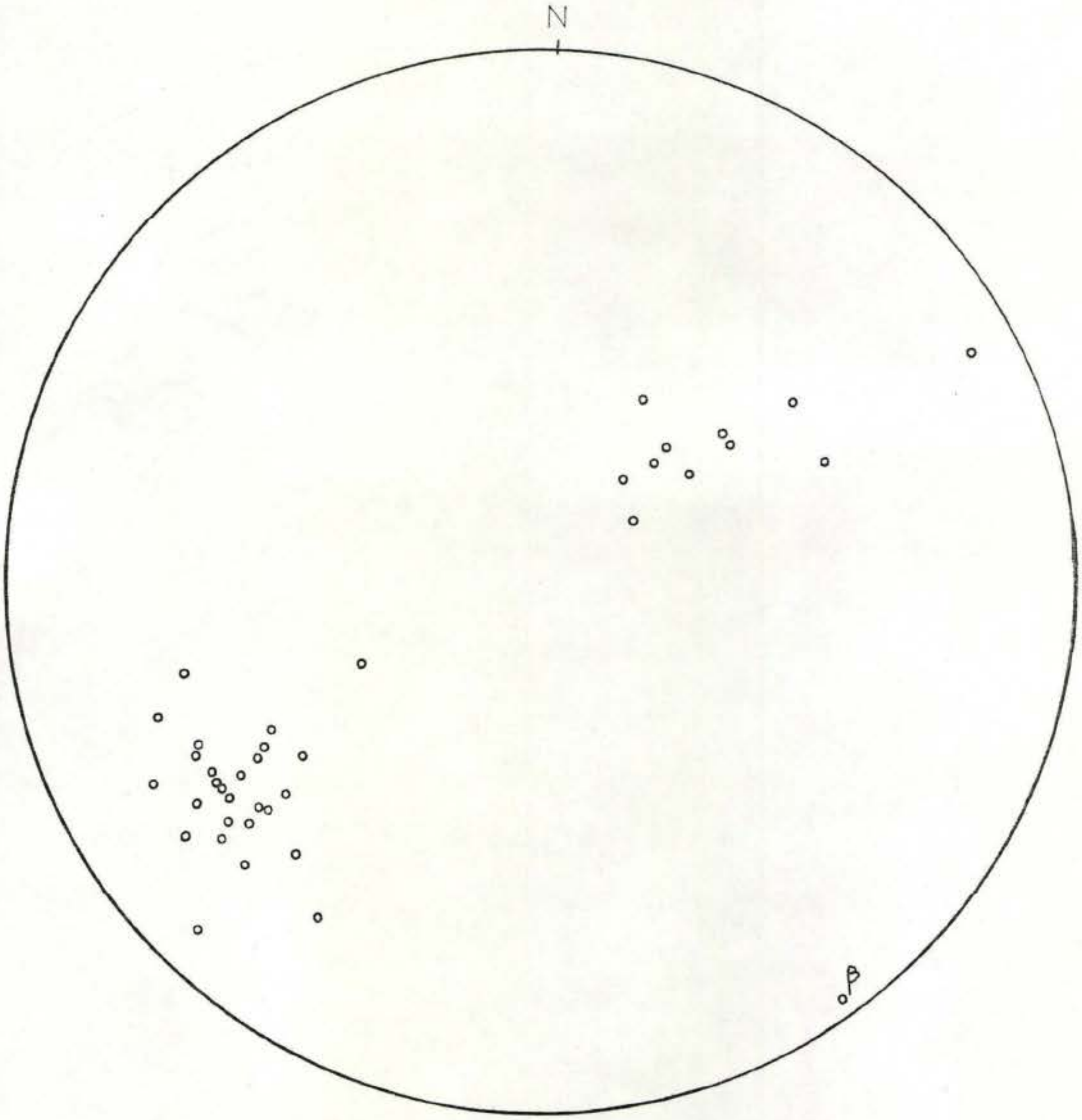

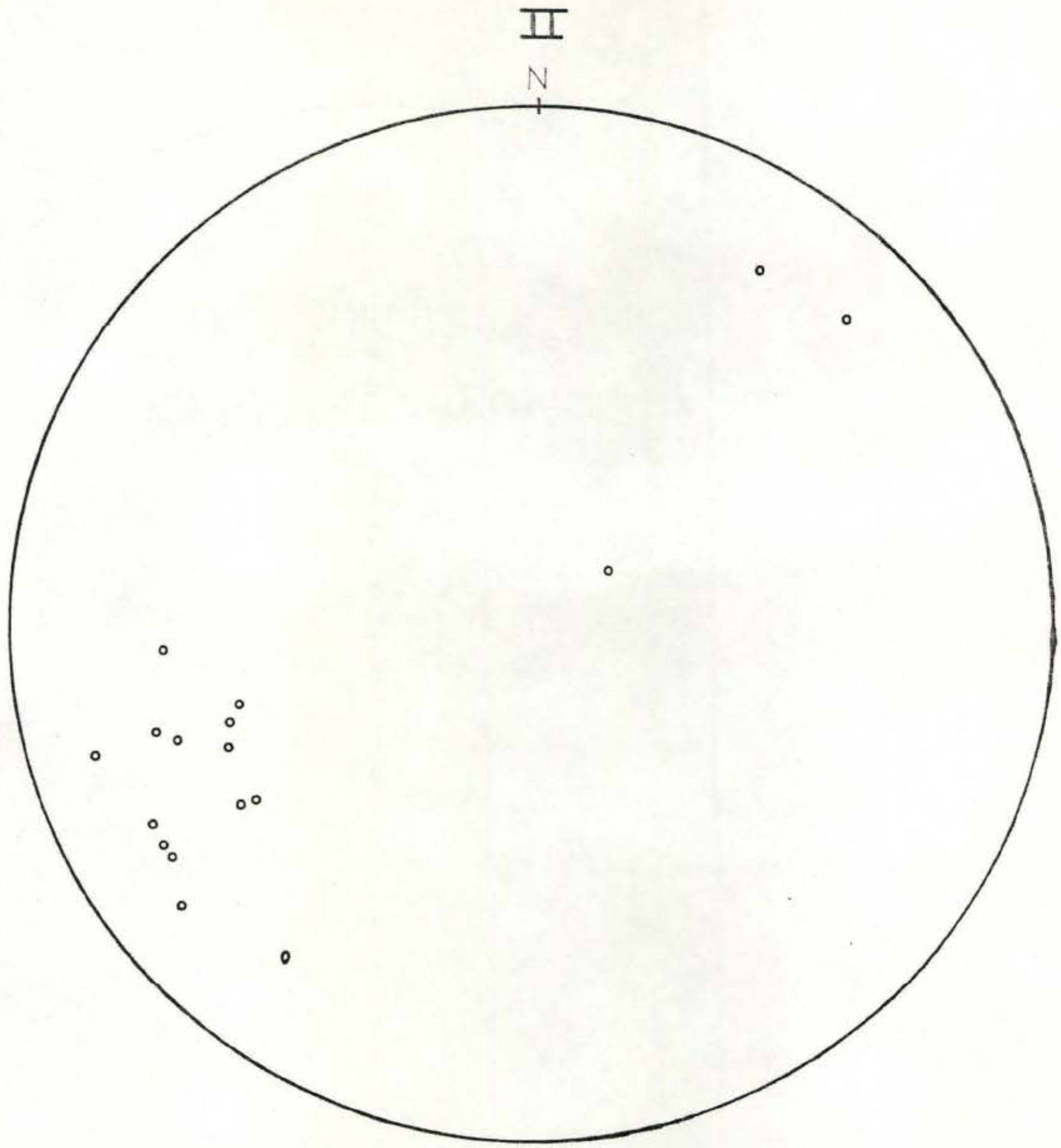
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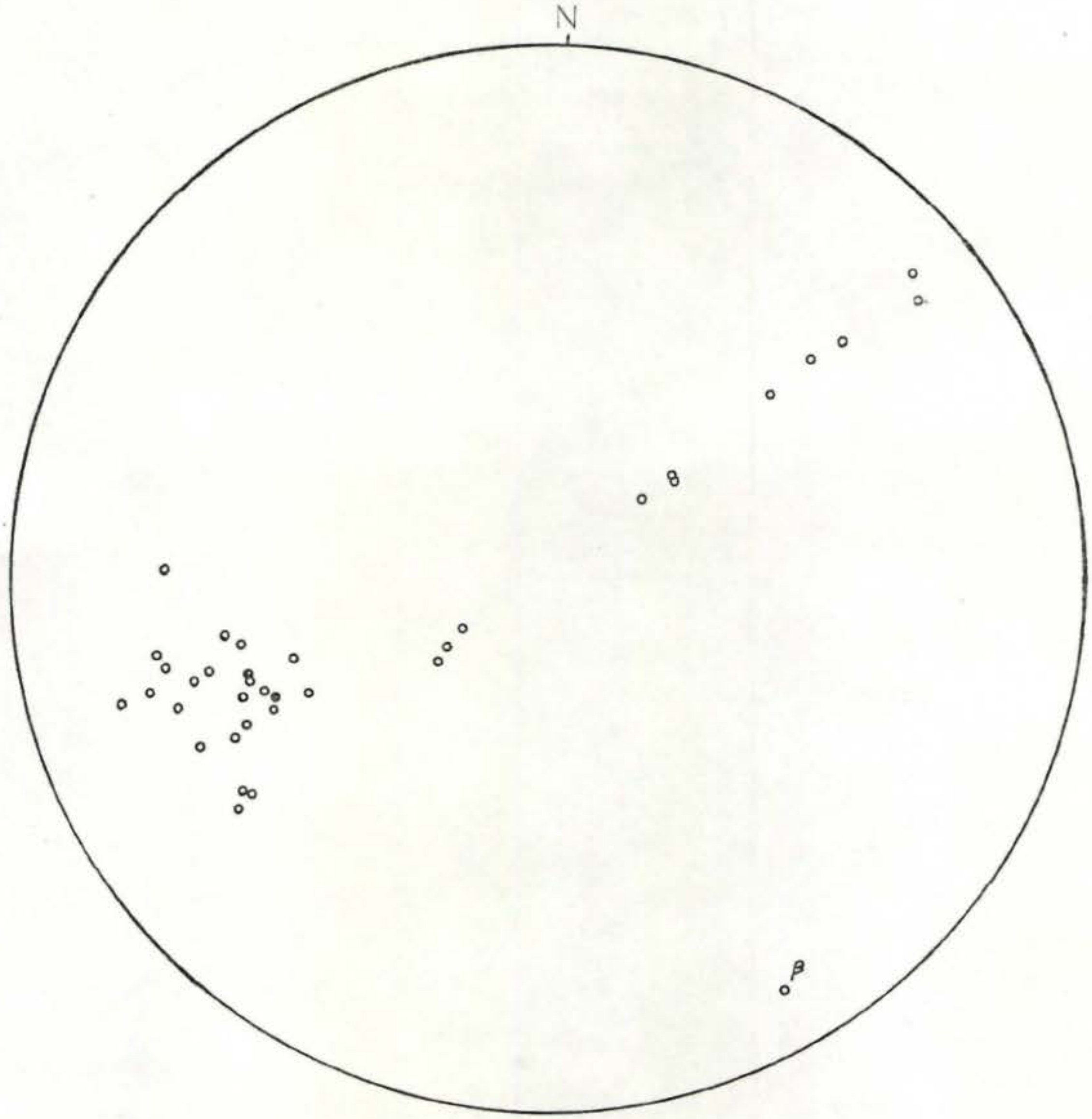

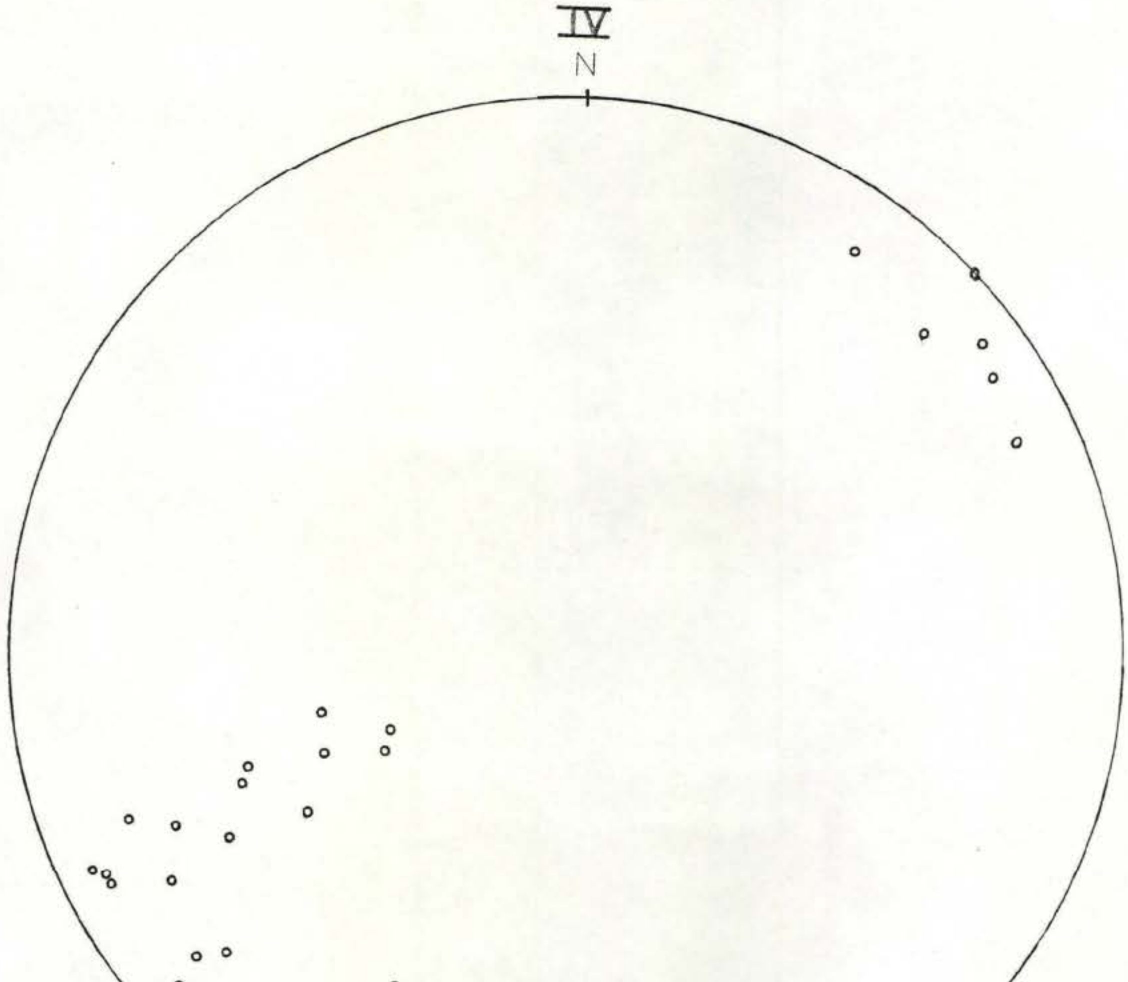
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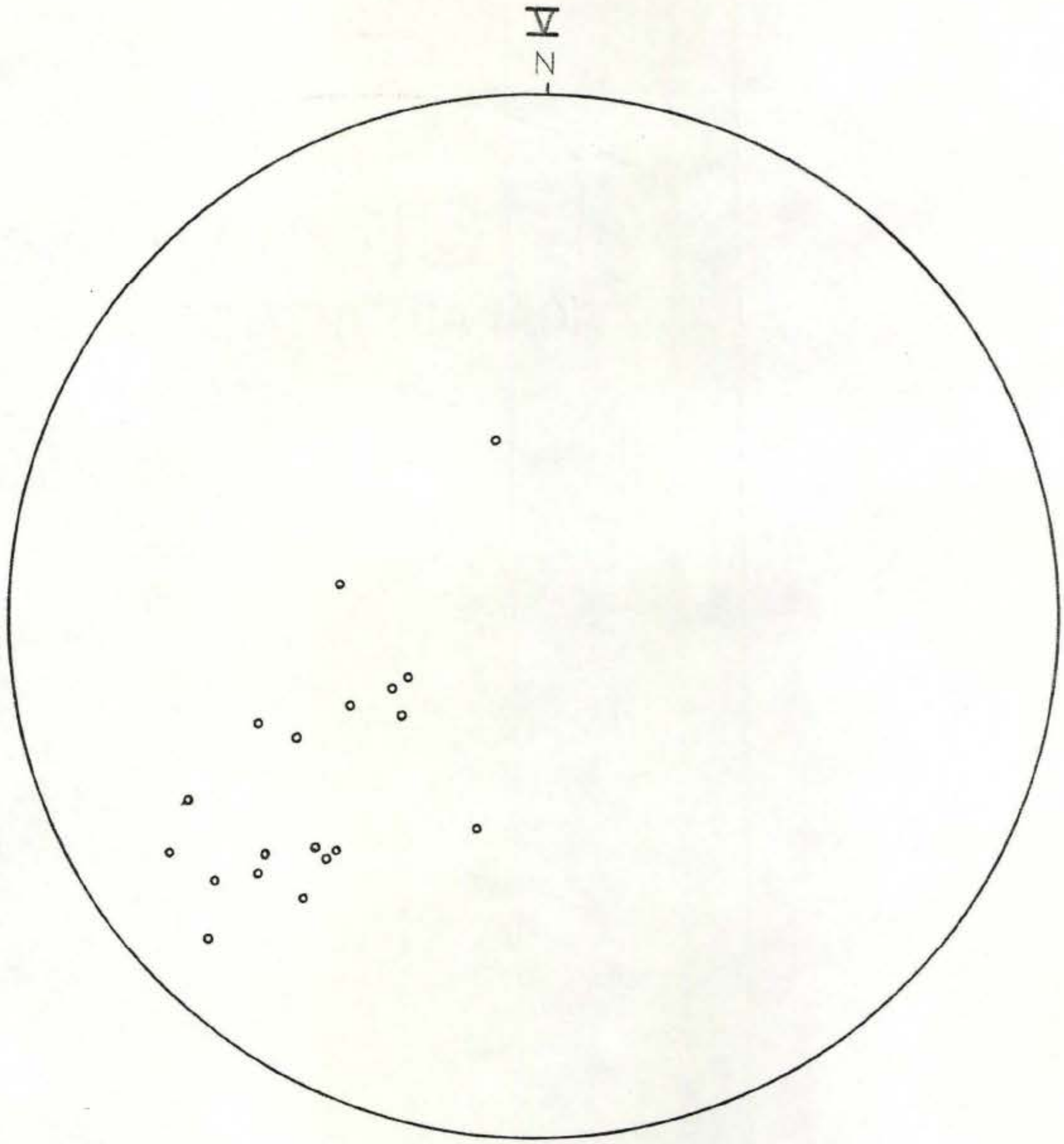
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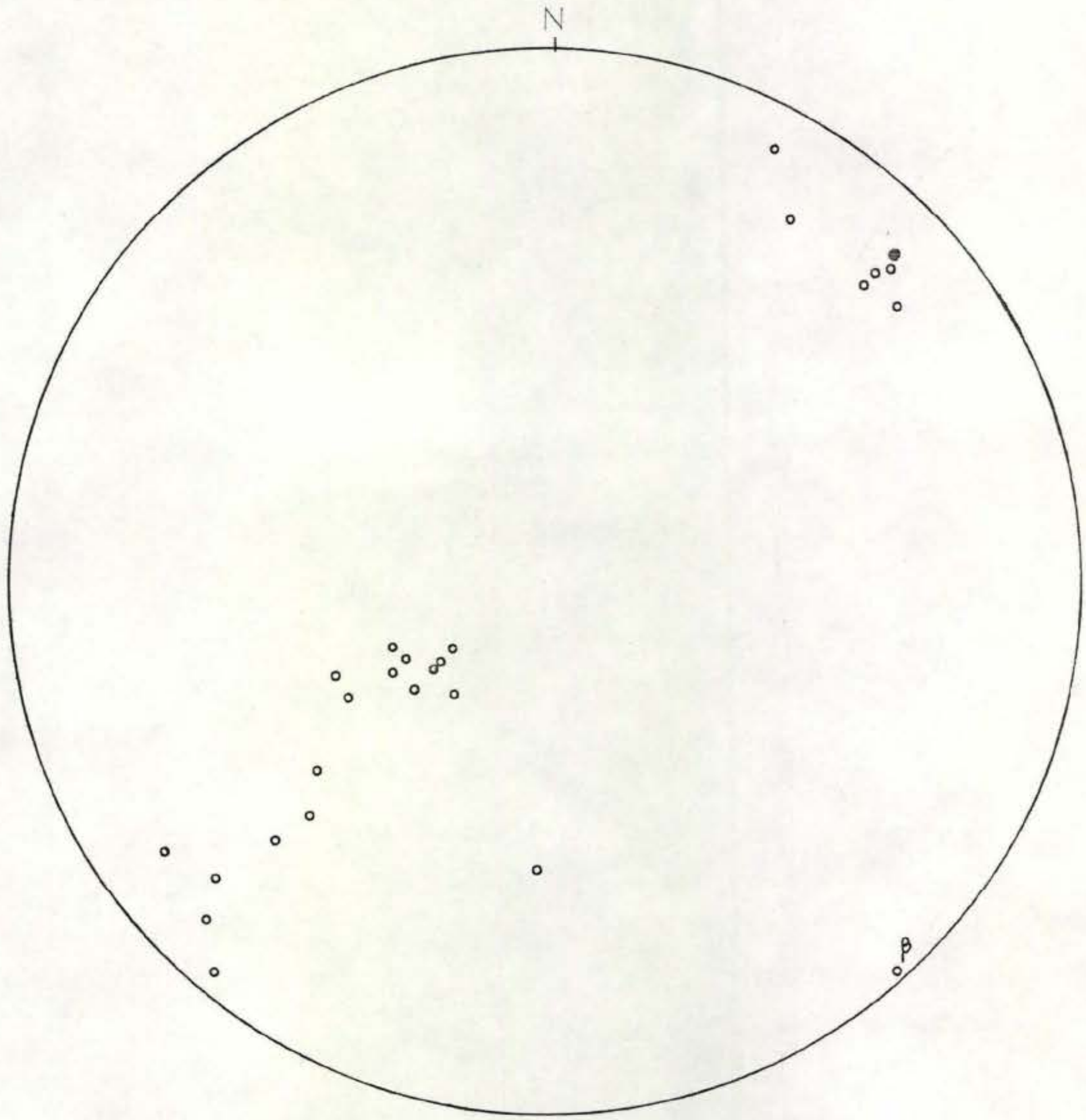

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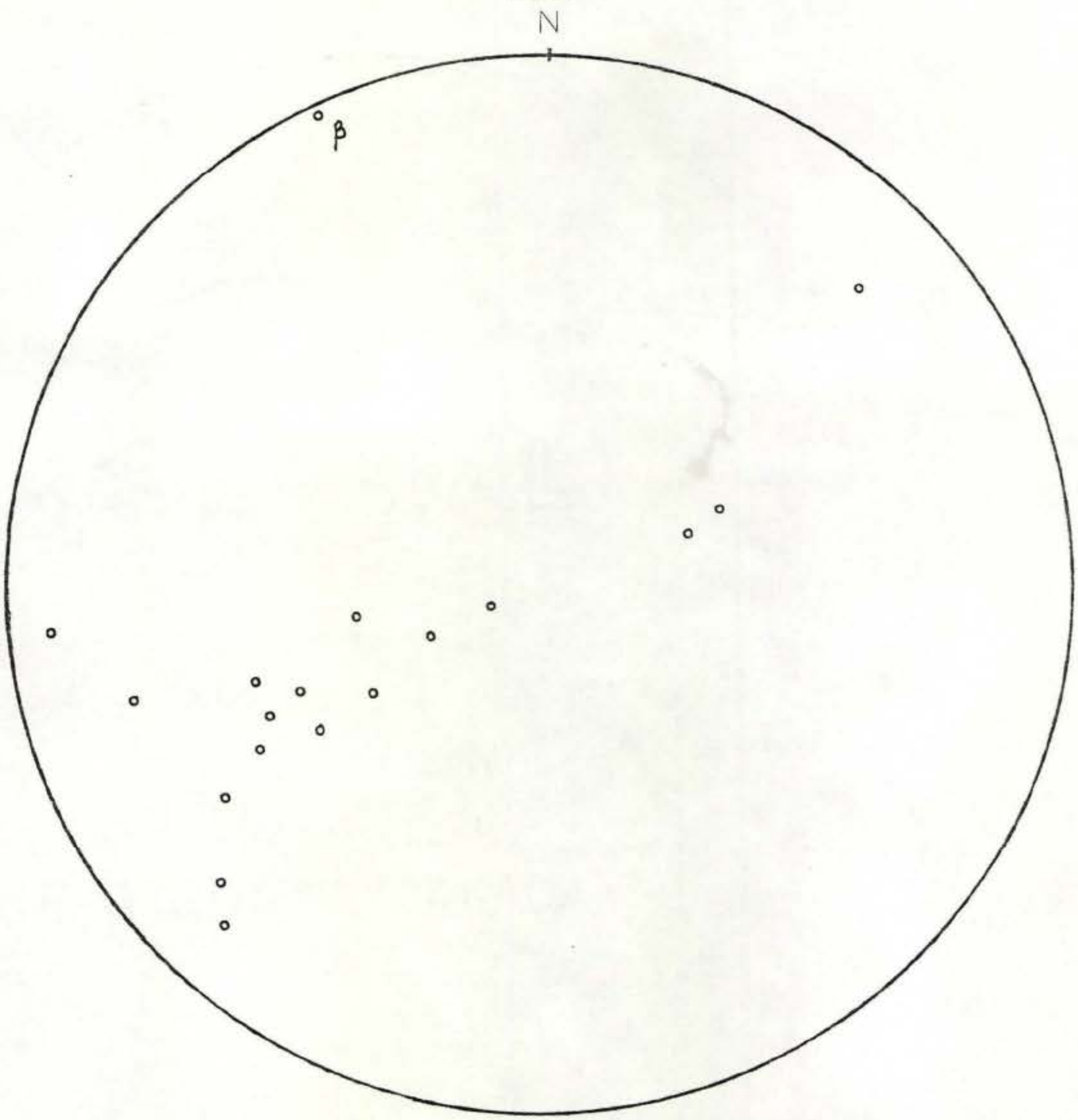


APPENDIX B

Appendix B contains five full slide photomicrographs of thin sections made from selected rock samples. Sample collection locations may be seen on Map B in Appendix C.

Magnification on all photomicrographs is approximately 6x.

PLATE 4

Plate 4: Wishart Quartzite Under Crossed Nichols. Note that there is no Internal Straining of the Quartz Grains. There is also no Development of a Preferred c-axis Orientation. This Sample was Collected at Location S-1 on Map B.

crossed nicols

magnification = 6x

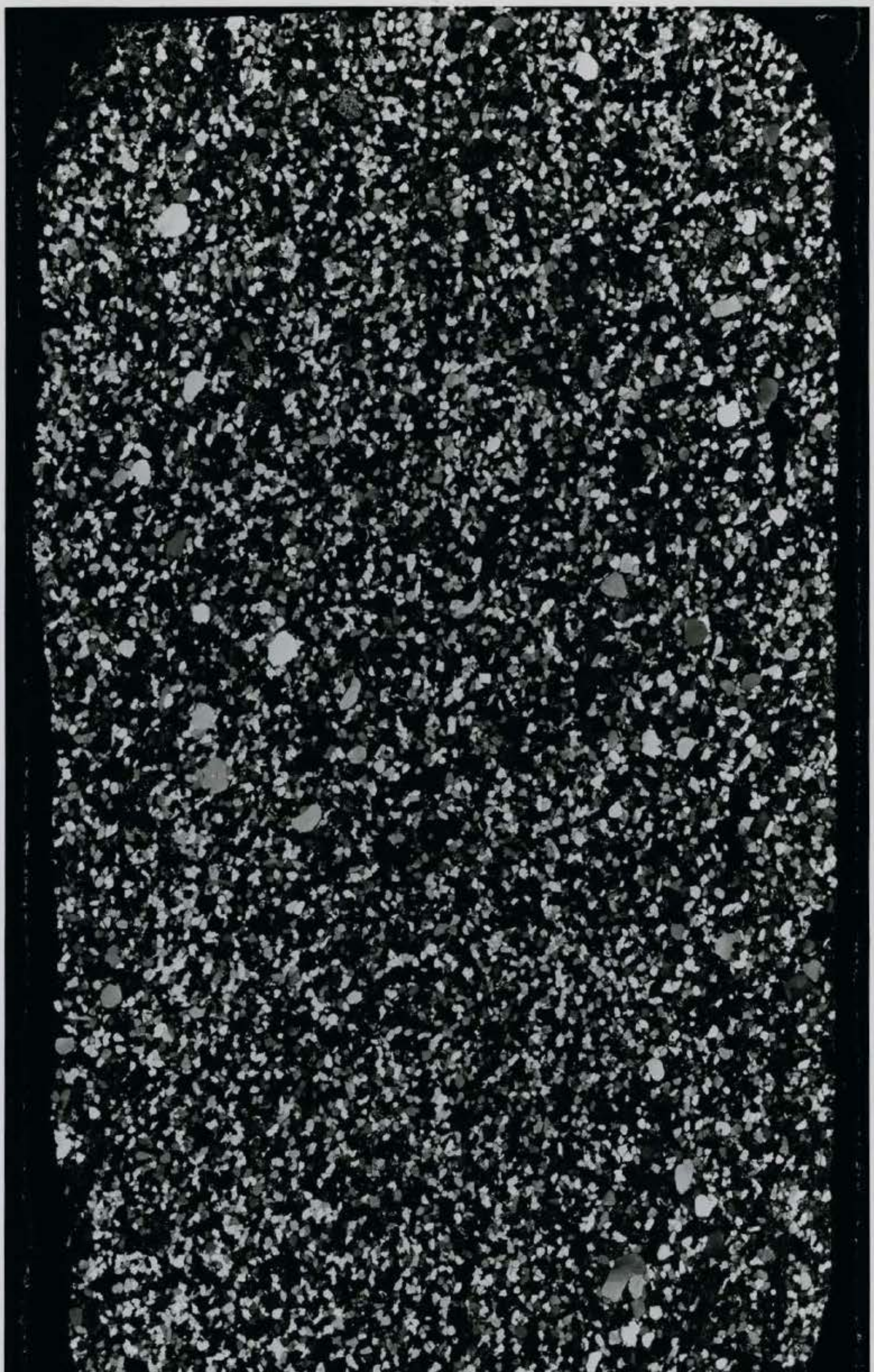


PLATE 5

Plate 5: Ruth Formation Under Plane Polarized Light. Original Sedimentary Features Such as Bedding and Slumping Can be Seen in an Essentially Undeformed Slate. This is from Sample Location s-2.

plane polarized light

magnification = 6x

PLATE 6

Plate 6: Jaspilite Member of the Sokoman Iron Formation. This is not Typical Laminated Jaspilite but Does Show Original Sedimentary Structures. This is from Sample Location s-3.

plane polarized light

magnification = 6x

PLATE 7

Plate 7: LIF Sub-member of the Sokoman Formation. Note the Typical Disseminated Iron Oxide Texture. Occasional Corroded Oolites that Show no Preferred Deformation Fabric are Visible. This Sample was Taken at Location s-4.

plane polarized light

magnification = 6x

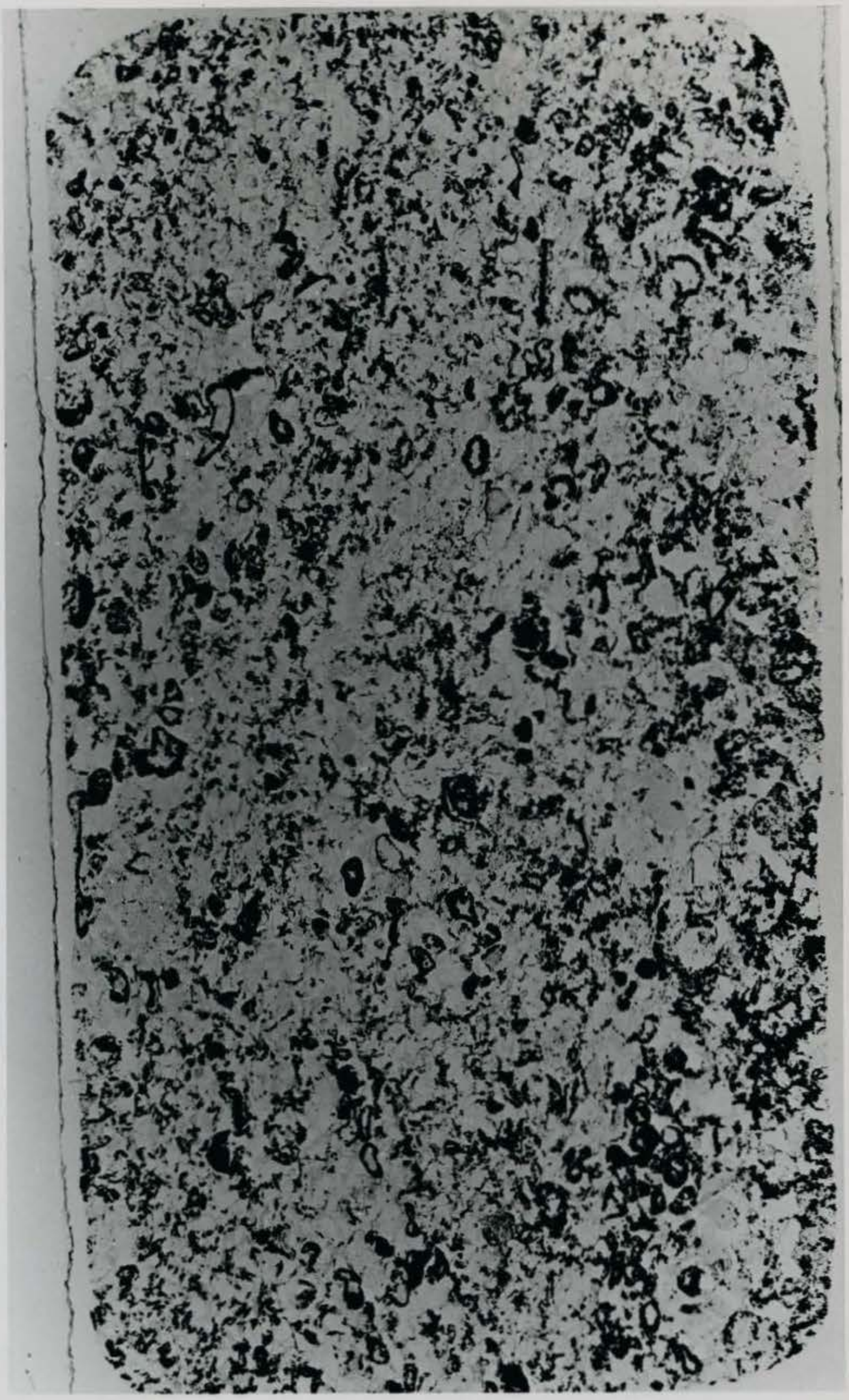
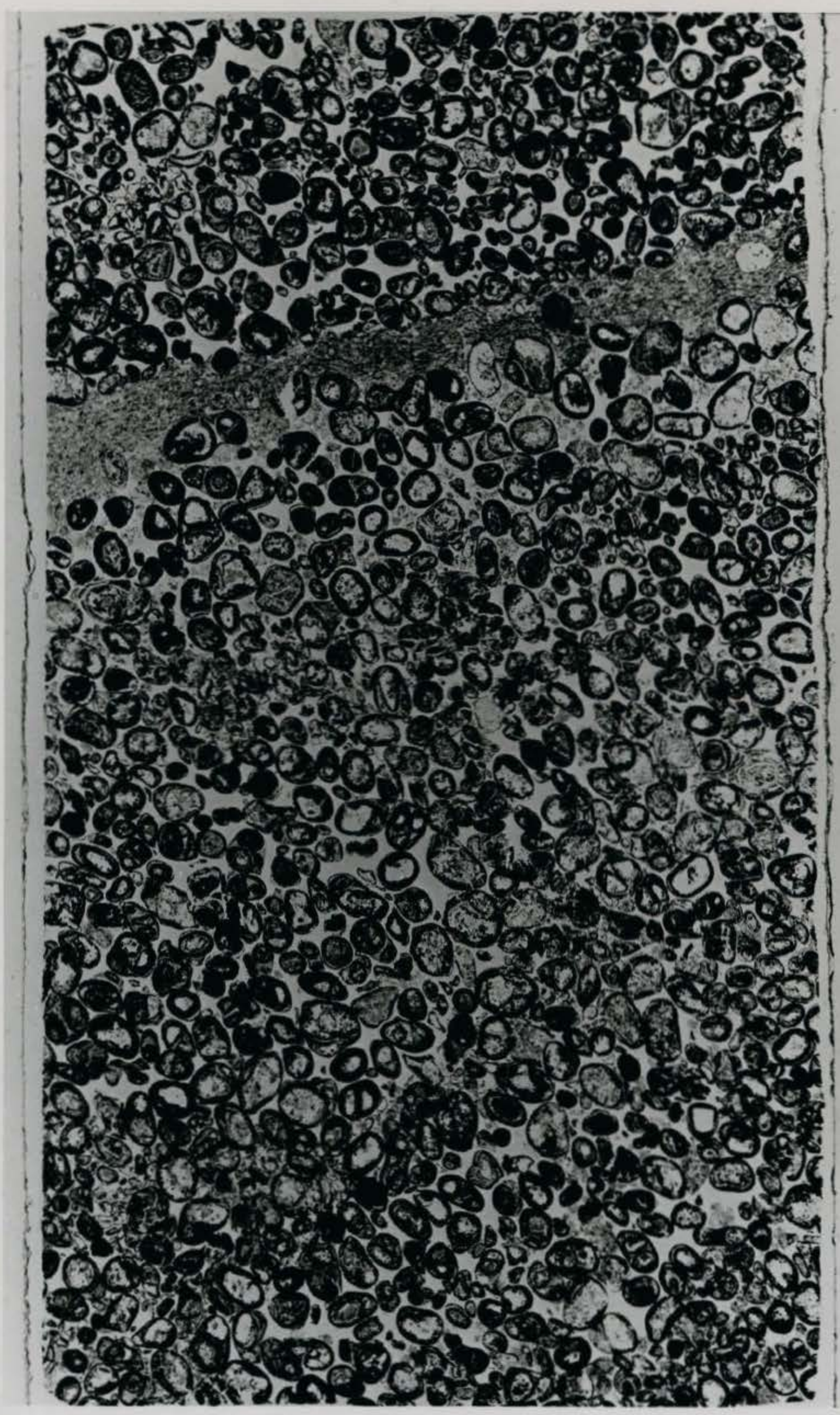


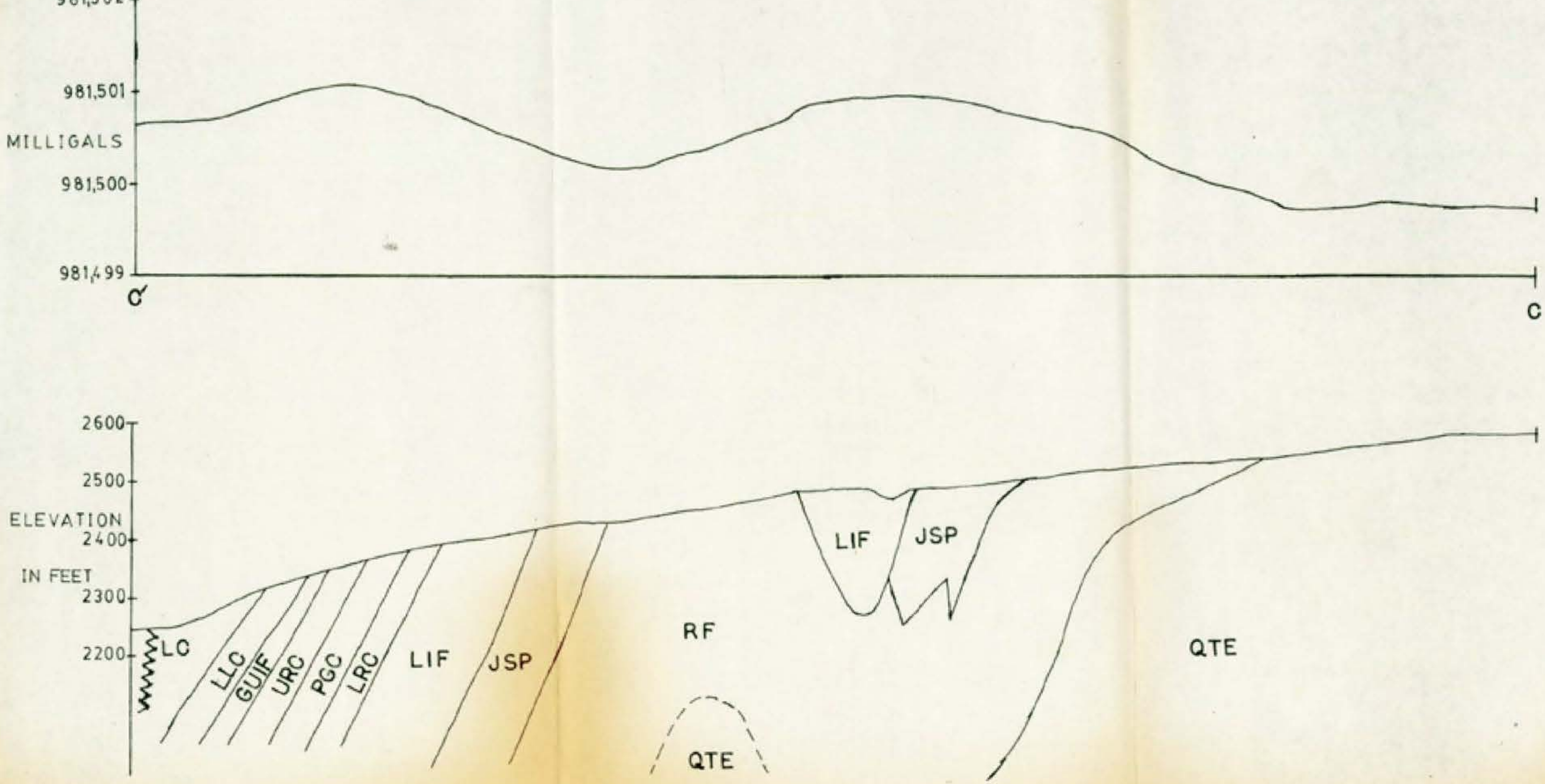
PLATE 8

Plate 8: LRC Sub-member of the Sokoman Formation. Note the Original Undeformed Oolites. There is Also an Original Bed of Clastic Material Crossing the Section and Infilling Around Oolites. These Sedimentary Features are Undeformed. Tops Can Clearly be Deduced from the Infillings. This was Taken in Sample Location s-5.

plane polarized light

magnification = 6x

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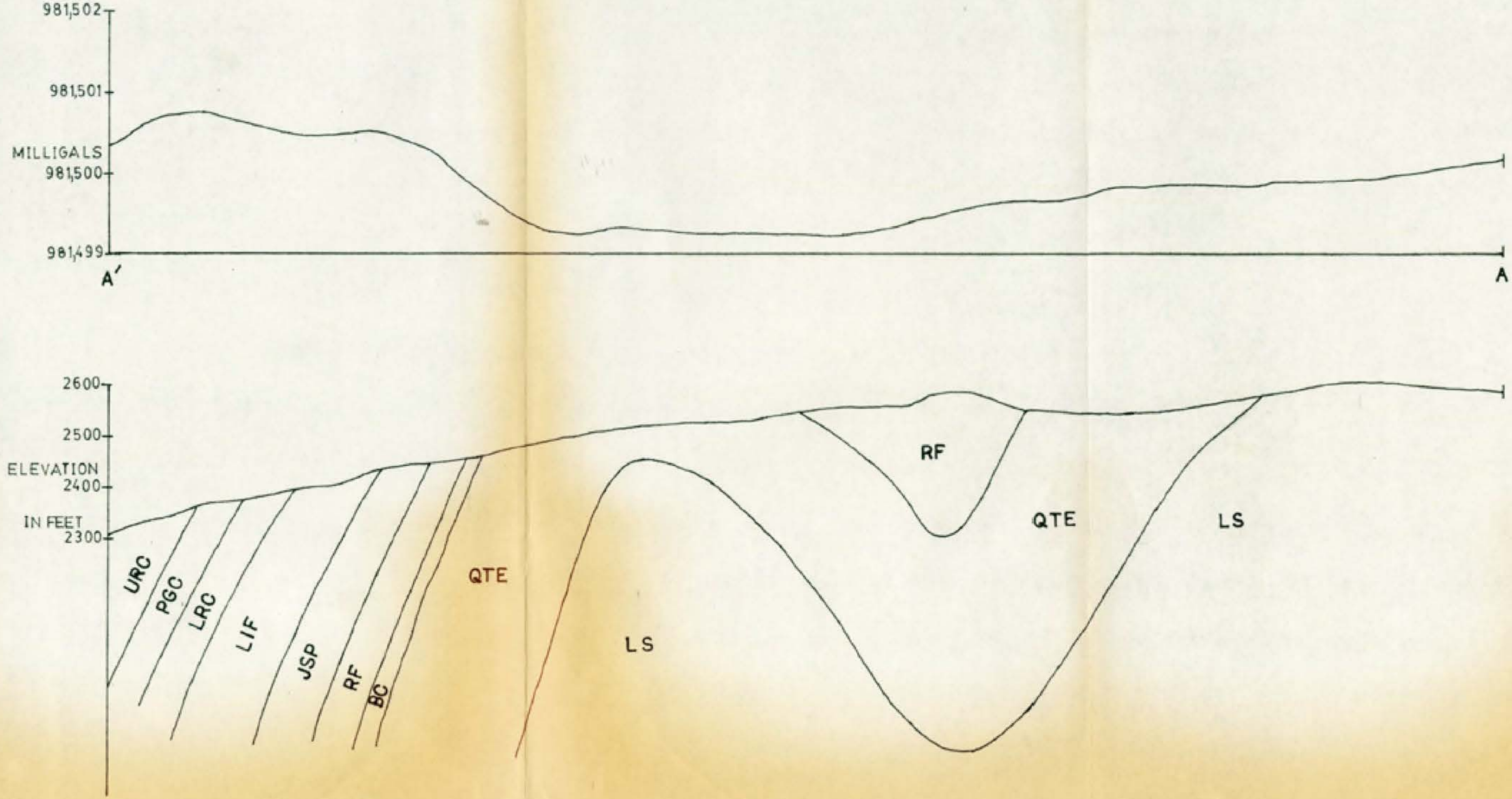
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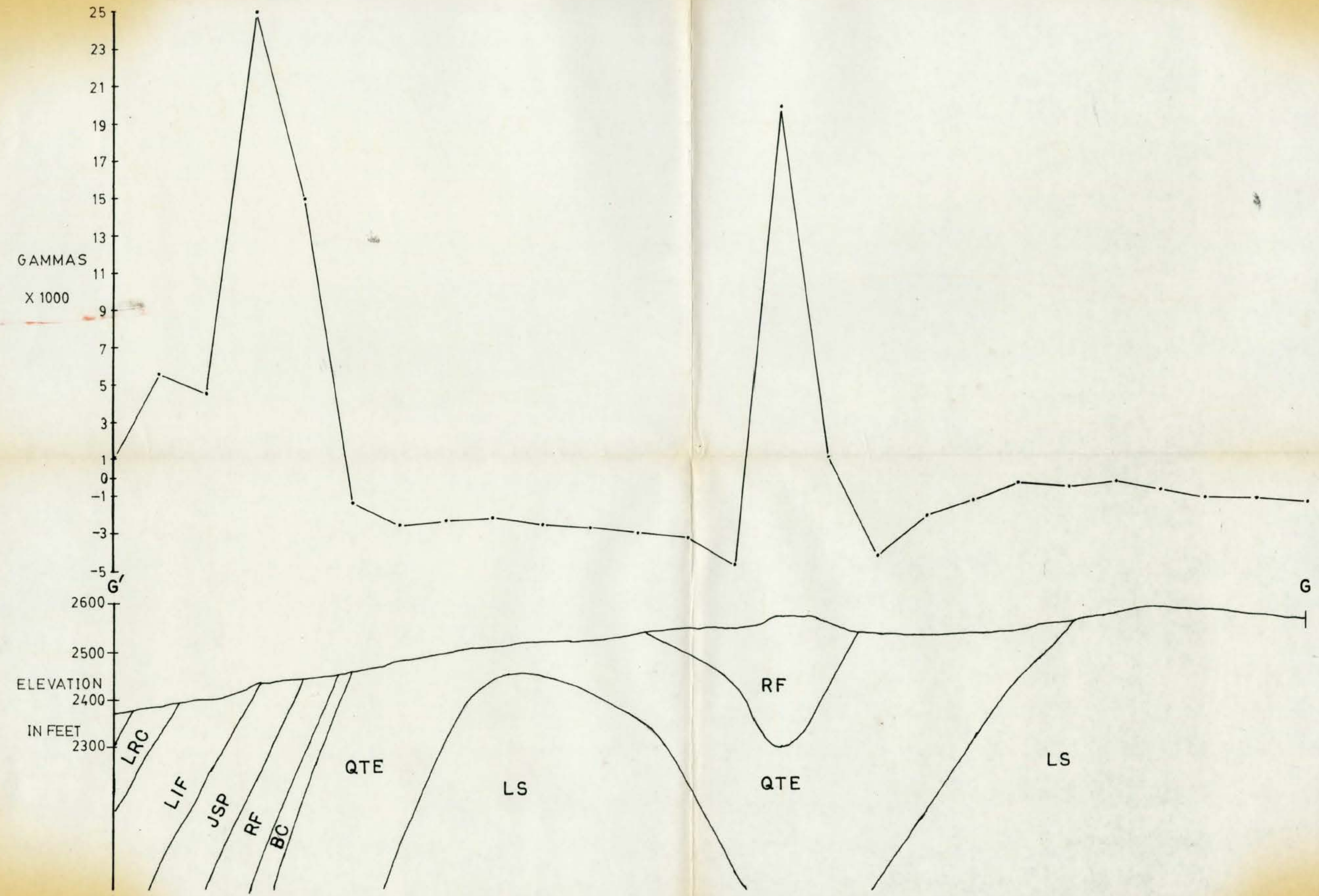

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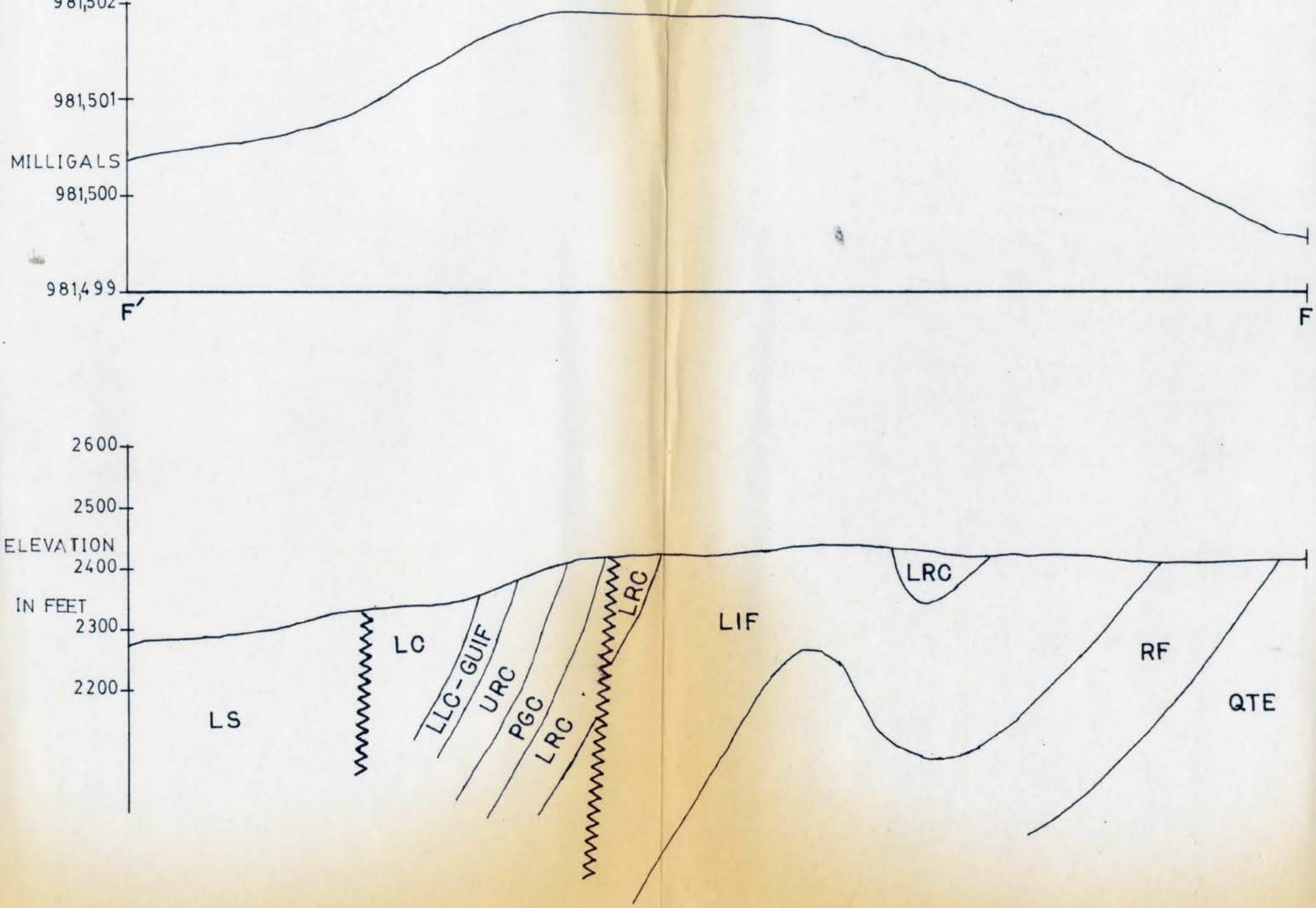

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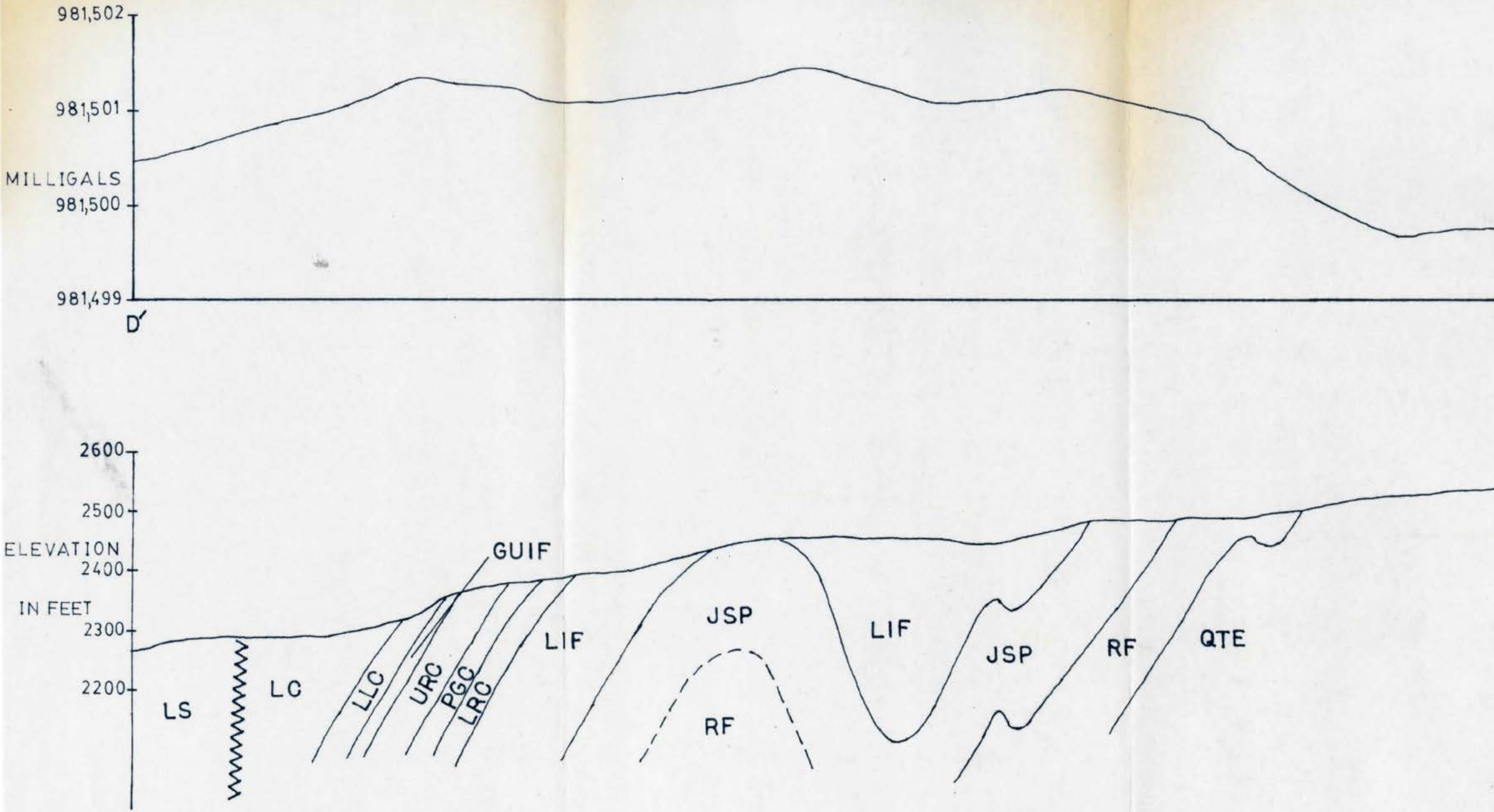
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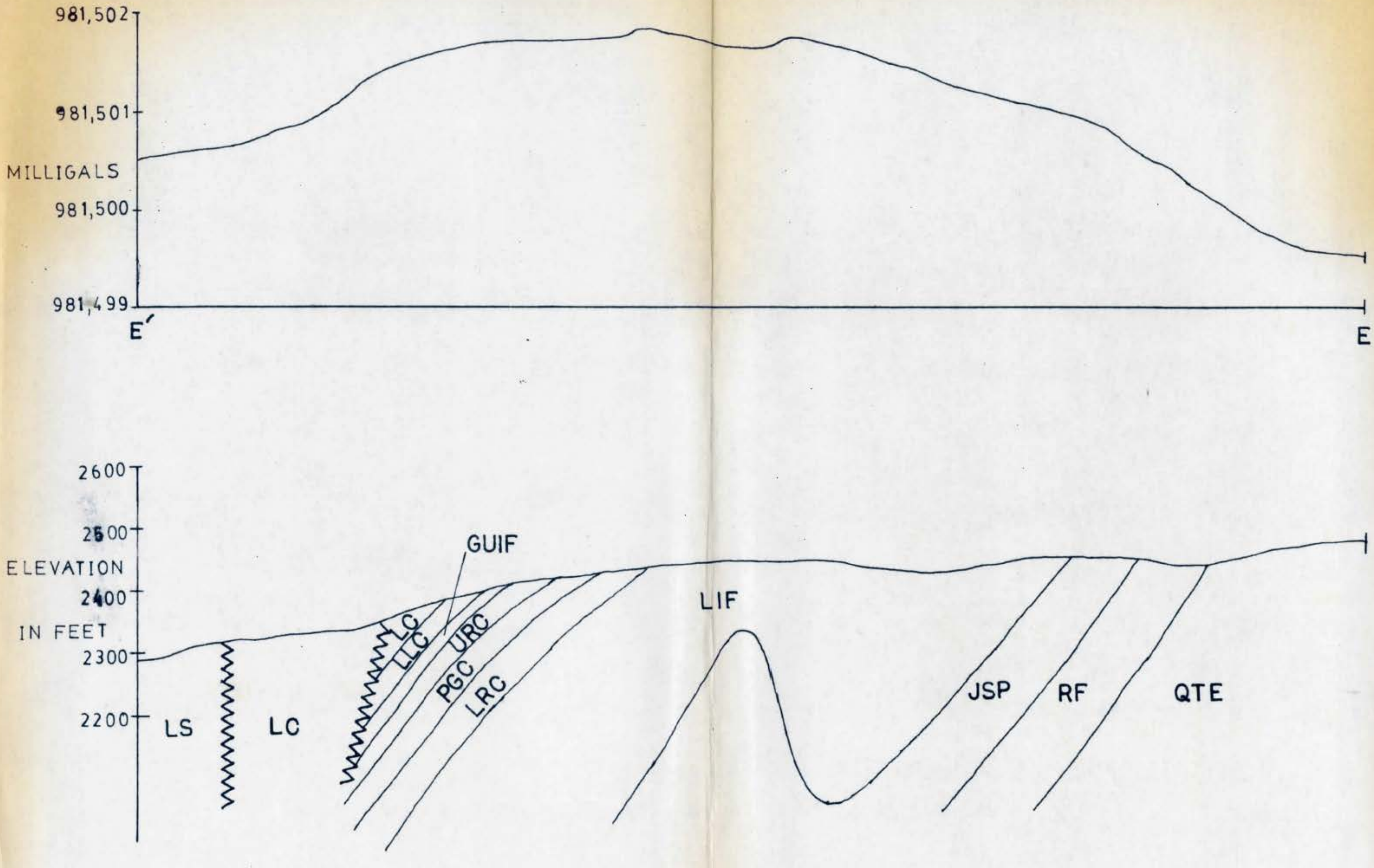
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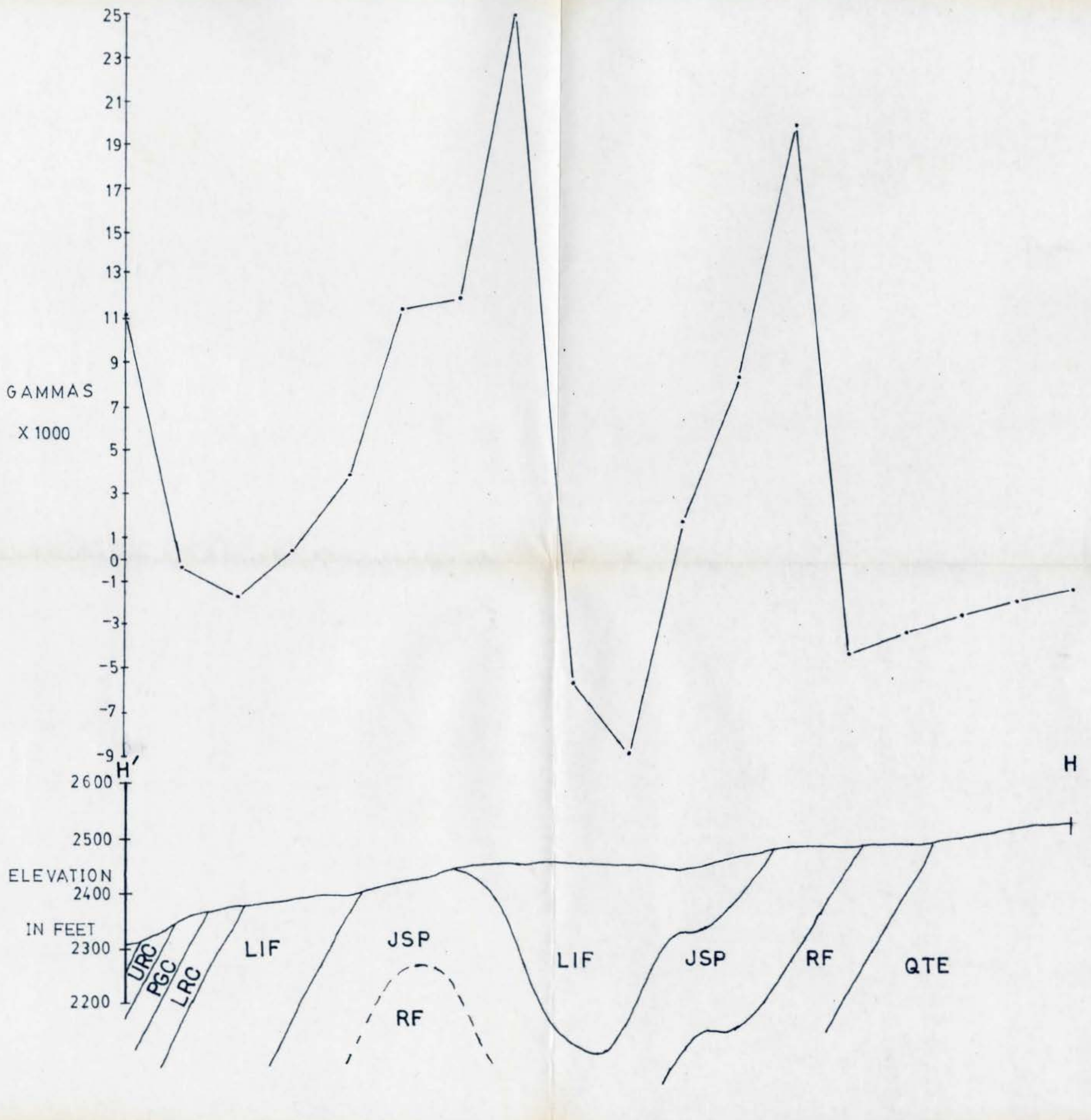

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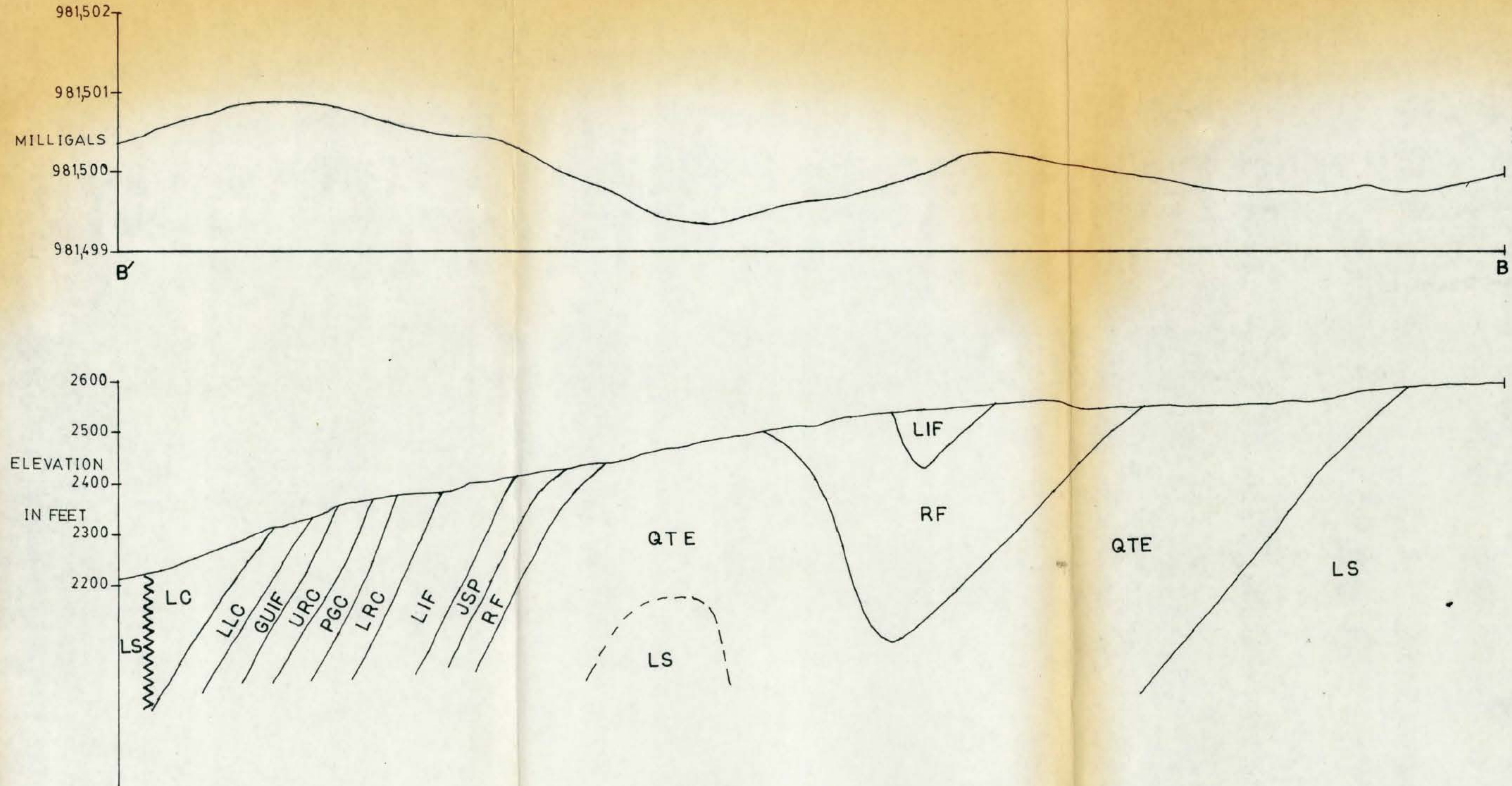
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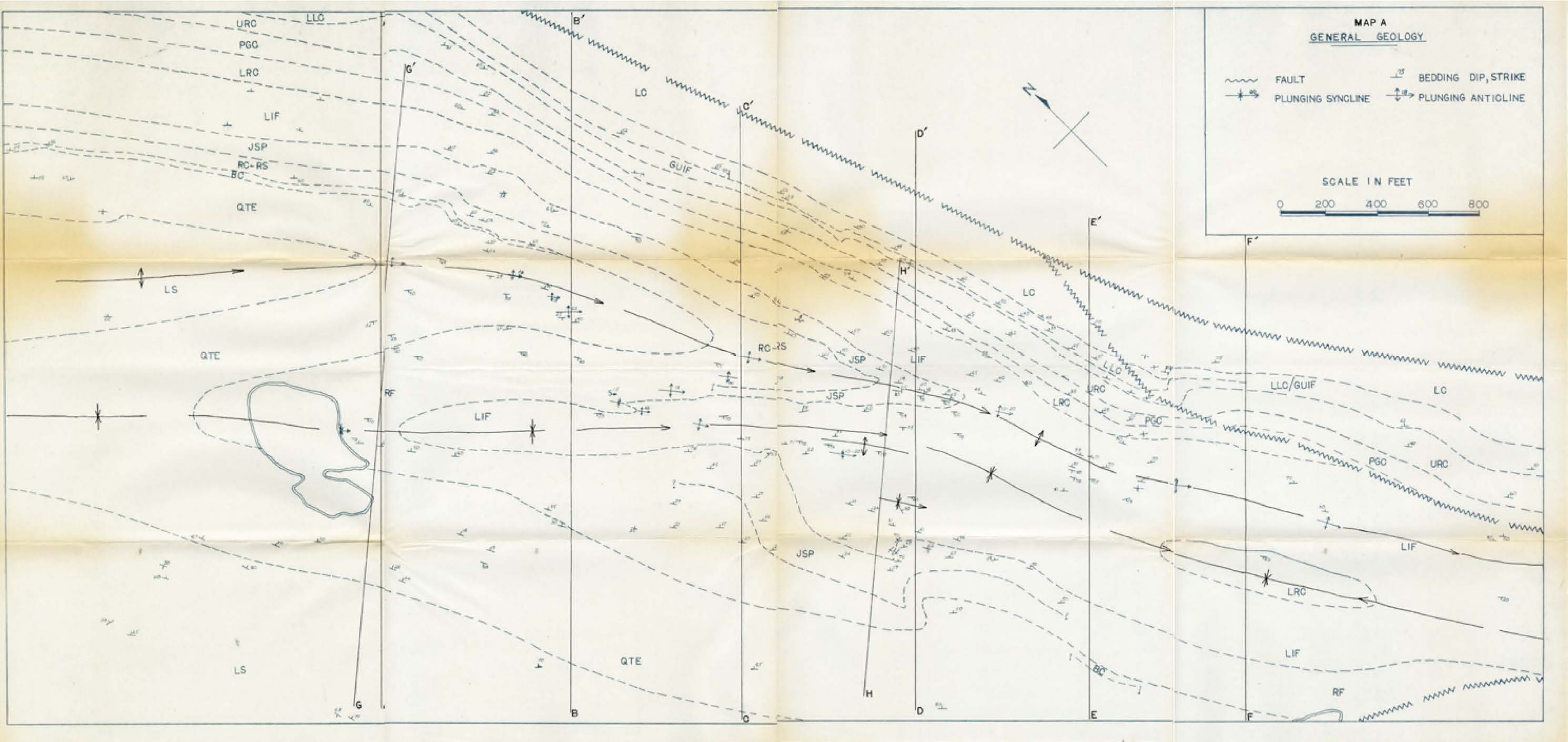
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PLUNGING ANTICLINE
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MAP B
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PLUNGING ANTICLINE
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S-1 SAMPLE LOCATION
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