DRIFT PROSPECTING AND GLACIAL GEOLOGY IN THE SHEFFIELD LAKE-INDIAN POND AREA, NORTH CENTRAL NEWFOUNDLAND

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DRIFT PROSPECTING AND GLACIAL GEOLOGY
IN THE SHEFFIELD LAKE - INDIAN POND AREA,
NORTH CENTRAL NEWFOUNDLAND

by

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A Thesis submitted in partial fulfillment of
the requirements for the degree of Master of Science.

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1975

St. John's Newfoundland

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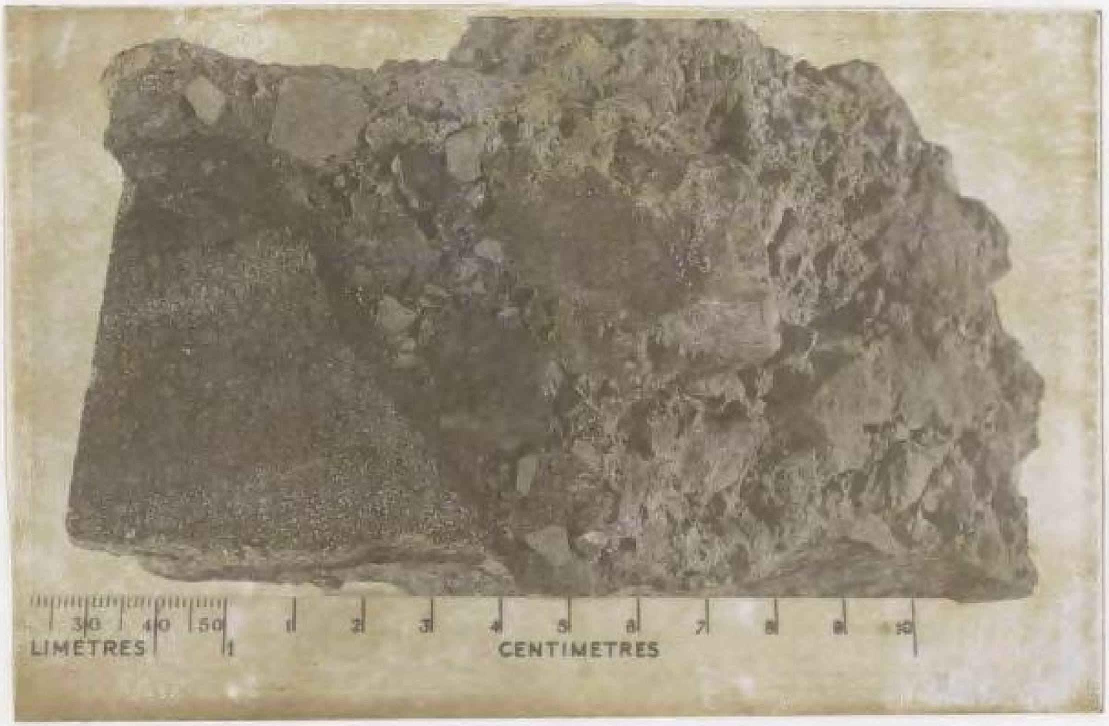

Plate 1: A sulphide float clast from the Sheffield Lake - Indian Pond Area; note Limonite rim and accretion of pebble sized andesite clasts.

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ABSTRACT

Drift prospecting is defined as the application of glacial geologic, geochemical, geophysical and sedimentological techniques to the problem of mineral exploration in areas mantled by glacial overburden. Glacial drift in the Sheffield Lake - Indian Pond area of north central Newfoundland contains local accumulations of massive sulphide float, grading up to 8.2% Cu. Previous investigations by industry have failed to locate the source of the float.

The objects of this research were to locate the source of the float by means of drift prospecting, to evaluate the applicability of combined exploration techniques to the glaciated terrain of Newfoundland and to resolve the glacial history of the study area.

Glacial drift thickness in the area, determined by hammer seismic profiling, varies from 5 to 60 feet. An extensive trenching program revealed the presence of two till units. Till fabric analyses indicated local ice flow directions toward 020 for the Lower Red Till, and either 020-045 (low) or 000-315 (high) for the Upper Grey Till. The sulphide float occurs as first-cycle clasts only in the Lower Red Till and, sparsely, as second-cycle clasts in the Upper Grey Till. The two lodgement tills have been differentiated on the basis of colour, stratigraphy, fabric, texture, pebble lithology, clay mineralogy and geochemistry. The two tills provide the first conclusive evidence of multiple glaciation in north central Newfoundland.

The sulphide float, which generally weighs 1-5 lbs., ranges in composition from weakly pyritized and chloritized (host) andesite to

massive phyrite-chalcopyrite. Clasts are concentrated in the Lower Red Till where they form a well-defined dispersion fan with the apex pointing toward the southwest. Anomalous concentrations of Cu, Fe, S, Co, and Zn in the Lower Red Till likewise indicate a southwesterly bedrock source of the micro-float dispersion fan. A target area for further detailed exploration of the bedrock source of the float has been delineated on this basis.

It was determined that the combination of methods employed was essential for delineating the probable source area and it is recommended that they be employed in any future investigations with similar objectives. Of the methods employed, trenching with a backhoe and geochemical analysis of only a restricted size fraction of till samples were found to be particularly valuable. Cu, Fe, and S were found to be the best geochemical tracer elements, particularly when they were mutually associated.

ACKNOWLEDGMENTS

My thanks are due to Mr. H.R. Peters, who first suggested the project and freely provided maps, reports, and his own knowledge of the area; to Dr. R.M. Slatt whose field help and editing greatly enhanced this thesis; and to the Newfoundland Department of Mines and Energy who provided the field support, equipment, and base camp for the project. Encouraging and learned discussions were held with W.H. Poole, D.R. Grant, E.H. Hornbrook and C.M. Tucker of the Geological Survey of Canada, and with D.F. Strong, G.L. Andrews, R.G. Cawthorn, J. Thurlow, D. Hawkins and D.E. Press, Department of Geology, Memorial University of Newfoundland. I should also like to thank F. Goudie, Atlantic Analytical Services, and J.M. Fleming, P.H. Davenport and W. Ryder, Mineral Development Division, Newfoundland Department of Mines and Energy for their assistance. Messrs. Ken Perry and George Sutton and Mrs. Daphne Alley ably assisted the author in the field and laboratory. Ken Byrne drafted the figures and Mrs. B. Lewis typed the manuscript.

CHAPTER I.

INTRODUCTION

Scope and Objectives

Prospecting for base metal occurrences in glaciated terrain presents problems which collectively make these areas among the most difficult in which to discover economic mineral deposits.

Geophysics (Electromagnetics, Induced Potential, Self Potential, Magnetics) are often found to be useless because of bogs, thick drift, aquifers and clay layers and Gravity methods have limited usefulness because the instrument cannot be calibrated for till thickness, unless supported by overburden drilling or seismic refraction profiling.

Exploration geochemistry which was, for many years, thought to be impractical in glaciated areas has been shown, by a slowly increasing dossier of case histories, to be of value to the "Drift Prospector" (Donovan and James, 1967; Kauranne, 1967; Presant, 1967; Garrett, 1971; Gleeson and Cormier, 1971; etc.).

Float tracing, a method which has been in use in Fennoscandia for 200 years (Grip, 1953) but which found its first systematic applications in Canada only at the turn of the century (Dreimanis, 1958) has enjoyed some success, e.g. the Sullivan Mine, B.C. and the Steep Rock Iron Mine of Western Ontario.

Although a combination of these techniques should be particularly applicable to the glaciated terrain of Newfoundland, they have not generally been used in a systematic fashion in this province. Nor, in fact, is the glacial geology of the province known to any great extent.

The present investigation is an attempt to delineate the source of sulphide-rich float in the Sheffield Lake - Indian Pond area of North Central Newfoundland, using Drift Prospecting a combination of glacial geological, sedimentological, geophysical and geochemical techniques. A second objective is to evaluate the applicability of each technique to Newfoundland terrain and conditions. Finally, the glacial geology of the area will be studied and interpreted.

Location and Access

The Sheffield Lake - Indian Pond area is located in the Springdale - Green Bay region of North Central Newfoundland (1:50,000 sheet, Springdale, 12H/B West Half) (Figure 1).

The area of most intensive study comprises approximately nineteen square miles (49 sq. km.) between 49° 28' and 49° 24' north latitude and 56° 30' and 56° 20' west longitude (Figure 2). A considerably larger area between 49° 28' and 49° 17' north and 56° 20' and 56° 39' west was studied at the reconnaissance level.

The old Trans-Newfoundland Highway (#2) approximately bisects the area. The northern half of the region is criss-crossed by a network of over-grown logging roads. All roads are only passable by means of a 4-wheel drive vehicle due to the numerous culvert removals and subsequent washouts. Travel in the southern half of the area is only practicable on foot.

The former Brinex permanent base camp located one mile south of Springdale was made available to the project by the Newfoundland Department of Mines and Energy. Tent camps were also used to some extent, especially in the southern half of the area.

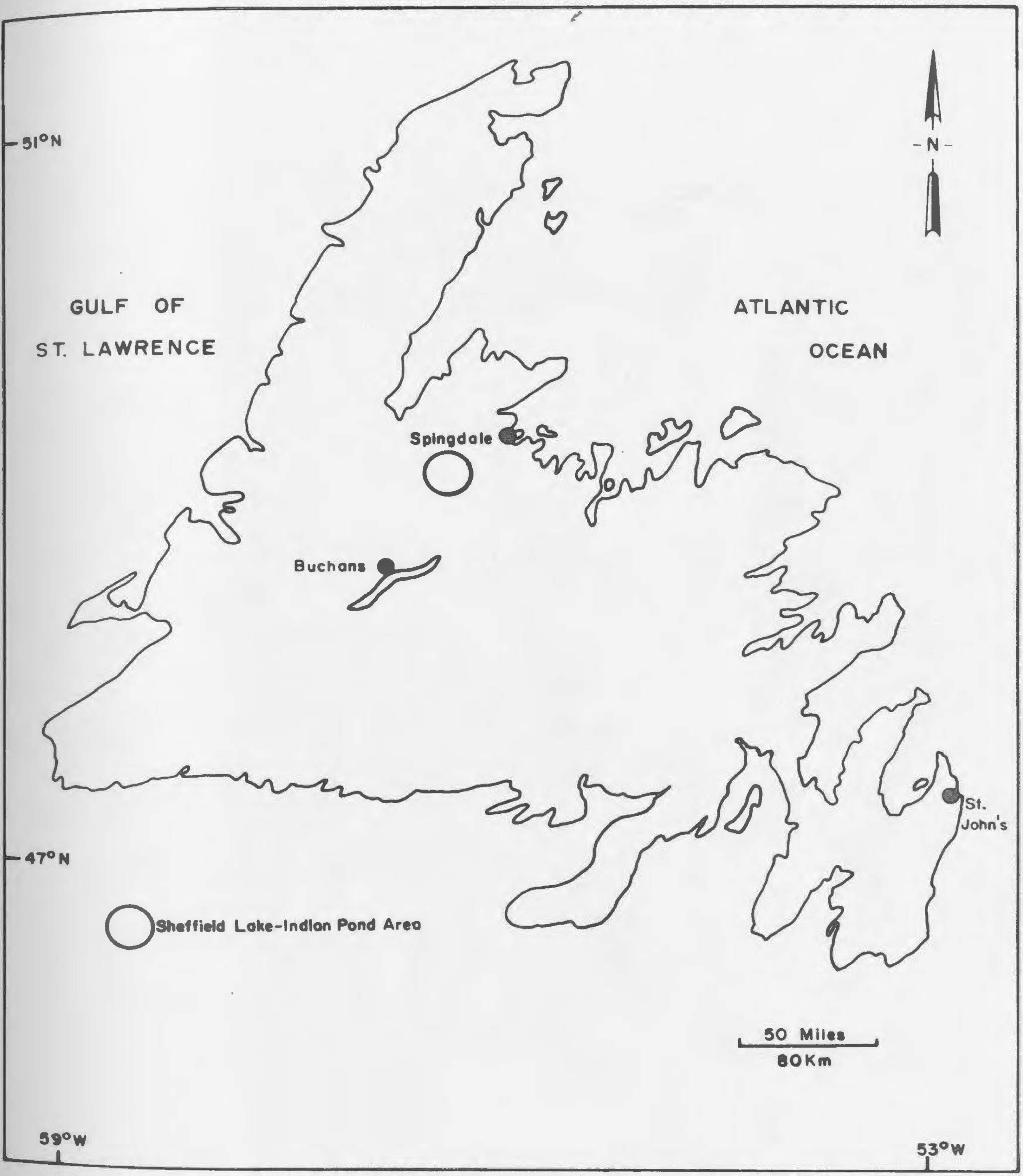

Figure 1 - Location Map

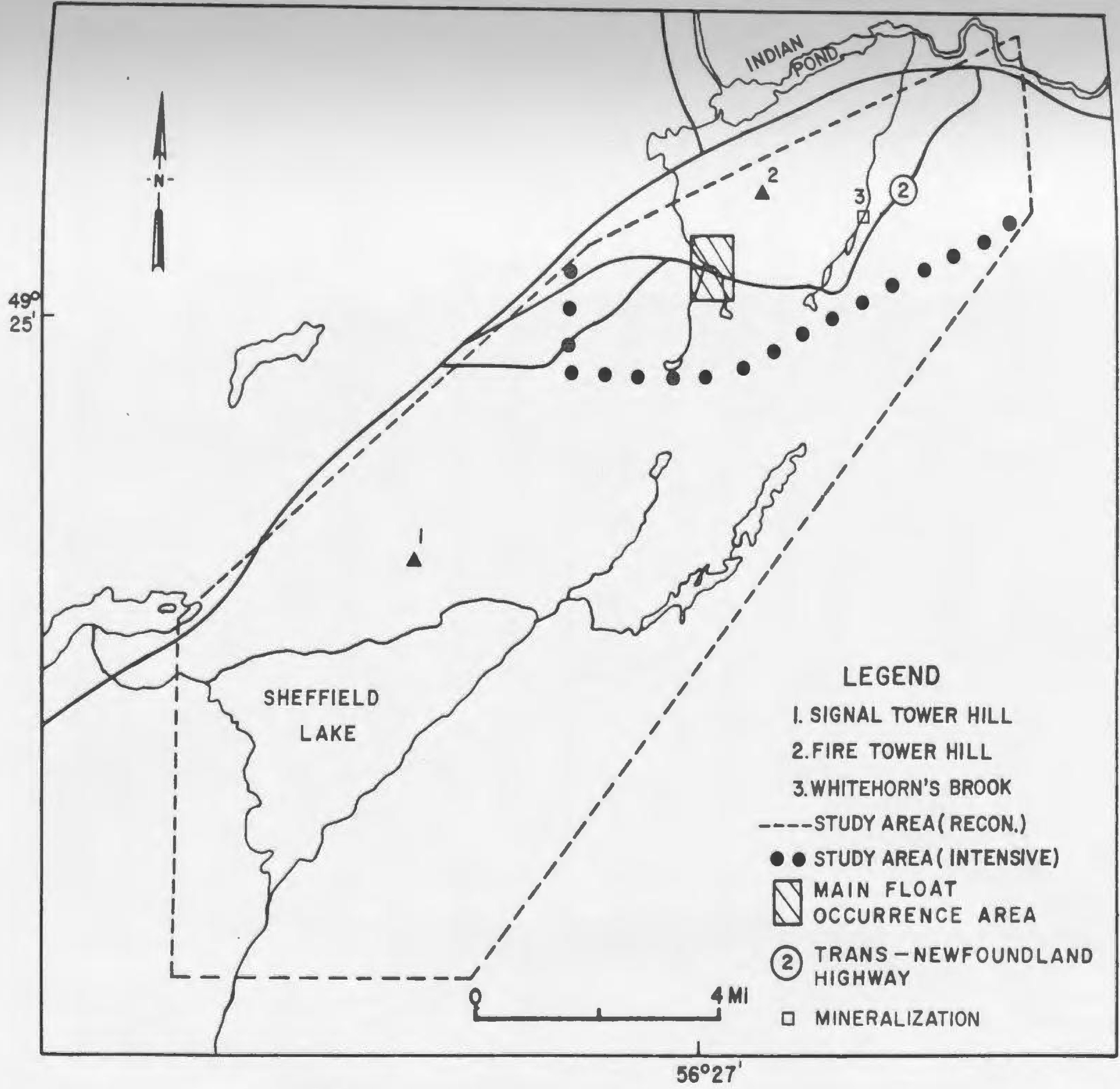

Figure 2 - The Sheffield Lake - Indian Pond Area

Climate, Vegetation and Topography

The annual precipitation in the Sheffield Lake -Indian Pond area is approximately 35 inches (114 ccm.) of which 10 inches (25.4 cm.) occurs as snowfall* (Tucker, 1973). The frost-free season of 100 days stretches from early June to mid-September. July is the warmest month with a mean maximum daily temperature of 73° F and December is the coolest month with a mean minimum daily temperature of 7° F.

The vegetation in the area consists of almost impenetrable alder thickets (Alnus), Tamarack (Larix laricina), and occasional patches of white spruce (Picea glauca) in poorly drained, sheltered areas. In the better drained areas are large open patches of caribou grass and varieties of low shrubs and bushes including Wild Rose (Wild nitida Willd.) and blueberry (Vaccinium angustifolium Ait.). Some extensive areas of forest also occur in the region in which balsam fir (Abies balsamea) and black spruce (Picea mariana) are the dominant species. A few scattered stands of hardwood forest are always of fire origin and contain white birch (Betula papyrifera Marsh) and trembling aspen (Populus tremuloides) (Tucker, 1973).

The Sheffield Lake - Indian Pond area is situated on a slightly undulating plateau about 6 miles (9.5 km.) wide, 11 miles (17.5 km.) long and at elevations between 525 (160 m.) and 625 (191 m.) feet (Plate 2 and Figure 2). To the west and north west the plateau is bordered by a range of bedrock hills commonly reaching a height of 500-600 feet above the mean plateau level. The two highest, Fire Tower Hill and Signal Tower Hill,

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* 10" precipitation = 100" snowfall

are at elevations of 1025 (313 m.) and 1537 (469 m.) feet, respectively.

Beyond the range of hills lies the major glacial outwash system of the Birchy Lake - Indian Pond depression, the bottom of which lies 500 feet below the mean plateau level.

The plateau is truncated in the north east by the Indian Brook Valley and bordered on the east and southeast by a range of low bedrock hills with a maximum height of 900 feet (275 m.) above sea level.

The southern boundary of the plateau is formed by Sheffield Lake (9 sq. miles), which occupies a large structural depression trending east-northeast.

The Plateau is covered by glacial drift which varies in thickness between 5 and 60^{+} feet. Bedrock is rarely exposed. Only one or two outcrops occur per square mile.

Sluggish misfit streams, large areas of bog and marshland, and a myriad of small kettle lakes (rarely exceeding 0.4 square miles in area) dot the plateau.

Previous Geological Work

Bedrock Geology

Because the Sheffield Lake - Indian Pond area is within the Central Mineral Belt of Newfoundland, (Snelgrove, 1928, Williams, 1967; Rose et al, 1970), it has attracted much attention from geologists in university, government, and industry.

Bedrock studies of the Sheffield Lake - Indian Pond region and adjacent areas include those by Peters (1954); Malmquist (1961); Neale and Nash (1963); Williams (1967); and Dean (1970).

Plate 2: The Sheffield Lake - Indian Pond plateau looking west toward the peripheral bedrock hills. The test trench was excavated during the 1961-1962 Brinex-Boliden joint attempt to discover the source of sulphide float in the area.

These workers indicate that the area is mainly underlain by a sequence of volcanic flow and pyroclastic rocks ranging in composition from rhyolite to basalt, with local intercalations of fossiliferous limestone. However, because of the highly sheared and faulted nature of the volcanic sequence its relation to nearby Ordovician volcanic rocks is uncertain.

Williams (1967) considered the volcanic rocks as part of the Silurian Springdale Belt which also forms the host rocks of the rich base metal orebodies at Buchans (Figure 1), however, Dean (1970) correlates these rocks with the Ordovician Catchers Pond Group to the northeast.

"Topsails" granite and red syenite of Devonian age form the bedrock of the remainder of the study area to the east, west, and south of the volcanic sequences (Neale and Nash, 1963).

Glacial Geology

The Sheffield Lake - Indian Pond area was glaciated during the Pleistocene Epoch. Several workers have postulated an insurgence of Laurentide (Labrador) ice over most of insular Newfoundland from the north or northwest during the early Wisconsinan glaciation (Murray, 1883; Tanner, 1940; Flint, 1951 Lundquist, 1965). Recent work by Grant (1969; 1972); Brookes (1970); and Tucker (1973), however, minimizes the role of Laurentide ice on the Island, with the exception of small areas of the Northern Peninsula.

The available data indicate that there was one or more glacial ice centres to the southwest of the Sheffield Lake - Indian Pond area during the Wisconsinan glacial period. MacClintock and Twenhofel (1940) and Murray (1955) speculate that there probably were migrating ice centres in the Red Indian Lake - Buchans area (Figure 1) on the basis of striation orientation.

Lundquist (1965) concluded from striation measurements in and around the Sheffield Lake - Indian Pond area that after the Wisconsinan ice maximum (during which the ice moved predominantly to the northeast - Tucker, 1973) thin, local ice was successively more affected by topography resulting in local vagarities of flow. He states that from a late local ice centre "in the flat depression on the southern side of the hills along Indian Pond" (the Sheffield Lake - Indian Pond plateau) ice flowed to the north and northwest (Figure 2).

Tucker (1973) has attempted to date the deglaciation of the region on the basis of marine shell samples dated at 12,000 BP. by the Geological Survey of Canada and average marginal recessions of 66 feet per year between 12,000 and 7,000 BP. (Andrews, 1972). He speculates that the deglaciation of the Sheffield Lake region (the southern edge of the Sheffield Lake - Indian Pond area in Figure 2) occurred approximately 1,500 years after the deposition of the dated shells, or 10,500 years BP.

Exploration Activities

In 1953 a Department of Highways road crew found a mineralized boulder in the study area which was assayed to contain 6% copper. Since then Brinex (British Newfoundland Exploration Ltd.) and several other companies have discovered hundreds of mineralized clasts in the region, but have had no success in discovering their source.

In 1953, Brinex conducted a reconnaissance geologic survey over much of the area and first found copper mineralization in place in the vicinity of Whitehorn's Brook (Figure 2). Subsequently, numerous pyritic and copper sulphide boulders in glacial drift were found scattered over a distance of 2-3 miles. Intensified, but sporadic, geological, geophysical, and geochemical prospecting by Brinex during the next few years turned up more mineralized float, but its source was not located (H.R. Peters, Personal Communication, 1974).

In 1956 and 1958, airborne geophysical surveys were conducted for Brinex over most of its Hall's Bay concession including the study area. Results were essentially negative, possibly because both the Electro Magnetic and Magnetic methods used went beyond the effective limits of the equipment. However, some anomalies were detected in the valley of Indian Brook west of the area of mineralized float. The airborne anomalies were not satisfactorily explained (H.R. Peters, Personal Communication, 1974).

In 1961-62, Boliden Co. of Sweden in joint partnership with Brinex made a detailed study of the area where sulfide float was concentrated, and from this, hundreds more massive sulfide cobbles and boulders were uncovered in the upper 2-3 feet of glacial drift. One cobble appeared very similar to Buchans type ore. Again, the source of the float was not found (Malmquist, 1961).

In 1965, Cominco Ltd. undertook a three year exploration program consisting of soil and glacial till geochemistry, geophysics, and bedrock sampling. This work in the Sheffield Lake - Indian Pond area was sketchy and samples were analyzed by THM cold extraction methods which have been found to be unreliable in heavily glaciated terrain (H.R. Peters, Personal Communication, 1974).

In 1970, Brinex collected over 200 drift samples over a 300 square mile area, including 35 in the proposed study area, for heavy mineral analysis. However, because of a change in company policy, the laboratory phase of this work was not completed.*

The tentative conclusions that were drawn from the exploration work, as well as from some independent academic investigations, were that: (1) because the ore body supplying the float was not found, it presumably was eroded away during glaciation, (2) Wisconsinan ice generally flowed northeastward, but evidence has been found for northerly and westerly components of flow, and (3) at least two tills <u>might</u> be present in the area. None of these conclusions have been suitably verified and are the result of several independent studies rather than a co-ordinated effort.

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* These 35 samples were later released to the Memorial University Geology Department by Brinex and were used for the initial laboratory phase of this investigation.

CHAPTER II.

GEOLOGICAL SETTING

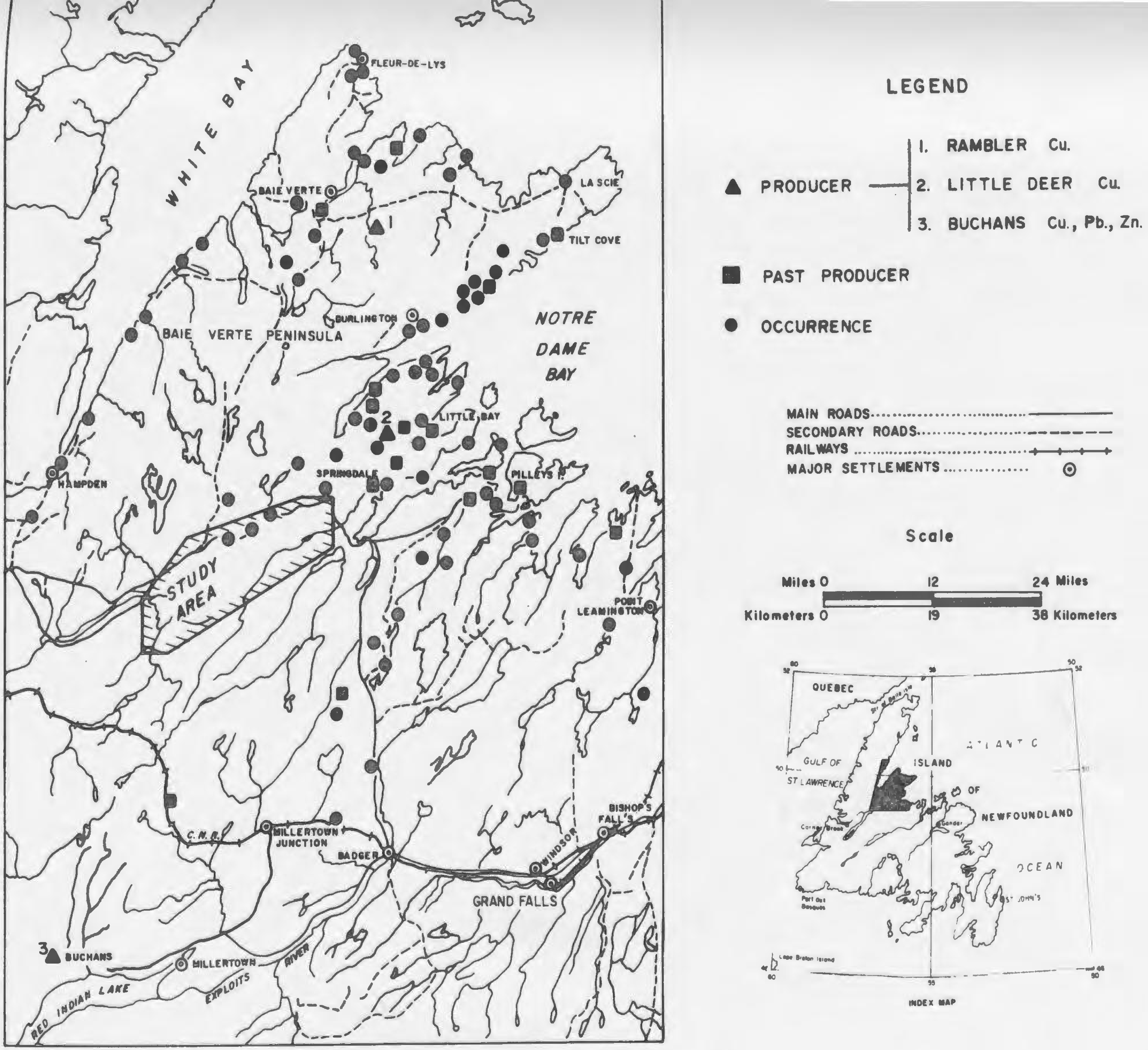
Economic Geology

Baird (1956) in his enthusiastic paper concerning the possibility of further mine discoveries in the Notre Dame Bay area of North Central Newfoundland, states

> "almost all of them (mines and prospects) are located along the coast or very close to it, for here was where the travellers passed, here was where the people lived, and here the rocks were bare and easy of inspection. --- Modern techniques of exploration, i.e. geochemcial, geophysical and geological, are being used for the first time in an area where drift and forest have preserved much of the country from the primitive plundering of early mining efforts. When one considers the southwestward extension of the same conditions for a hundred miles a geologist sees only optimism".

The Sheffield Lake - Indian Pond area is located within Baird's one hundred mile long belt. The attention of mining companies was first drawn to the area with the discovery in 1953 of a copper rich boulder in till (H.R. Peters, Personal Communication, 1974). The chequered exploration history of the area, however, has yielded no definite source for the hundreds of sulphide boulders subsequently discovered in the region.

The study area, located within the Central Mineral Belt of Newfoundland (Snelgrove, 1928) is within a larger region of extensive past and present base metal mining activity (Figure 3). Thus, bedrock in the Sheffield Lake - Indian Pond area is prime prospecting terrain for sulphide mineralization. Bedrock in the region consists dominantly of andesite, dacite, and rhyolite flows and proclastics that were originally mapped as the Silurian Springdale Group, (Williams, 1967) but which were later redefined as the Lower Ordovician Catchers Pond


LEGEND
PRODUCER
1. RAMBLER Cu.
2. LITTLE DEER Cu.
3. BUCHANS Cu., Pb., Zn.
PAST PRODUCER
OCCURRENCE
MAIN ROADS
SECONDARY ROADS
RAILWAYS
MAJOR SETTLEMENTS
Scale
Miles 0
12
24 Miles
Kilometers 0
19
38 Kilometers
WHITE BAY
FLEUR-DE-LYS
BAIE VERTE
LA SCIE
TILT COVE
BURLINGTON
BAIE VERTE PENINSULA
NOTRE DAME BAY
LITTLE BAY
SPRINGDALE
PILLEYS I.
HAMPDEN
STUDY AREA
POINT LEAMINGTON
C.N.R.
MILLERTOWN JUNCTION
BADGER
WINDSOR
BISHOP'S FALL'S
GRAND FALLS
BUCHANS
MILLERTOWN
RED INDIAN LAKE
EXPLOITS
RIVER
QUEBEC
Str of Belle Isle
GULF OF
ST LAWRENCE
ISLAND
OF
NEWFOUNDLAND
ATLANTIC
OCEAN
Corner Brook
Gander
Port aux Basques
St. John's
Cape Breton Island
INDEX MAP

group, (Dean, 1970).

Mineral Occurrences in the Study Area

Malmquist (1961) mentions a small massive pyrite lens in dacite outcropping 200 metres west of Pond II (Figure 4), however, although the author made a concerted attempt to find and inspect the showing, it could not be located. Bedrock chalcopyrite mineralization occurs in place near Whitehorn's Brook (Figure 2) to the northeast of the main float occurrences, and has been drilled by Brinex. However, it was found to be a sub-economic occurrence, and no further work has been attempted (H.R. Peters, Personal Communication, 1974).

Bedrock Geology

A compilation of the bedrock geology of the main float area from maps by Peters (1954, 1962, Neale and Nash (1963), Malmquist (1961) and Williams (1967) appears in Figure 4). The bedrock contacts are based on very little empirical bedrock data, because of the paucity of outcrop in the region, and must, therefore, be construed as approximate locations only.

The andesite (Neale and Nash's, 1963, Unit 14) which makes up the bedrock of the largest part of the map area may be part of the Catchers Pond volcanics. It consists of plagioclase and mafic phenocrysts set in a fine grained dominantly feldspar matrix, showing flow alignment. The mafic phenocrysts and the matrix have been chloritized and epidotized. In some cases the andesite is brecciated along shear zones. This chloritized andesite is recognized as the host rock of the sulphide

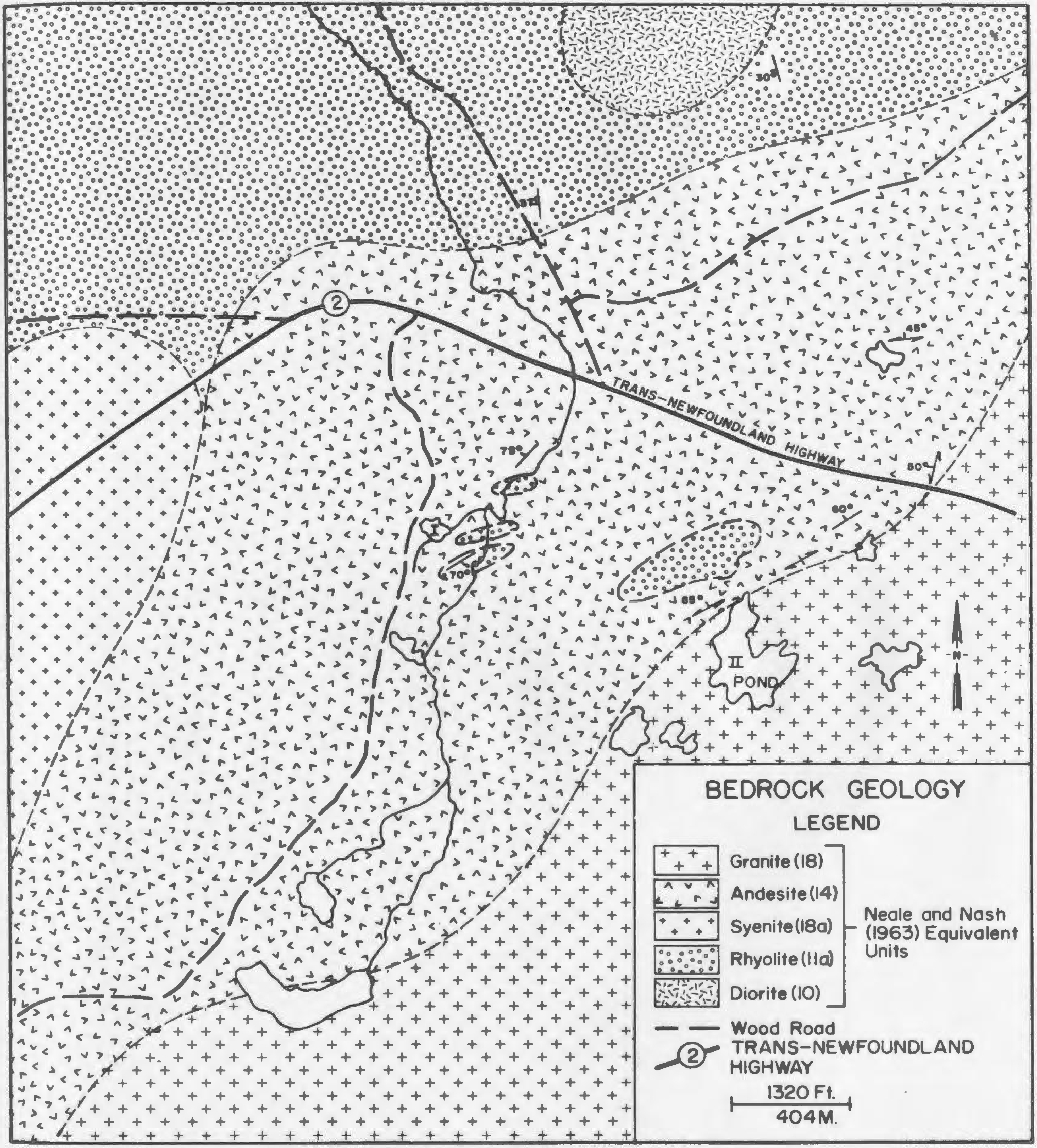


Figure 4. Bedrock geology of Main Float Zone

mineralization in the float clasts (see frontispiece). Where exposed in the study area, the andesite rarely exhibits original depositional structures since these have been obliterated by low grade metamorphism of greenschist facies, and by intersecting fault zones. The andesites dip dominantly to the west at angles of 50° - 90°, with small variations in strike (Malmquist, 1961, Figure 4).

The remainder of the bedrock in the study area is composed of granitoid betholitic intrusions (units 18, and 18A of Neale and Nash) of probable Devonian age, to the east, west and south of the volcanics. These rocks range in composition from granite to granodiorite, but locally include important amounts of pale reddish-brown to greyish-red syenite (Neale and Nash, 1963). The granitoid rocks generally are massive, equigranular and medium to fine grained, although coarse grained and porphyritic types do occur, especially south and west of the main float zone, respectively (Figure 2). Potash feldspar and plagioclase occur in roughly equal amounts. The rocks contain 10 to 20 per cent quartz. Amphibole is the chief mafic mineral with lesser amounts of biotite, locally altered to chlorite.

The geology is complicated by the occurrence of several shear and fault zones. Two dominant faults, oriented N. 60° E. and N. 20° W. occur in the region. The dominant of these (N. 60° E.) may be an extension of the Lobster Cove Fault system into the Sheffield Lake - Indian Pond area. Neale and Nash (1963) indicate that this fault ends inside the study area but to the east of their unit 14.

Drill Logs

Subsequent to a joint attempt by Boliden and Brinex to discover the bedrock source of the sulphide float (Malmquist, 1961), nine diamond drill holes were drilled in the vicinity of the float discoveries (Peters, 1962). All of the holes penetrated an alternating volcanic sequence of andesites, rhyolites and dacites (see Appendix A) and minor chalcopyrite was encountered in many of them.

Only two of the holes drilled, however, can be considered as "up-ice" (southwest) of the apex of the float fan to be described in Chapter 1V. The two, #62-6 and #62-7, are 400' and 325' in length, respectively. Hole #62-6 is composed dominantly of chloritized and brecciated andesite containing a few inches of massive pyrite and a small amount of disseminated chalcopyrite throughout its length. The dominant feature of the section exposed in #62-7 which is located about 200 feet to the west of the first discovered float occurrence, is the alternating volcanic sequence of rhyolite and andesite, which is repeated at various depths in the section. Chalcopyrite is present in minor amounts as disseminated blebs.

Bedrock Chemistry

Two of the trenches (TB60 and TB92) opened in till during the study (see Chapter 1V) bottomed on chloritized andesite bedrock. In both cases, bedrock samples were collected for chemical analyses (Chapter V). TB-60 is located 2,000 ft. northeast of the centre of Pond II, while TB-92 is located near the main float occurrence area, about 2,000 ft. northwest of Pond II (Figure 4). Two rock samples were collected at

TB-92; one from the weathered bedrock/till interface (R92W) and a second deeper unweathered sample (R92F).

It must be noted here that after the rock samples were powdered, they were submitted to the same partial dissolution (F. Goudie, Personal Communication 1974) as were the till samples (see Chapter V). Results of chemical analyses appear in Table 1 and are discussed in Chapter V along with chemical analyses of similar lithologies in the Buchans area (Thurlow, 1973).

The Float

Subsequent to the original float discovery in 1953, hundreds more float clasts have been unearthed in the Sheffield Lake - Indian Pond region, primarily during a joint Brinex-Boliden study in 1961-1962.

As mentioned above, the host rock of the sulphide float clasts in the main float zone (Figure 2) is chloritized andesite. Malmquist (1961) described and analyzed 29 of the float boulders in the main float zone (Malmquist's area A), of which 10 were found to contain between 2.75% and 8.20% Cu (Table 1).

He noted that some of the boulders weighed over 300 pounds (136 Kg.), and this author observed one weighing approximately 500 pounds (227 Kg.) Plate 3. Most of the float clasts however weigh between one and five pounds (0.5 to 2.3 Kg.).

Where the float occurs in the Lower Red Till (Chapter 1V), the clasts are usually angular to subangular, and in some cases have developed limonite oxidation rims to which have been cemented many adjacent float

Plate 3: The largest sulphide float boulder discovered in the Sheffield Lake - Indian Pond area.

Table 1.

Andesite and Float Analyses

	#R60	#R92 f	#R92 w	F_1	F_2	F_3	Maximum Float Values Obtained in % (Malmquist, 1961)
ppm Cu	25.0	43.0	120.0	1217.0	1172.0	1238.0	8.20
ppm Pb	4.0	5.0	6.0	50.0	32.0	23.0	--
ppm Zn	14.0	30.0	22.0	132.0	152.0	320.0	--
ppm Co	17.0	20.0	29.0	93.0	143.0	90.0	--
ppm Ni	30.0	55.0	55.0	108.0	130.0	83.0	--
ppm Mn	20.0	580.0	680.0	725.0	750.0	1250.0	--
% Fe	0.70	3.90	4.85	16.10	15.70	15.30	57.20
% S	0.03	1.45	4.80	39.10	28.40	23.60	42.90

R - designates bedrock samples

f - designates an unweathered bedrock sample

w - designates a weathered bedrock sample

F - designates float boulders

clasts and unmineralized pebbles (Plate 1). In the Upper Grey Till (Chapter IV) the clasts are most often rounded to subrounded, are heavily weathered, and tend to crumble easily when disturbed. The previous occurrence of many small float fragments and weakly mineralized andesite pebbles in the Upper Grey Till are evidenced only by a localized limonite stain in the first case and by boxwork structures in the second.

The mineralization of the float clasts is dominantly pyrite (FeS_2) and chalcopyrite ($CuFeS_2$) with lesser amounts of bornite (Cu_5FeS_4) and malachite ($Cu_2(Co_3)\ (OH)_2$). The mineralization ranges from disseminated blebs and small stringers in the andesite host rock to clasts which are 100 per cent massive sulphides.

Ore Microscopy

Four samples taken from sulphide rich boulders in the study area (see frontispiece) were mounted in plastic and polished. The metallics in the polished sections were almost entirely pyrite or limonite, with traces of magnetite. Chalcopyrite was present as a consistent 2% of the metallics in the four samples studied, occurring as small disseminated blebs. Two of the samples were slightly magnetic. The actual percentage of metallics in the sections were 40, 50, 75, and 90.

CHAPTER III.

BASIC PRINCIPLES OF DRIFT PROSPECTING

Drift prospecting, as defined in the introduction, involves the application of glacial geological, geochemical, geophysical and sedimentological techniques to the problem of mineral exploration in areas of glaciated terrain.

Glacial Geological Investigations

Glacial geological techniques are important to every phase of drift prospecting. Without a thorough understanding of the glacial history of the area to be studied, further work (with the possible exception of some geophysical studies) will be futile (Hyppa, 1948; Dreimanis, 1960; Hawkes and Webb, 1962; Riddell, 1967; Hyvärinen, 1967; Wennervirta, 1968; Garrett, 1969; Forgeron, 1971; Lee, 1971; Nichol and Bjorklund, 1973; Milsson, 1973; Gunton and Nichol, 1974; Levinson, 1974; and others).

Widely known techniques for determining the most recent ice flow direction precisely, such as striation and groove measurement, often need to be supplemented by till fabric analyses (Holmes, 1941; Kauranne, and others), particularly in till covered areas where striated bedrock outcrops are scarce. Also a trenchant air photographic interpretation often will reveal the dominant ice flow direction in the region and the distribution and type of glacial drift deposits present.

The sequence of former ice flow directions can also be determined by these techniques. The vector sum of the measured directional data may often reveal a complicated transport history of mineralized float and point to its probable bedrock source area (Kauranne, 1967).

Boulder and Micro Float Tracing

Boulder tracing is also an integral part of drift prospecting. This technique dates from the work of Daniel Tilas (1712-1772) in Finland and Sweden (Sauramo, 1924), and possibly can even be linked to prehistoric American workings in Michigan (Pollock et al., 1960). These workers, however, predated the advent of contemporary glacial geological theory which stemmed from the work of De Carpentier and Agassiz in the mid-19th Century.

Boulder tracing principles are simple and strightforward. The discovery of a mineralized clast (termed float*) in unconsolidated glacial drift* generally is prime evidence that bedrock mineralization occurs in the vicinity. The discovery of tens or hundreds of such clasts increases the probability of a proximal provenance for them.

Not only do the float clasts indicate bedrock mineralization, but they also give a clue to the tenor of the source deposit (on the basis of which the level and type of further work is guided), the mineralogy of the source deposit and, most importantly, the host rock of the minerals of interest. From available geological reports and maps, large areas of unassociated geological terrain can be ruled out as a source area on this basis.

Other clasts associated with the float are studied (by means of pebble counts) to determine probable transport directions and distances for the float deposit in question. Finally, glacial ice flow indicators

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*The terms "Drift and Float" date from the Diluvial or Noah's Deluge theory which was in vogue until the mid-19th century.

are measured (either by means of air photographs or in the field) to determine the direction(s) of probable float transport.

This rather simplistic approach has accounted for almost all of the base metal mine discoveries in Fennoscandia since the time of Daniel Tilas and has had some notable successes in Canada as well, such as Sullivan Mine, British Columbia and Steep Rock Mine, Ontario (Lee, 1971).

Recent work by Bayrock and Pawluk 1966, has suggested that the fine fraction of lodgement till is probably of more local origin than the boulder sized float clasts. However,

> "there is no general agreement as to which textural parts of till are indicative of long-distance transport, if indeed, any such generalization may be made" (Shilts, 1971)

Nevertheless, most investigators involved in boulder tracing studies try to corroborate their findings on the basis of float tracing, by studying the fine, matrix fractions in glacial till (Enmengen, 1957; Wennervirta, 1968; Hyvarinen, 1967).

The study of the Micro float train (Dreimanis, 1960) or Micro boulder fan (Bolviken, 1967) associated with the Macro float or boulder train is usually more precise in delimiting a source area because of its greater continuity in glacial till (Figure 5). Most detrital mineral grains in glacial drift have been derived from freshly ground-up bedrock. In the unweathered "C" horizon of the soil profile the grains are virtually unaltered since deposition. By means of deep overburden sampling, ideally profile sampling, unaltered matrix samples can be obtained, and the Micro float fan outlined through geochemical analysis of the fine fraction in the till (Nichol and Bjorklund, 1973).

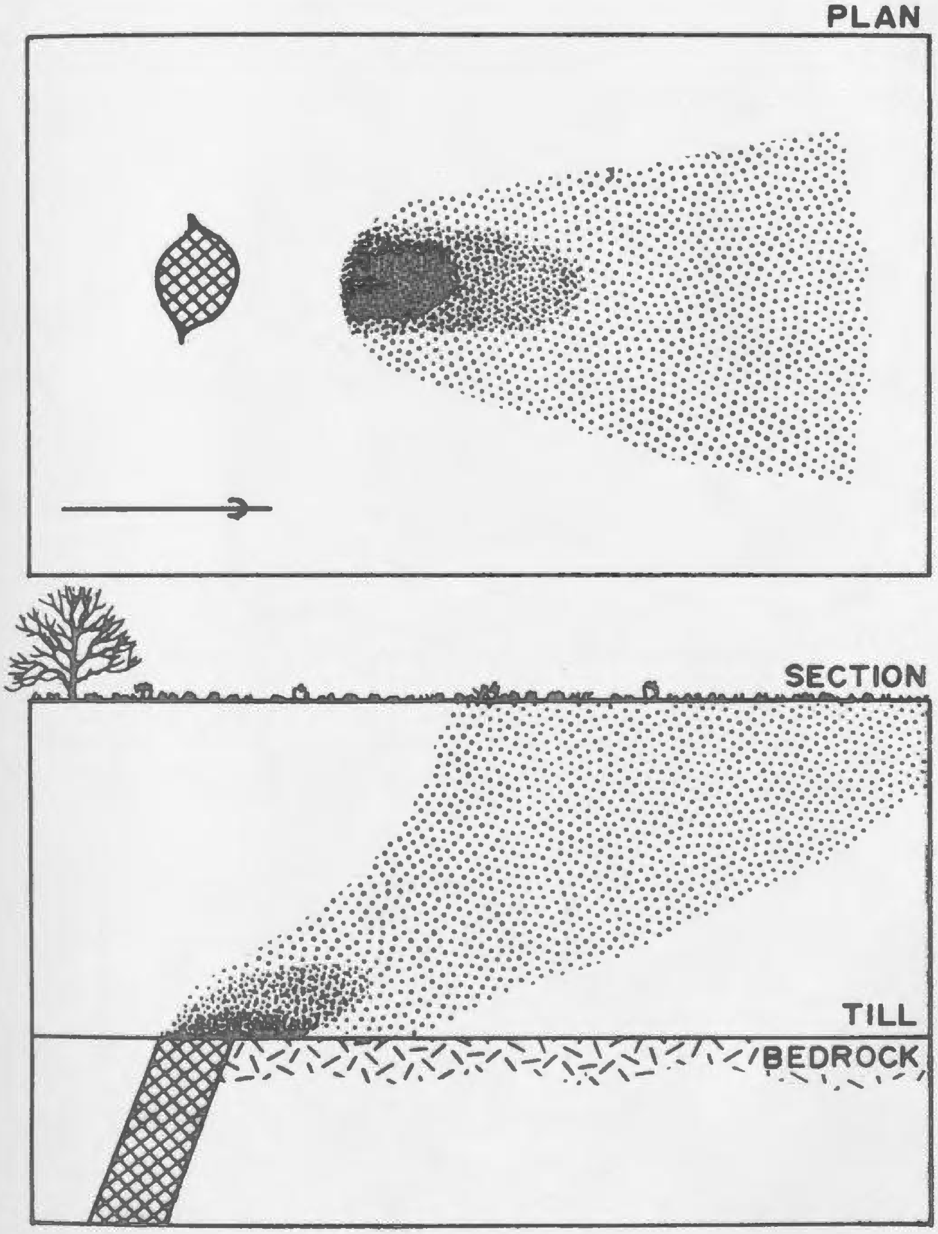

Figure 5. Indicator Fan in glacial till (after Hawkes and Webb, 1962).

Geochemical Investigations

Exploration geochemistry is hampered in glaciated terrain because of the heterogeneity of the glacial deposits encountered. The use of glacial till as a sampling medium is not always an easy or simple procedure, and yet, in the last decade, the application of exploration geochemical techniques in glaciated terrain has seen a marked upsurge of interest. and has led to many successes (Kvalhiem, 1967; Jones, 1973).

There is an apparent overlap between Micro float studies and glacial till geochemistry. Geochemical analysis is usually conducted on the -80 mesh (0.180 mm.) fraction of till. (Ermengen, 1957; Dreimanis, 1960; Fortescue and Hughes, 1965; Bolviken, 1967; Fortescue and Hornbrook, 1967; Garrett, 1969; Peters, 1971; Nichol, 1973; Govett, 1973; Hornbrook, 1973; Govett et. al., 1974; Gunton and Nichol, 1974; and others). This size fraction includes not only the detrital Micro float particles but also secondary oxides and hydroxides, clay minerals, organic matter and sometimes carbonates, all of which selectively "scavenge" and concentrate metal ions, often in amounts out of proportion to the actual local background values (Hawkes and Webb, 1962; Canney and Wing, 1966; Shilts, 1971; Govett, 1973; and others).

The secondary oxides and hydroxides are best avoided in till sampling by utilizing the unweathered portion of the "C" zone of the soil profile (below the oxide rich "B" zone). This zone is also impoverished in organic matter relative to upper soil horizons (Scott and Byers, 1965; Bayrock and Pawluk, 1966; Kauranne, 1967; Forgeron, 1971; Govett, 1973).

Clay minerals, which are ubiquitous in all but the leaches "Ae" zone of the podzol profile, are a more difficult problem. If till samples are only seived to -80 mesh then the sorption propensities of the clay minerals in the sample could have a profound effect on the elemental concentration in it (Kreiter, 1968; Nichol, 1971; Shilts, 1971; Gunton and Nichol, 1974). If, for example, one sample contains 10% clay and the next sample in the sequence contains only 5%, there might arise significant elemental variation at the ppm. level due solely to variations in the clay content.

Clay mineralogy must also be considered in geochemical analysis. If, for example, the clay contained in a sample is mostly Montmorillonite, which has a very high adsorption potential (C.E.C.), then a mobile element like zinc would be expected to be enriched in that sample. If, however, the next sample in the sequence has the same clay content but Kaolinite is dominant, then the zinc content would be expected to be much lower simply because of Kaolinite's lower adsorption potential.

For these reasons Shilts (1973) has strongly urged that clay-sized material be removed from any till sample to be analyzed geochemically, and either be analyzed separately or discarded. He suggests that the end result of a geochemical survey which includes clay in the samples analyzed will be a sophisticated and expensive map of textural variation (Shilts, 1971). He suggests that the -80 230 mesh (0.108-0.063 mm. fine to very fine sand) fraction might be the best size range for geochemical analysis.

Geophysical Investigations

Most geophysical methods are limited in their usefulness in areas of thick, or variable, glacial drift cover, (Halonen, 1967), particularly where the deranged drainage caused by ablation moraine has formed large areas of bog, marshland and kettle lakes (Nilsson, 1973).

Nevertheless, geophysics (airborne and ground based methods) have had some successes in discovering massive sulphide deposits in glaciated terrain in areas of thin drift cover, or where a very large conductor was present in the suboutcrop (e.g. Buchans, Newfoundland; Kidd Creek, Ontario).

Of the possible ground methods available to the drift prospector in areas of thick drift cover, those which are best adapted to a support role for the other facets of Drift Prospecting are resistivity and seismic refraction profiling.

Resistivity is limited in very wet areas but is useful in well drained ones. Seismic refraction profiling, while also being adversely affected by damp conditions, has the advantages of speed and portability. It can also give rapid determinations of drift thickness in the field which can provide a guideline for further work. For example, a trenching program for geochemical sampling can be guided to the lee-side of suboutcropping bedrock highs, where a good sampling medium such as lodgement till might be expected to be best preserved (Brotzen, 1967; Okko, 1967).

Sedimentological Investigations

Sedimentological techniques which can be applied to drift prospecting include studies of till pebble lithology (pebble counts), till stratigraphy, structure, and component size range (e.g. sandy till vs clayey till, etc.).

Sedimentological techniques are also important in the pre-treatment of samples for geochemical analysis (wet and dry sieving, splitting, etc.) as well as for heavy mineral and clay mineralogy studies.

CHAPTER IV.

GLACIAL GEOLOGY

Previous Work

The Sheffield Lake - Indian Pond area was glaciated during the Pleistocene Epoch. MacClintock and Twenhofel (1940), Murray (1955), and others, postulate that migrating ice centres (Figure 6) on the high Central Plateau near Buchans were the major centres of ice accumulation which affected all of Newfoundland with the exception of the Avalon Peninsula.

Most early workers (Coleman, 1926; MacClintock and Twenhofel, 1940; Flint, 1940 and 1951) envisioned an inundation of Labrador ice onto Newfoundland prior to the development of a discrete island ice cap. Recent workers (Brookes, 1970; Grant, 1969 and 1972; and Tucker, 1973) however feel that Labrador ice may only have invaded the extreme northwest tip of the island.

MacClintock and Twenhofel (1940) hypothesize the following sequence of events in the Wisconsinan glacial period:

Stage 1) insurgence of Labradorian ice over all of Newfoundland with deposition of drift as far east as the Grand Banks during the Wisconsinan maximum;

Stage 2) Labradorian ice wanes;

Stage 3) relict ice on Newfoundland develops radial motion as impeding ice melts away from its margins;

Stage 4) local ice cap development and migration of ice centres (Figure 6) i.e., St. Georges River Stage;

Stage 5) ablation of main island ice cap;

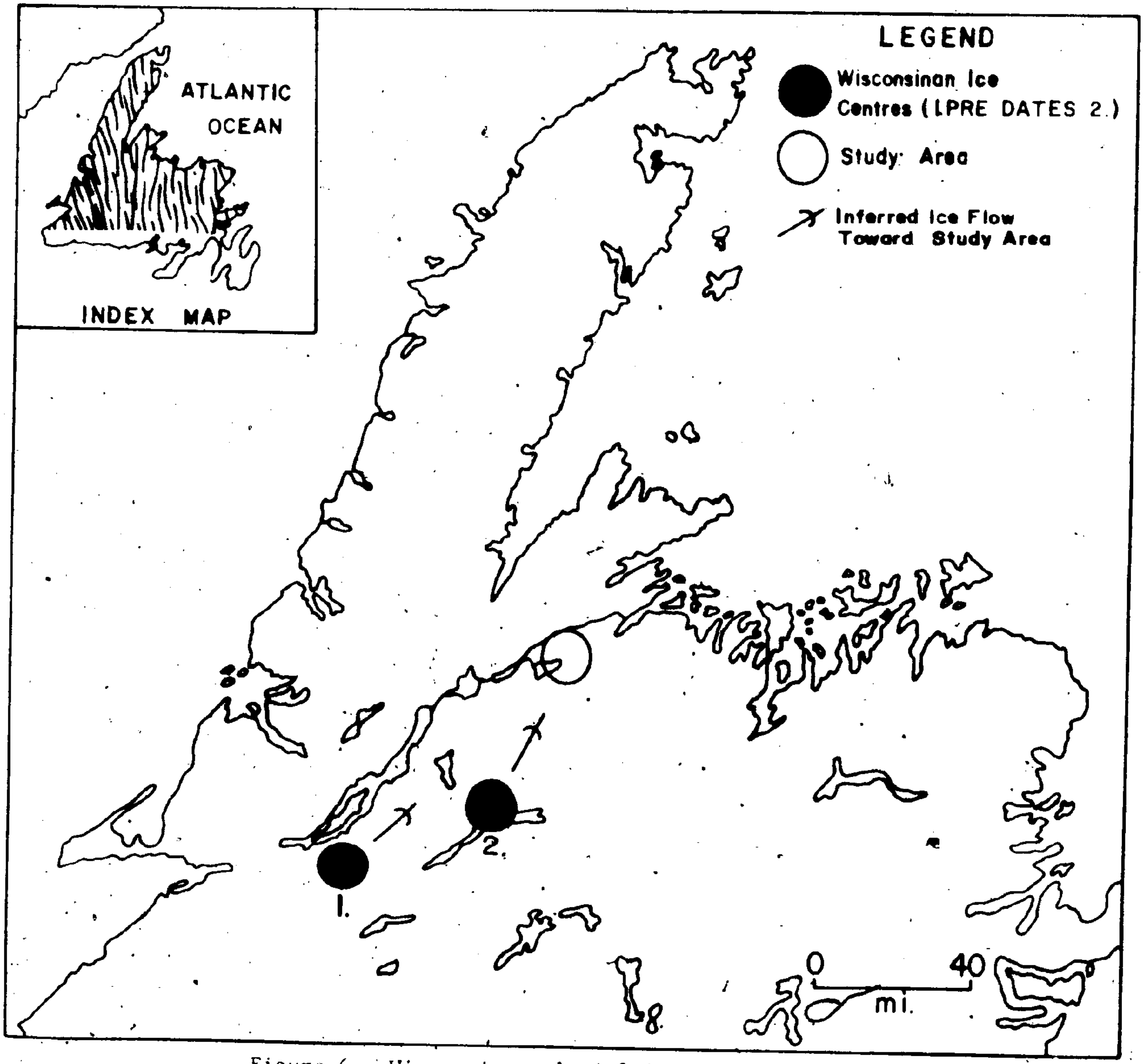

Figure 6. Wisconsinan glacial ice centres (see text for explanation).

Stage 6) formation of deltas during deglaciation;

Stage 7) re-advance of ice, i.e., Robinsons Head Stage;

Stage 8) final retreat of the island ice cap;

Stage 9) local cirque and valley glacier formation.

Evidence presented by Grant (1969 and 1972); Brookes (1970); and Tucker (1973) including the re-interpretation (Brooks, 1970) of south-trending striae on the Port au Port Peninsula which indicate not Laurentide ice flow, but rather a southward swinging arm of island-based ice, has lead these workers to restrict the effect of Labrador ice on the island to the extreme north west tip. Grant (1969) states that Labrador ice inundated the lowland portion of the Northern Peninsula, as evidenced by unidirectional grooving, Labradorian erratics, and a shelly drift that is spread widely over the area, but that, it did not move over the Long Range Mountains.

Tucker (1973) points out that if Laurentide ice was to affect the north-central part of the island without overriding these mountains then it would have had to "wrap around the tip of the Northern Peninsula with a southerly component of flow", then flow southeast into White Bay and back up onto the island. There is no evidence for this hypothetical onshore flow anywhere on the north coast of Newfoundland.

The sequence of glacial events in north central Newfoundland as outlined by Tucker (1973) are as follows:

Stage 1 - Late Wisconsinan maximum ice flow to the north east from an ice cap in the Buchans area.

Stage 2 - Topographically controlled later ice flow indicated by multi-directional striae and ribbed moraine zones confined to valley bottoms.

Stage 3 - Ice retreat, and delta formation shortly before 12,000 B.P.

Stage 4 - Valley and lowland ice stagnation, indicated north of Sheffield Lake by ridged ablation moraine which partially overlies a zone of ribbed moraine, and formation of radial meltwater channels.

Stage 5 - Stillstand near Sheffield Lake due to abrupt elevation increase; some late topography controlled flow.

Stage 6 - Last ice approximately 9,250 B.P. near Buchans.

Glacial History of the Study Area

In the Sheffield Lake - Indian Pond region, no evidence is available to indicate the primary stages (1, 2 and 3) hypothesized by MacClintock and Twenhofel (1940). However, their stages 4 through 8 are possibly better preserved in the study area than in any of the formerly studied regions.

Stage 4

The development of an island ice centre to the south of the study area and flow from it towards the north east are indicated by stoss-and-lee forms oriented southwest - northeast as seen on air photos of the study area (Grant, 1973).

Striations preserved southwest, west, north and northeast of the study area also indicate an early, strong northeasterly ice flow in the region (Lundquist, 1965).

Till fabric analyses performed on basal till layers (Figures 13 and 14) in the study area also support an early, strong north easterly ice flow.

Stages 5 and 6

The development of a heavily oxidized basal till sheet in the study area indicates a protracted period of sub-aerial oxidation probably during an interstadial period of unknown duration. If the Wisconsinan maximum occurred in the same time interval as in the rest of Canada (18,000 – 20,000 B.P. – Prest, 1970) this warm, moist interlude may have been 4 to 5,000 years in duration, as determined from marine fossils discovered nearby and dated at 12,000 220 B.P. (G.S.C. 1733).

Stages 7 and 8

The Robinsons Head readvance stage (MacClintock and Twenhofel, 1940) may be contemporaneous with the Ten Mile Lake Readvance of Grant (1969), dated at 10,900 B.P. These events may also correlate with a readvance of relatively thin ice over the Sheffield Lake – Indian Pond plateau which became more topographically controlled as it ablated. Lundquist (1965) postulates from fine crossing striations in the study area, that this ice flowed first toward the north and then toward the northwest and west. These directions are preserved in the fabric of an upper till unit which overlies the lower, heavily oxidized unit earlier emplaced in the study area (Figures 13 and 14).

The relatively clean, thin ice probably ablated quickly, as evidenced by a dearth of ablation till in the region, and left some large blocks emplaced in the upper till unit. These blocks probably remained for many years before finally melting and forming the myriad kettle lakes and bogs of the region.

Stage 9

No evidence of cirque formation or valley glaciation is preserved in the study area, however, "last ice" in the southern part of the region was probably located in the deep Sheffield Lake depression (Figure 16), as evidenced by fine striae trending toward this area from the adjacent highlands. Ice was probably maintained for some time here by the protection afforded by the high bedrock hills which almost completely surround this feature. Major spillways (Tucker, 1973) radiate from this general area and are accounted for by the persistence of ice in this area until after regional deglaciation.

Valley glaciers may have occupied the deep, U shaped Birchy Lake - Indian Pond depression at this time (Figure 16).

Glacial Flow Indicators

Preliminary and essential to the success of any investigation in glaciated terrain is an extensive air photographic interpretation, which may reveal the dominant ice flow direction in the region and also the distribution and type of glacial drift and surficial deposits present. Some idea of relative drift thickness, outcrop distribution and probably surface and groundwater flow are also available to the experienced air photograph interpreter.

Field checks are then directed to "problem areas", to study "micro ice flow indicators" (i.e. striae, chatter marks, crescentic gouges, etc.) or to collect bedrock information and samples, especially in areas where there is a paucity of outcrop. From all of this information a good map of the surficial geology and physiography can be produced and the glacial history interpreted.

Some workers (Fortescue and Hornbrook, 1967; Hyvarinen, 1967; Kreiter, 1968; and Forgeron, 1971) stress the importance of one further step; a seismic refraction survey, to determine drift thickness more precisely than is possible from air photographs.

Results

The air photographs interpretation done on the area indicates a general southwest - northeast ice flow preserved as stoss-and -lee features. However, these are always located in the bedrock hills (Figure 2) to the west and east of the study area. Tucker (1973) cites the occurrence of northeast trending drumlinoid forms as indicating a strong northeast ice flow in the region. O'Donnel (1973) also found evidence for an early northeast trending ice flow from roche moutonnée orientation in the Gullbridge area (Figure 3).

Striae

Field checks in the bedrock areas near the study area, and measurements of 30 striae sets (Appendix D) and crescentic gouges support a dominant southwest - northeast ice flow (020-060Az.) which overrode these high hills (Figure 2). However, at two locations crossing sets of striae (preserved on hard Rhyolite bedrock) were noted, trending 020 (coarse), 090 (fine). At one site, located in the bedrock hill "saddle" through which the Trans Newfoundland Highway #2 passes (Figure 16), the mean striae direction was toward 315. This striae set may post-date the dominant north east trending set since no 020-060 striae were discovered crossing the 315 set on the hard, polished, bevelled, rhyolite exposure investigated.

Lundquist (1965) discovered east-west trending striae south of Fire Tower Hill (Figure 2) which probably correspond to the 315 trending set mentioned above.

Nevertheless, all of the rock-preserved flow indicators were located on the margins of the study area, because of the paucity of suitable outcrop elsewhere.

Till Fabrics

As a means of determining precisely, the ice flow direction in the study area, 141 till fabric analyses (Appendix B) were performed in the

108 pits dug during the trenching program (Figure 12). The results obtained from this work reveal a complicated ice flow history and will be described at length in the section on the Two Till Hypothesis.

Properties of Glacial Till

The outstanding characteristic of glacial till is the lithologic and physical heterogeneity. It is the most poorly sorted of sediments, commonly containing particles that range from colloidal size to fragments whose volume may be conveniently measured in cubic miles (Shilts, 1971).

Generally, the upper part of a till sheet includes more abundant material of distant provenance as compared to the basal portions (Fortescue and Hughes, 1956; Lee, 1971; Hyvarinen, 1973; and others). Thus, the tracing of till components to their bedrock source is most efficiently accomplished by examining the basal portion. Nevertheless, even in its basal zone, the relatively "local" components of a till sheet are diluted due to the continuous admixture of fresh and weathered bedrock material and unconcolidated pre-and interglacial drift, all of which is subjected to severe comminution during emplacement (see page 24).

Although glacial transport can cause rounding of clasts, a high proportion of rounded to subrounded till fragments usually indicates prior sorting of the sediment (e.g., in proglacial outwash deposits); conversely, a predominance of subangular to angular till clasts indicates till formation by primary process (e.g. grinding and crushing) (Holmes, 1952; Slatt, 1971).

The Tills of the Sheffield Lake - Indian Pond Area

Malmquist (1961) concluded from his work in the study area that two till units probably exist in the region but their relationship and mode of deposition (ablation/lodgement) are imcompletely described.

In the present study, two distinct till units were recognized as occurring in the study area. The Lower Red Till is a heavily oxidized, indurated, fissile, gravelly till in which angular primary bedrock fragments of local provenance (e.g. chloritized andesite) including sulphide float, occur.

The Upper Grey Till is a lightly oxidized, massive, friable, sandy till in which rounded clasts, predominantly of more distant provenance (e.g. granite), as well as secondary, reworked local and float fragments, occur.

The outcrop areas of both of these units appear in Figure 7.

Surficial Geology

The Surficial Geology of the area of most intensive study in the Sheffield Lake - Indian Pond area consists of only three main units (Figure 7). The Upper Grey Till is the major surface deposit of 90 per cent of the area. It occurs as hummocky, bedrock controlled ground moraine decreasing in thickness up the flanks of the bordering bedrock hills to the west (Figure 7). The areas of thin and thicker (see Seismic Refraction section) Upper Grey Till are separated by a long, glacial fluvial spillway in which flows a misfit stream. The Lower Red Till is exposed at the surface at only one location in this area, and its outcrop is biseeted by Highway #2. It was at this location in 1953 that the first sulphide float discovery was made.

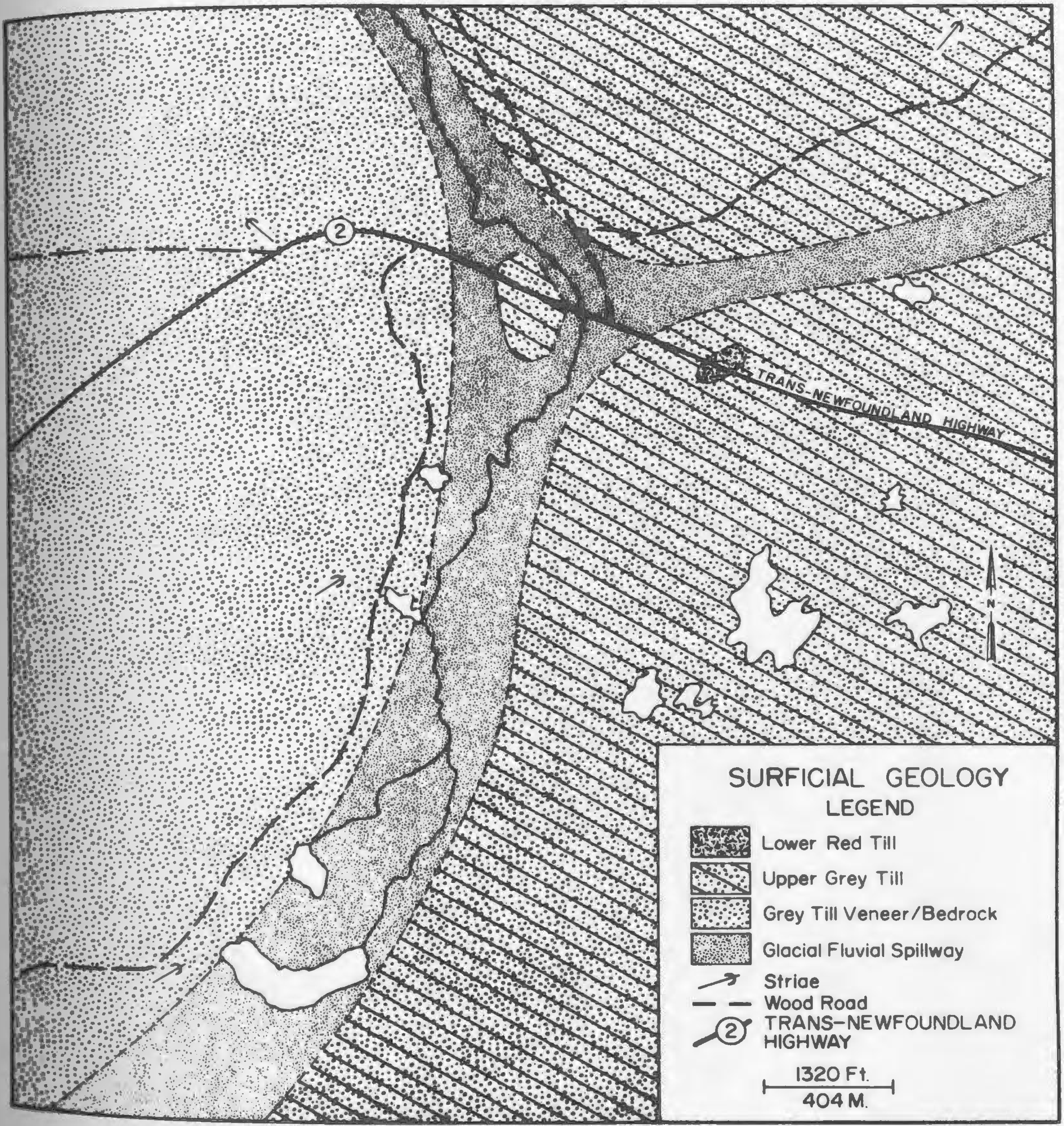

Figure 7. Surficial geology of main float zone.

Seismic Refraction Survey

Preliminary to the trenching program, 122 hammer seismic refraction lines were run in the study area (Table 2), each consisting of 15 - 20 impact points spaced at 10 foot intervals. Damp and very heavily wooded (e.g., alder thickets) areas were avoided, except where old cut lines were encountered. A Huntec FS-3 portable facsimile seismograph was used (Plate 4).

The instrument print-out, recorded on dry electro-sensitive paper by a sweeping electric stylus, was interpreted by the critical distance method (Todd, 1959), using the standard equation;

$$H = \frac{xc}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

where H = layer thickness; xc critical distance; V velocity layer 1 and V velocity layer 2 (Figure 8). This method is generally considered to yield depth determinations within an accuracy of 10 per cent of the true value (Hobson, 1967).

Six Brinex drill holes were located in and around the main float zone and a series of seismic lines were run near enough to each to check the accuracy of the seismograph and far enough away so that no effect of the casing would appear on the print out. The results appear on Table 3.

Wave velocities of 800' to 3000 feet/sec. (Figure 8) were commonly encountered for the glacial drift. The bedrock velocities varied from 10,000 to 30,000 feet sec. however, an attempt to correlate bedrock velocity with rock type proved fruitless in this terrain, probably due to the sheared, chloritized and interbedded nature of the bedrock.

The glaciofluvial outwash choked spillways usually contained drift

Table 2

Seismic Refraction Drift Thickness Determinations (See Figure 9)

Station Number	Drift Thickness (nearest foot)	Station Number	Drift Thickness (nearest foot)
1	9	30	11
2	11	31	10
3	14	32	10
4	5	33	19
5	8	34	5
6	11	35	12
7	12	36	12
8	14	37	14
9	18	38	17
10	11	39	23
11	13	40	8
12	17	41	17
13	No reading	42	19
14	8	43	14
15	13	44	12
16	13	45	5
17	13	46	10
18	15	47	30
19	16	48	17
20	11	49	9
21	12	50	12
22	23	51	19
23	60	52	22
24	20	53	48
25	19	54	55
26	8	55	18
27	6	56	17
28	12	57	No reading
29	7	58	30

Table 2 (continued)

Station Number	Drift Thickness (nearest foot)	Station Number	Drift Thickness (nearest foot)
59	20	91	5
60	40	92	9
61	12	93	25
62	8	94	44
63	10	95	60
64	10	96	12
65	14	97	60
66	38	98	40
67	44	99	22
68	5	100	8
69	20	101	50
70	22	102	30
71	17	103	19
72	11	104	24
73	60	105	11
74	40	106	16
75	60	107	No reading
76	15	108	60
77	5	109	20
78	6	110	14
79	12	111	12
80	12	112	20
81	6	113	16
82	8	114	8
83	No reading	115	10
84	7	116	16
85	14	117	10
86	17	118	10
87	10	119	60
88	19	120	60
89	17	121	60
90	13	122	60

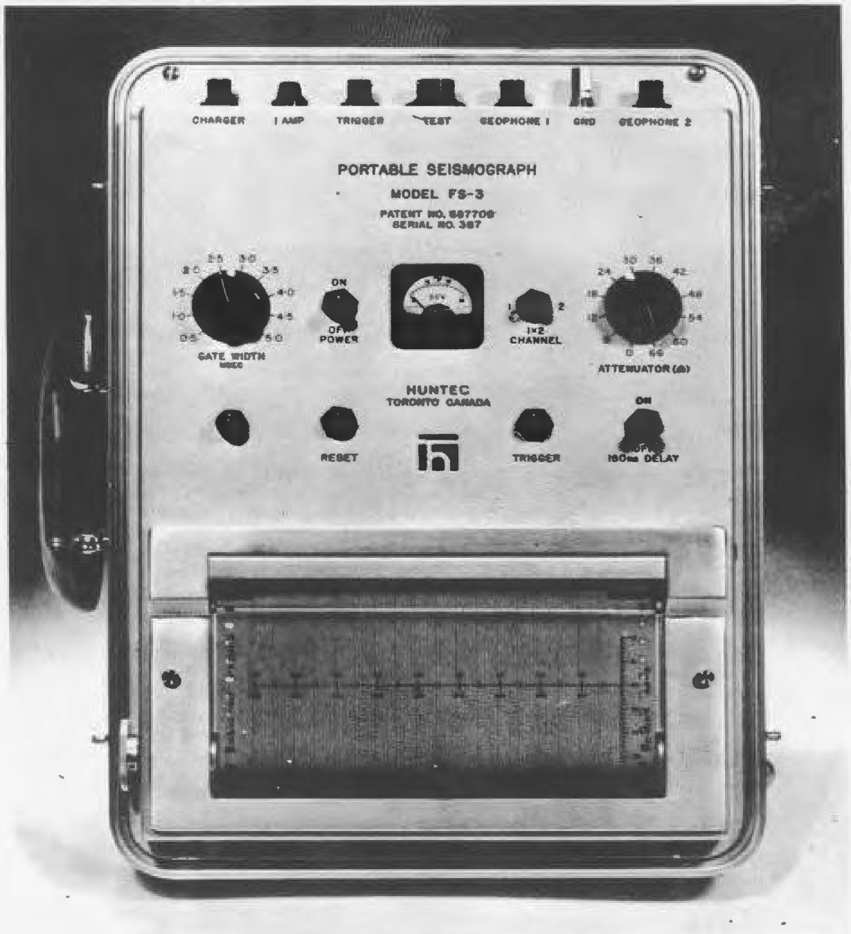

Plate 4: FS-3 Seismograph

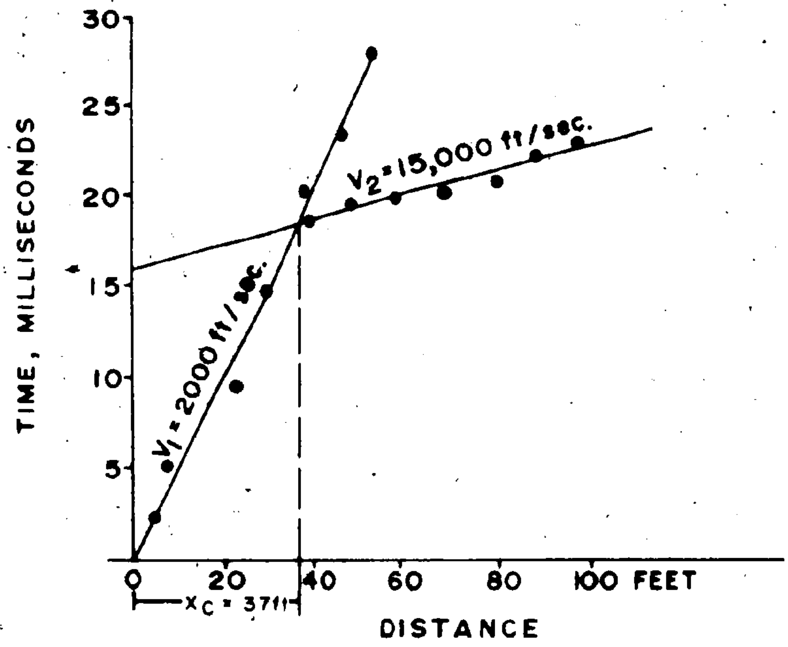

Figure 8. FS-3 Seismic Refraction Print-Out and thickness determination.

TABLE 3: SEISMIC REFRACTION ACCURACY

*D.D.H. NUMBER	SEISMIC STATION NUMBER	D.D.H. DRIFT THICKNESS DETERMINATION (in feet)	(FS-3) SEISMIC DRIFT THICKNESS DETERMINATION (in feet)	ACCURACY
62-3	104	25	24	-4%
62-5	103	21	18.5	-12%
62-6	47	32.5	30	-8%
62-7	39	21	23	10%
62-8	33	18	19	6%
62-9	33	18	17	-6%

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*D.D.H. = Diamond Drill Hole

thickness beyond the practical capabilities of the instrument and are plotted as 60 feet. A drill hole in the Indian Brook Valley bottomed, still in outwash gravels, at 190 feet (H.R. Peters, Personal Communication, 1974).

The interface between the two till units did not represent a significant velocity increase (see ternary gravel, sand, mud diagrams) and so could not be delineated with this equipment. However, good drift thickness readings were usually obtained and appear on Figure 9.

On the basis of the seismic thickness readings in the main float zone, the trenching program was directed to the lee ("down-ice") side of suboutcropping bedrock "highs". Theoretically, lodgement till should be best preserved in such an environment (Brotzen, 1967; Okko, 1967; Garrett, 1969). The trenching program revealed that indeed, the Lower Red Till was always preserved in these areas (Figure 10), or in small bedrock depressions.

Altimeter Survey

The seismic refraction survey yielded good drift thickness values. However, before a profile diagram including depth determinations could be made (Figure 11), an upper surface elevation had to be established. For this purpose an FA-181, Wallace and Tierman barometric altimeter, with a range of 0-7000' was utilized.

The altimeter stations were always measured within two hours of "zeroing" the instrument at high tide level, to minimize the effect of atmospheric temperature variations. Immediately after the measurements were taken the instrument was again "zeroed" at sea level. The amount of change (which never exceeded 3 feet) was recorded as a factor to be applied to the altimetered elevations obtained.

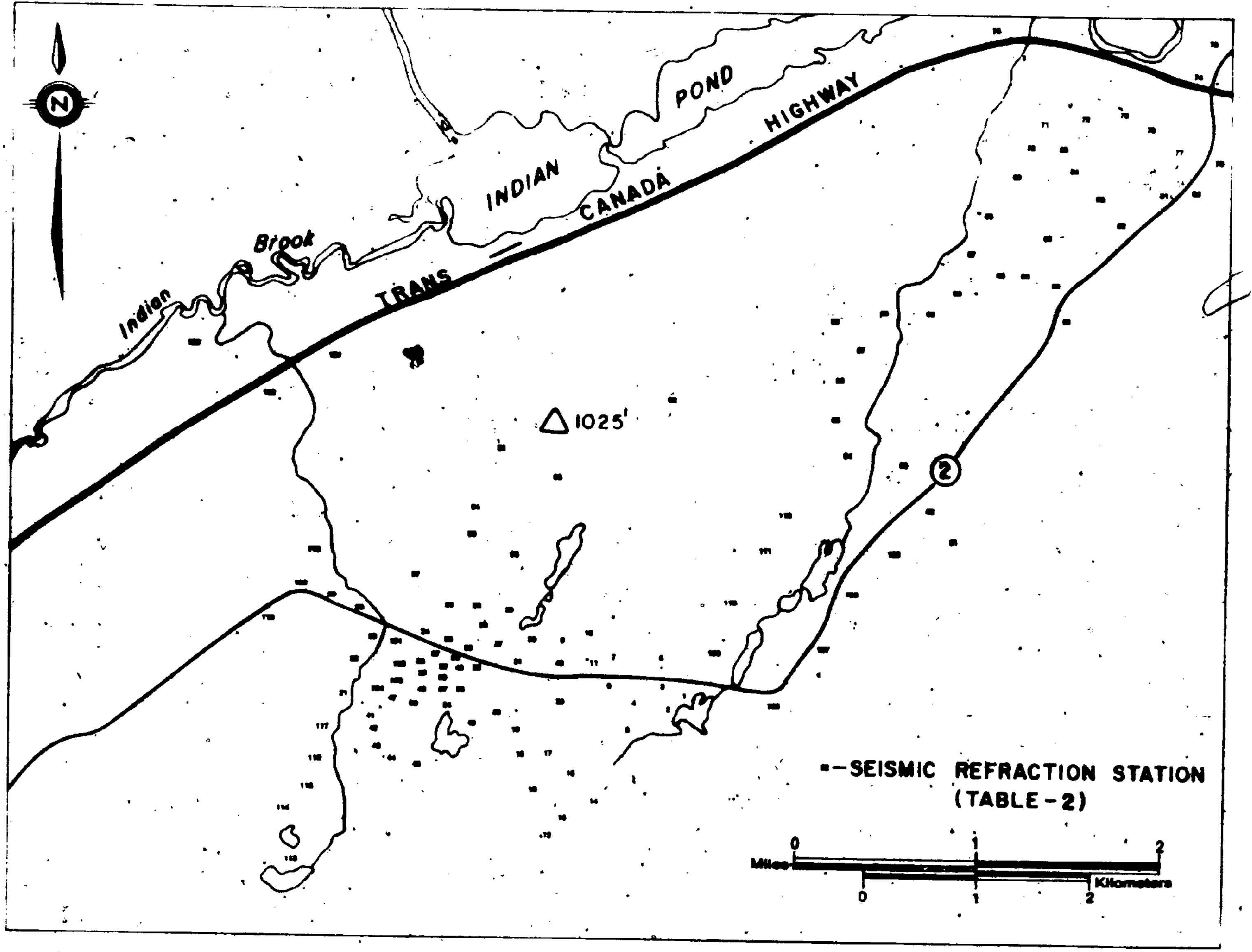


Figure 9. Seismic Refraction Stations.

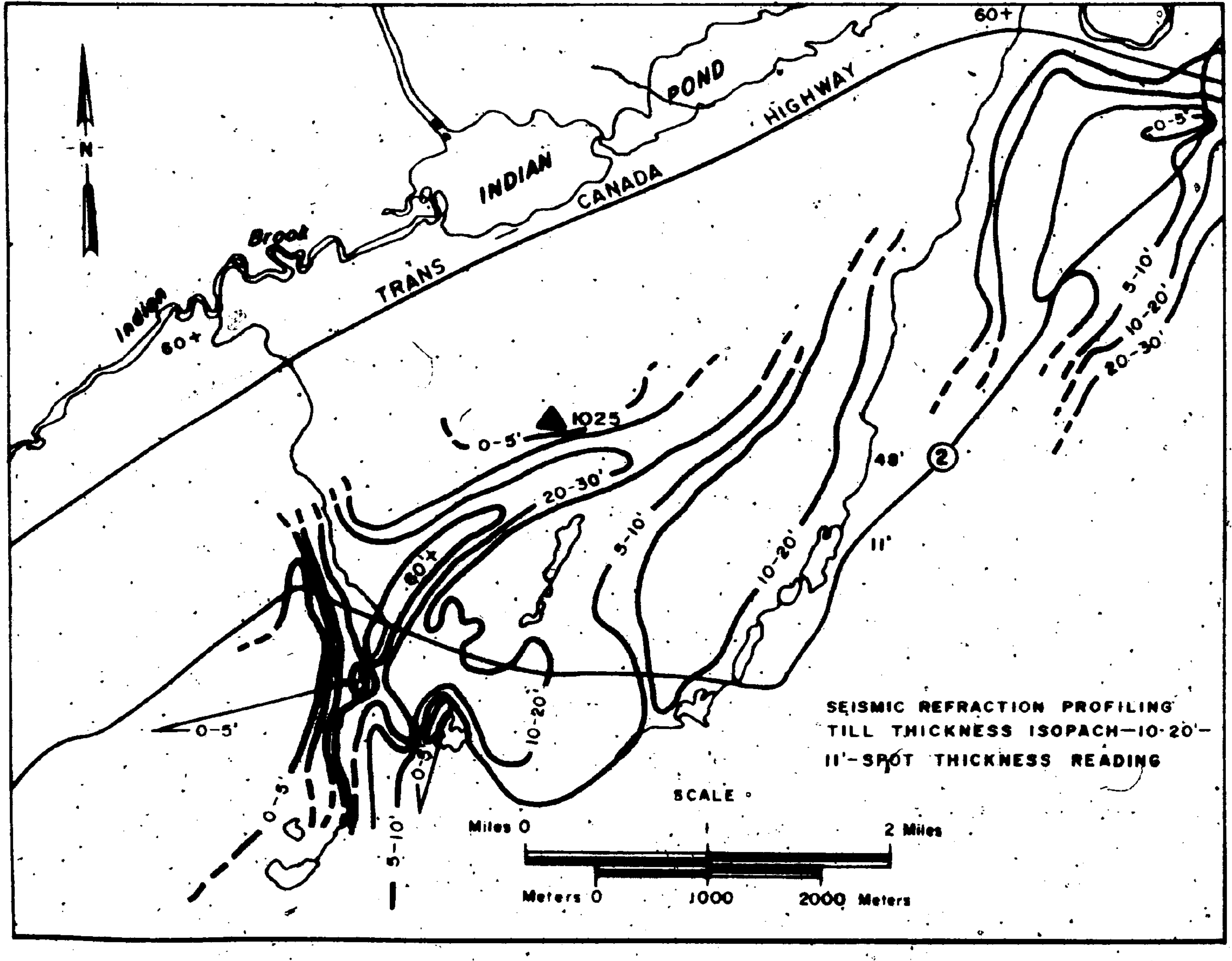


Figure 10. Seismic Refraction Isopach Map of Drift Thickness.

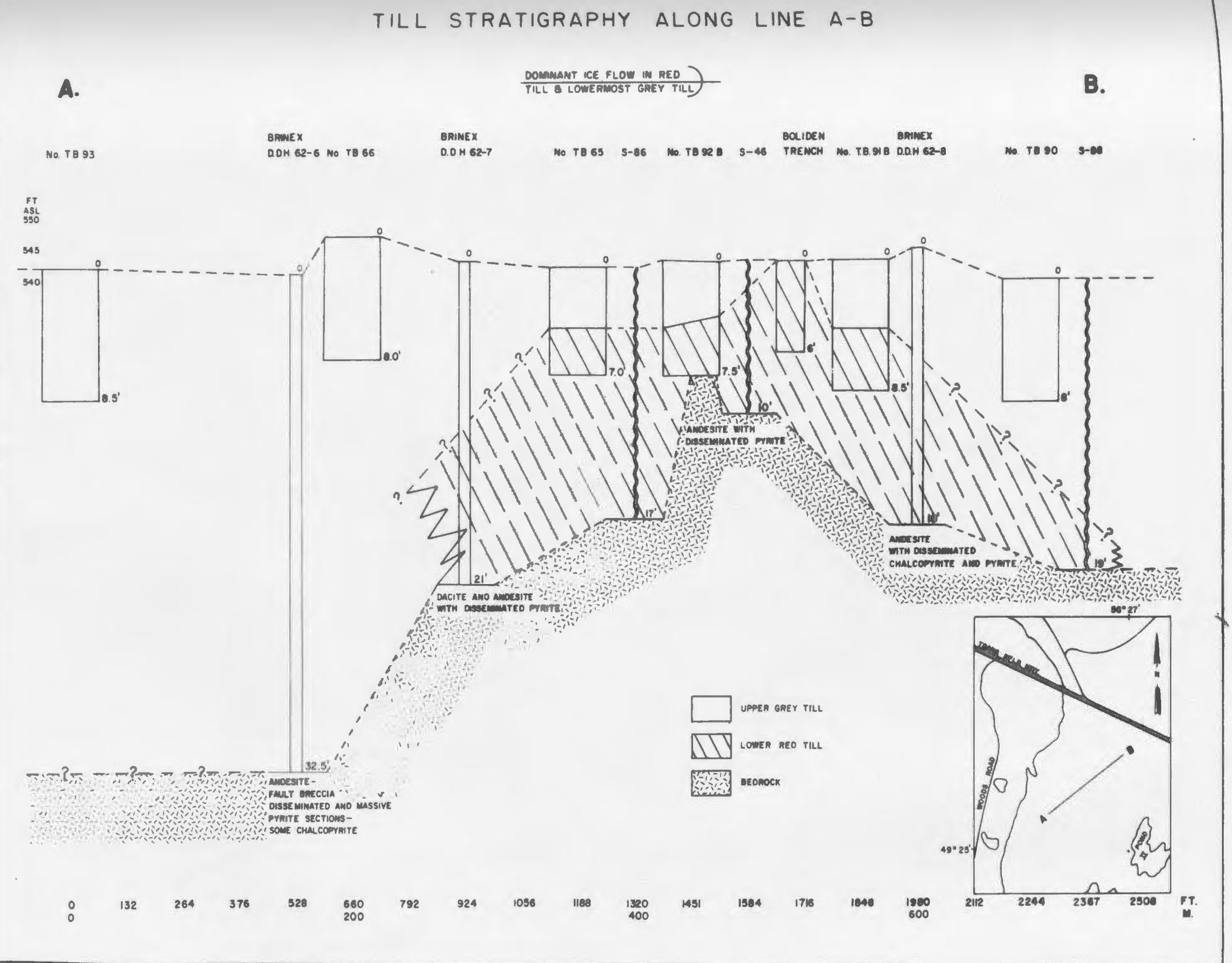


Figure 11 Stratigraphic section of the two tills

Drilling and Trenching

Gleeson and Cormier (1971) and Hornbrook and Davenport (1972) have had good success with overburden drilling in glaciated terrain using the "portable", Pionjar overburden drill - a type of gasoline powered jack-hammer.

However, in the Sheffield Lake - Indian Pond area, this machine was found to be less than satisfactory for obtaining drift samples at depth. Attempts were made at dozens of locations to attain penetration to a suitable depth for sampling but owing to equipment failures, operator inexperience and the very compact, cobble till into which drilling was attempted, good results were unobtainable.

After a concerted attempt, the overburden drilling program was curtailed in favour of a remarkably successful trenching program.

One hundred and eight pits were dug at selected sites in the study area (Figure 12), sixty six were excavated by a rented International 3122 backhoe equipped with a 2' bucket. The remaining 42 were dug by the "tried and true" - pick, shovel and "elbow grease" method. The fan shape attained for the Lower Red Till occurrence - and the float within it - was not, then, a function of random "up ice" trench spacing, but rather the result of a careful effort to expose the lower unit wherever it was preserved, based on drill hole and seismic drift thickness determinations.

Not only did the trenching accomplish that which the drilling could not do, attaining bulk samples at depth in the glacial drift, but it also allowed the author to map the stratigraphy of the drift, (Figure 11) take profile samples, trace the sulphide boulder train in both its horizontal and vertical component (Figure 5), and complete

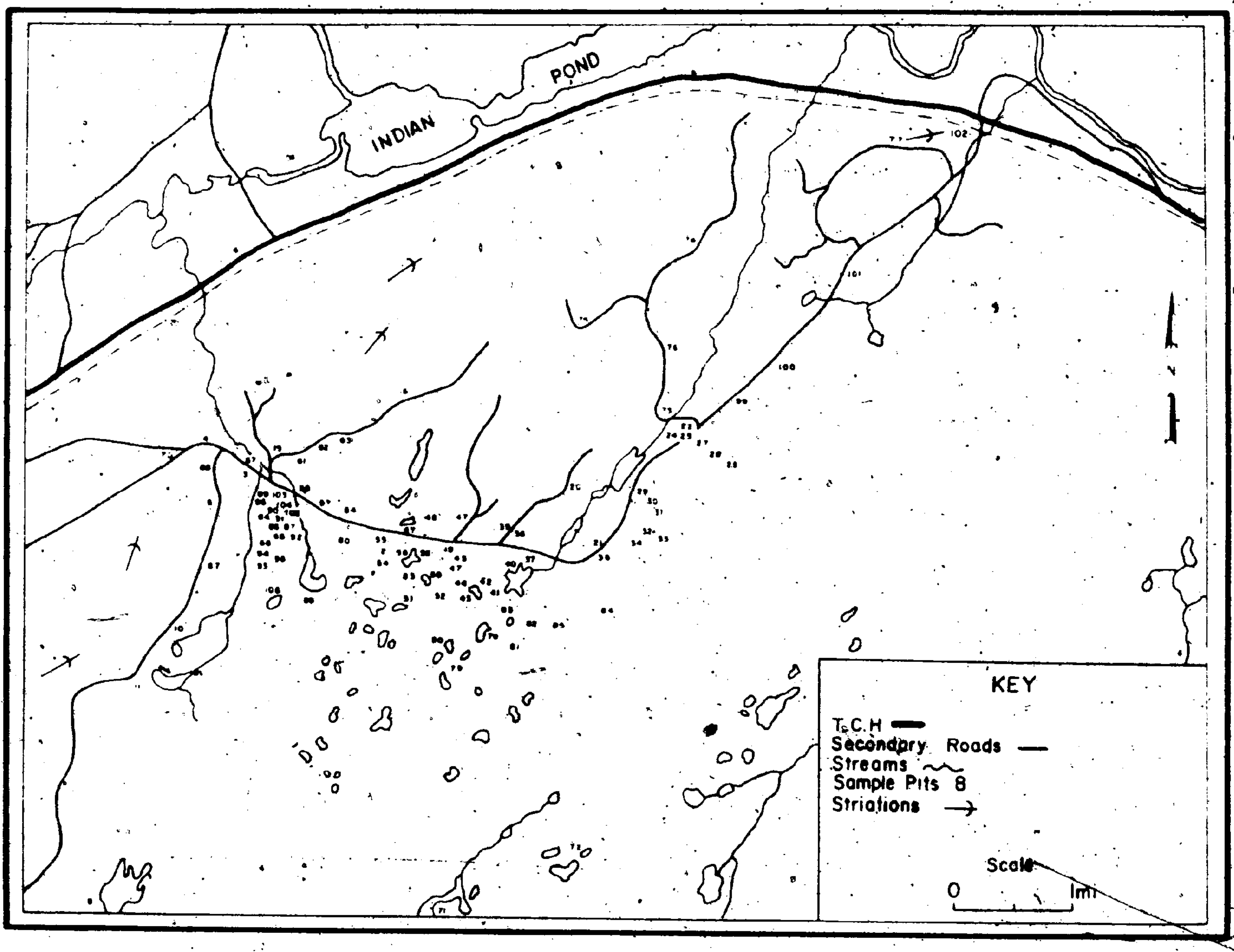


Figure 12 Location of trenches and sampling sites

141 till fabric analyses.

Properties of the Tills

Attempts were made to differentiate the two till sheets in the study area on the basis of colour, stratigraphy, till fabric, till lithology, clay mineralogy, geochemistry, gravel-sand-mud ratios, sand-silt-clay ratios and the occurrence in at least two locations, of re-oriented blocks (Schollen) of the lower unit enclosed within the upper one.

Colour

The Lower Red Till of the Sheffield Lake - Indian Pond area varies in colour between dark yellowish orange (Munsell chart #10YR6/6) and moderate reddish brown (10R4/6).

The Upper Grey Till varies in colour between greyish red (10R4/2) and greyish red (5R4/2). The slight reddish tint is probably due to reworked Lower Red Till material.

Stratigraphic Relationships

The Upper Grey till, as the designation implies, is usually superimposed on the underlying Lower Red till (Plate 5). In some cases, however, the Lower Red till is not overlain by Upper Grey till, particularly near the Trans-Newfoundland Highway (Figure 7) where it has been protected from later glacial erosion by suboutcropping bedrock "highs" and has since been exhumed by erosion. Okko (1969) and Garrett (1969) describe similar lee-side protected basal till units discovered in their investigations in Scandinavia and in mainland Canada.

The Upper Grey till forms the surface deposit over 90 percent of the study area, with the exception of glacio-fluvial gravels and, very minor, bedrock outcrop occurrences (Figure 7).

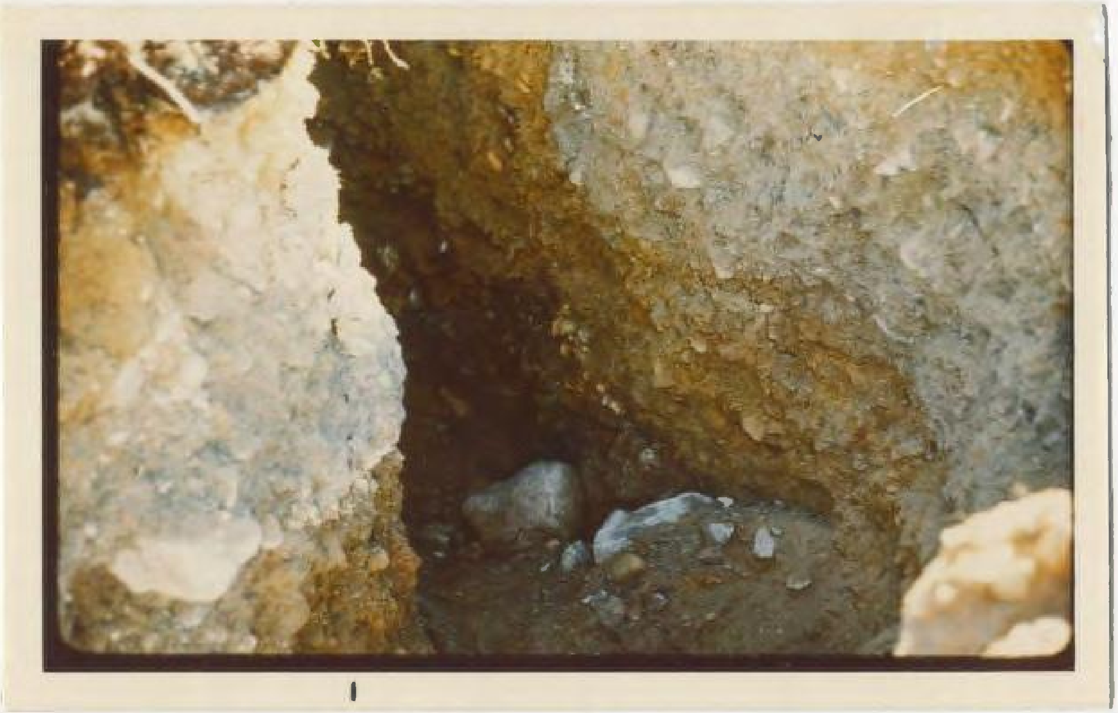


Plate 5: Upper Grey till resting on the Lower Red till in TB-92 (Figure 11). The 10" thick BF soil horizon of the Upper Grey Till can be seen at upper right of Photograph.

The contact between the two tills is shown on Plate 5. The ice moved from right to left in the photograph and a short distance from this point the Lower Red till outcrops at the surface, as indicated by the escalating till contact.

Till Fabric

In 1855, H.Y. Hind, studying a quarry in Toronto, Ontario, became the first researcher to note aligned clasts in glacial till (Elson, 1966). Many workers have since studied this phenomenon, (Holmes, 1941; Harrison, 1957; Kauranne, 1960; and others). Till fabric analyses (synonymous with till pebble orientation analyses) is now a routine practice in determinations of ice flow direction in glaciated terrain.

Till Fabric Origin

In a viscous fluid medium, elogate particles are observed to adopt an orientation which corresponds to the least dissipation of energy. Under laminar motion and the pressure melting conditions prevalent in a thick, moving ice mass, viscous fluid conditions may be considered to exist (Kauranne, 1960).

A preferred orientation of elogate till clasts is achieved by flow within the till itself during glacial movement (Andrews and King, 1968; Andrews and Smith, 1970). The movement of the fluid-like matrix is faster relative to the till clasts which are then aligned. High clay content in the till matrix has been correlated with stronger pebble orientation (Harris, 1971).

Nevertheless, scattering does occur, indicating that other processes also influence till fabric. The most important of these include rolling, attributed to the presence of enough meltwater to promote re-orientation of the formerly aligned clasts, and ice thrusting, due to irregular surfaces of loading conditions prevalent when the till was deposited. Both of these processes will result in a pebble orientation transverse to the ice flow direction. If, however, these two processes have had only limited affect on the till, a distinctly bimodal orientation can occur, with a portion of the clasts aligned parallel to ice flow and the rest transverse to it (Andrews and Smith, 1970).

As well as elongate pebble alignment parallel to ice flow direction, some workers (Harrison, 1957; Evanson, 1971; and others) have noted an "up-ice" imbrication or plunge of elongate till clasts. This phenomenon is attributed to up-curving shear zones which develop in till in response to the loading conditions of overiding ice, or to alternating high and low pressure zones at the base of the moving ice mass (Evanson, 1971).

Results

The profuse angular clasts of the Lower Red till, in the Sheffield Lake - Indian Pond area were deposited with their dominant long axis orientation and "up-ice" imbrication indicating a strong ice flow during their emplacement towards 020 (Figure 13), (Appendix B). On the other hand, more rounded, long travelled clasts in the Upper Grey till indicate two separate ice flow directions. In many cases (crossing directions in Figure 14) two till fabric analyses were done in the same pit in Upper Grey till. The fabrics measured at a depth of 6-8 feet in the Grey till indicate a strong 020-045 flow sub-parallel to that of the underlying Red till. However, higher in the grey till unit, 3-5 feet below the surface, the indicated flow swings to the north, then to the west as the "saddle" south of Fire Tower Hill

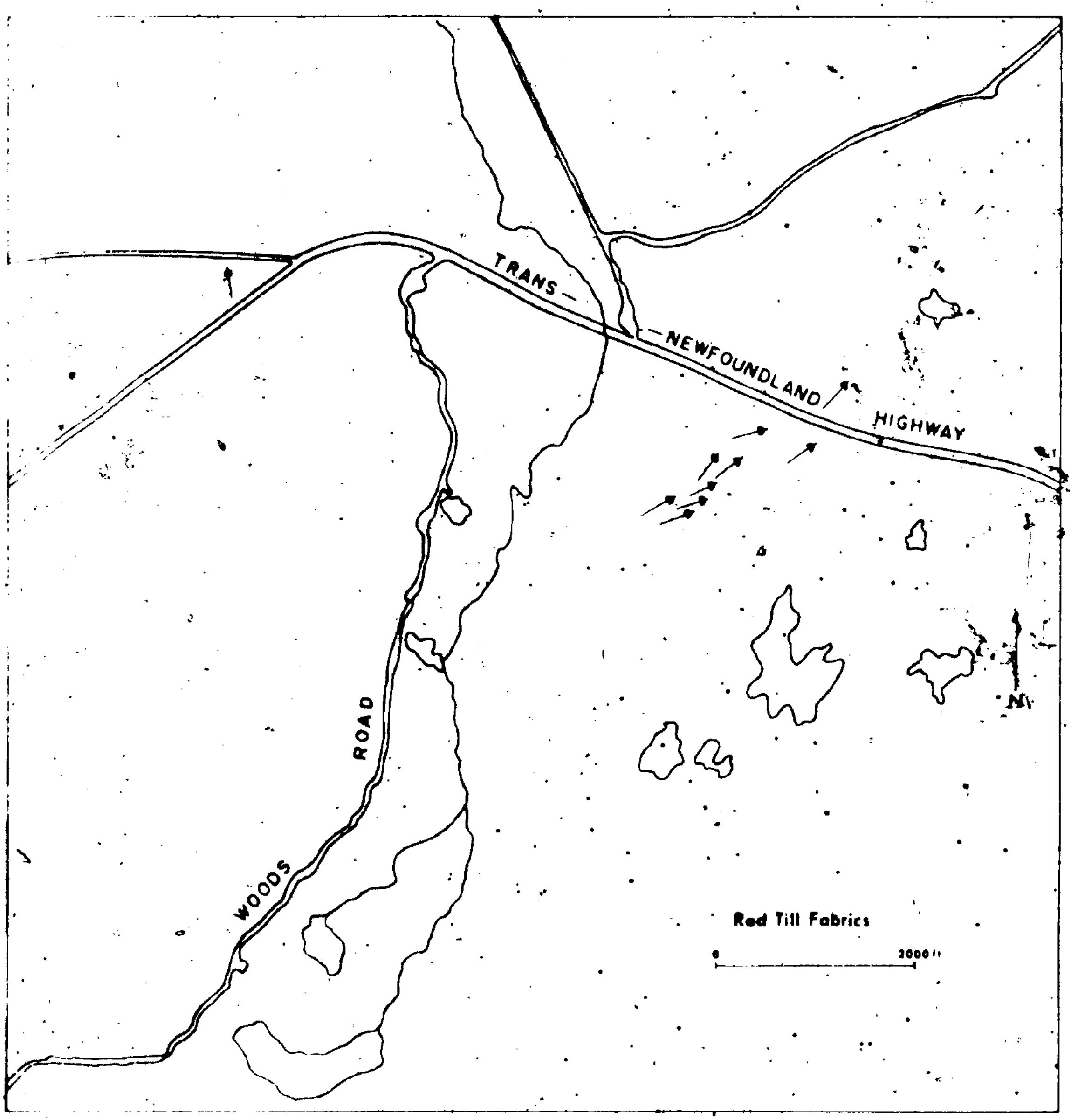


Figure 13: Lower Red Till fabric in Main Float Zone

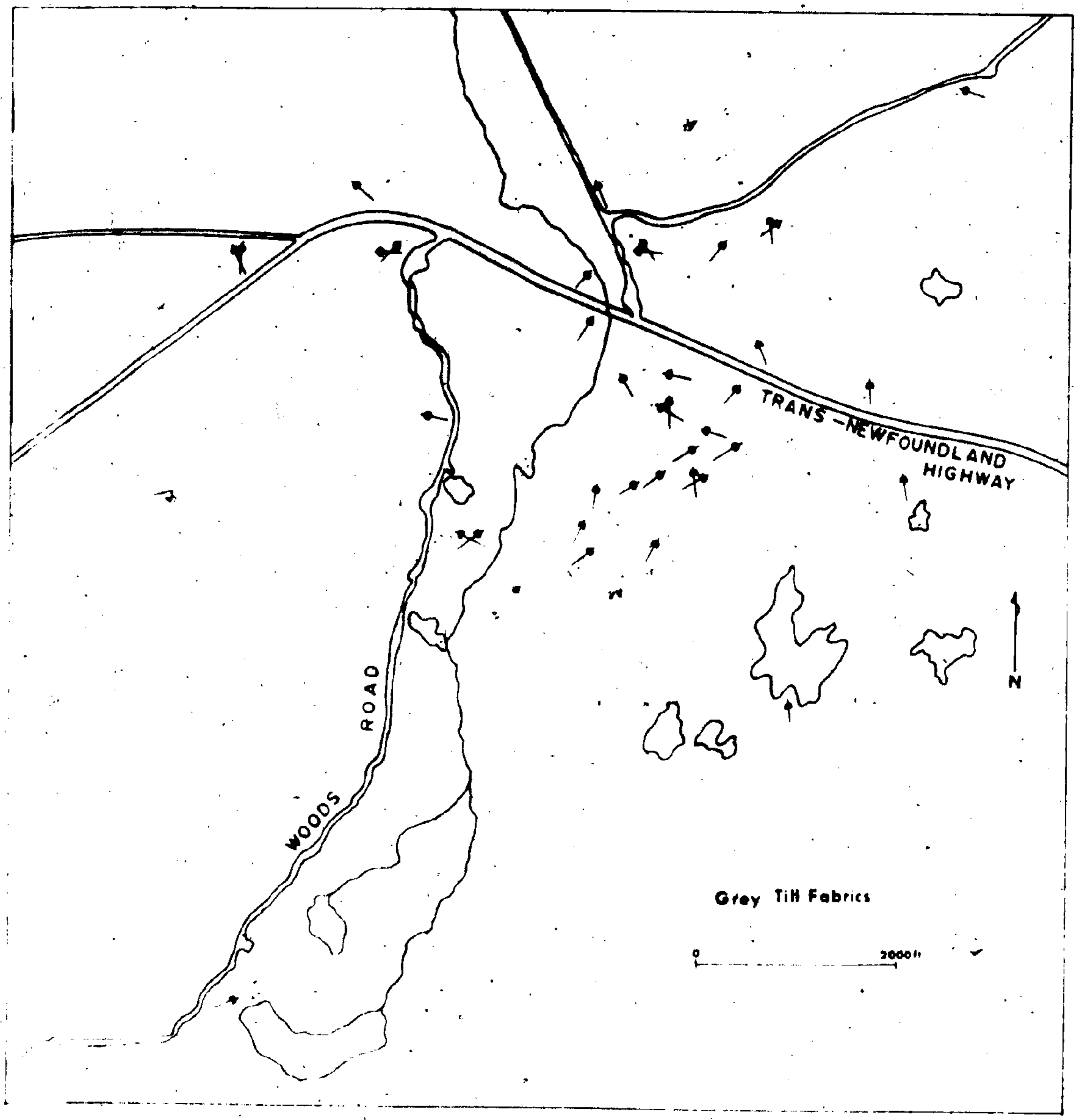


Figure 14: Upper Grey Till fabric in Main Float Zone

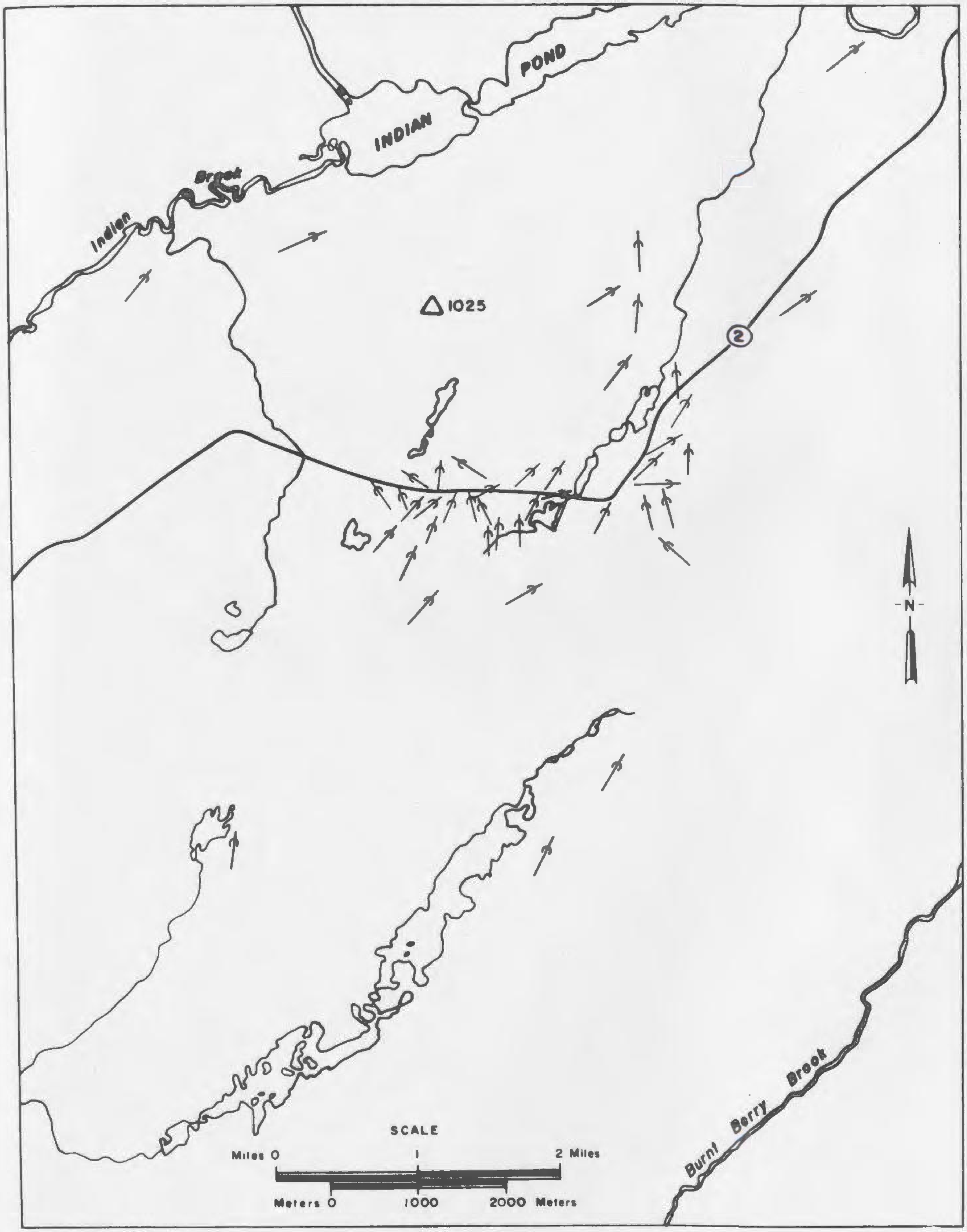


Figure 15: Upper Grey Till fabric outside Main Float Zone

(Figure 16) is approached. This is indicative of the same topographically controlled late ice flow as was described by O'Donnell in the fabrics he studied at Gullbridge, 20 miles to the east. These findings also substantiate the hypothesis of migrating ice centres to the south of the study area.

The two till units can then be differentiated on the basis of till fabric.

Clast Lithology

141 pebble samples with an average pebble content of 385 were collected in the study area. In all, 54,581 pebbles were washed, broken, classified as to lithologic unit and counted (Alley, 1972). A reference collection of bedrock types in the area was used to assign each clast to its proper source (Alley and Slatt, 1973). Table 4 summarized the varying pebble lithologies encountered in the two till units (see Appendix G).

The till clast lithologies clearly demarcate the contact between the two till units formerly indicated by colour and stratigraphy, (see below):

		TB-65	TB-92	TB-91A	TB-91B	$\overline{X}$%
Upper Grey Till	Granite	42	19	31	16	27
	Andesite	47	65	59	73	61
Lower Red Till	Granite	3	0	20	5	7
	Andesite	94	88	72	92	87

$\overline{X}$ - mean per cent.

From these results, the Upper Grey till can be shown to be enriched in granite clasts in the order of between 4 and 8 times that of the Lower Red till (Table 4). The Lower Red till is correspondingly enriched between

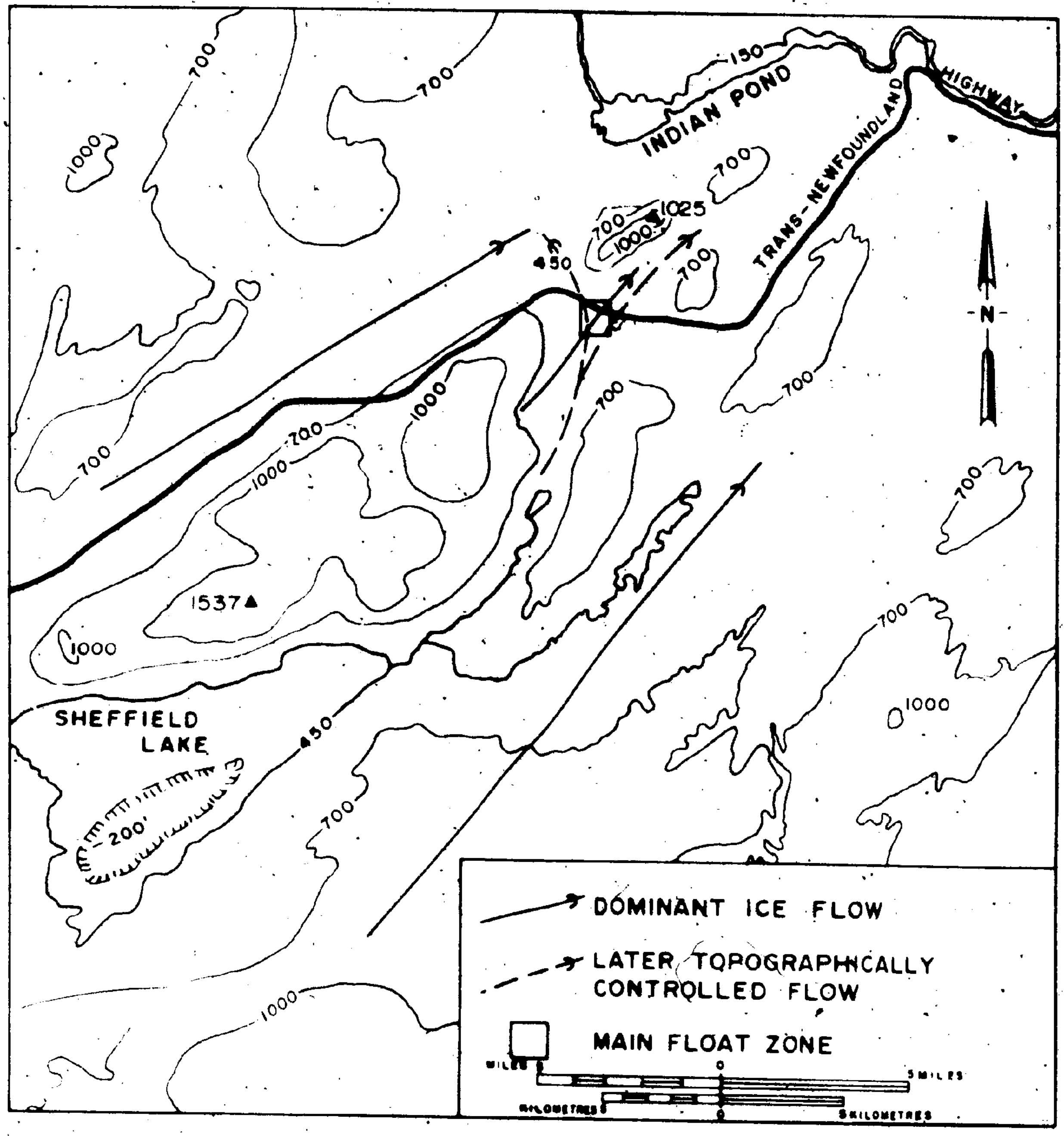


Figure 16: Late Wisconsinan ice flow directions

ABLE 4 : TILL PEBBLE LITHOLOGY

Main Float Area Material	Rock Type	$\bar{X}$%	S.	$E\bar{X}$	N.	$\bar{X}$ N.P.C.	T.P.C.
Upper Grey Till	Granite (18)	31	15.70	2.36	44	357	15,708
	Andesite (14)	42	24.08	3.85	44		
Lower Red Till	Granite (18)	4.	6.92	2.08	12	314	3,768
	Andesite (14)	88	15.07	4.76	12		

$\bar{X}$% - mean per cent lithology in sample.

S - standard deviation.

$E\bar{X}$ - standard error of mean.

N - number of samples

$\bar{X}$ N.P.C. - mean number of pebbles counted per sample.

T.P.C. - total pebbles counted from unit, in main float zone.

(18) (14) - Neale and Nash (1963) units.

1.5 and 2.1 times in andesite clasts of relatively local provenance (Figure 17).

The discrepancies of 3 to 16 percent in the table and figures are caused by the presence in all samples of clasts of indeterminate provenance (eg. monomineralic fragments usually quartz), a few far travelled pebbles of lithologies not mapped in the study area and small percentages of rhyolite clasts.

The presence of subrounded andesite and sulphide float clasts in the Upper Grey till must have resulted from reworking of the Lower Red till rather than from primary bedrock erosion. At the time of Upper Grey till emplacement, most of the andesite bedrock of the region was probably already masked by Lower Red till.

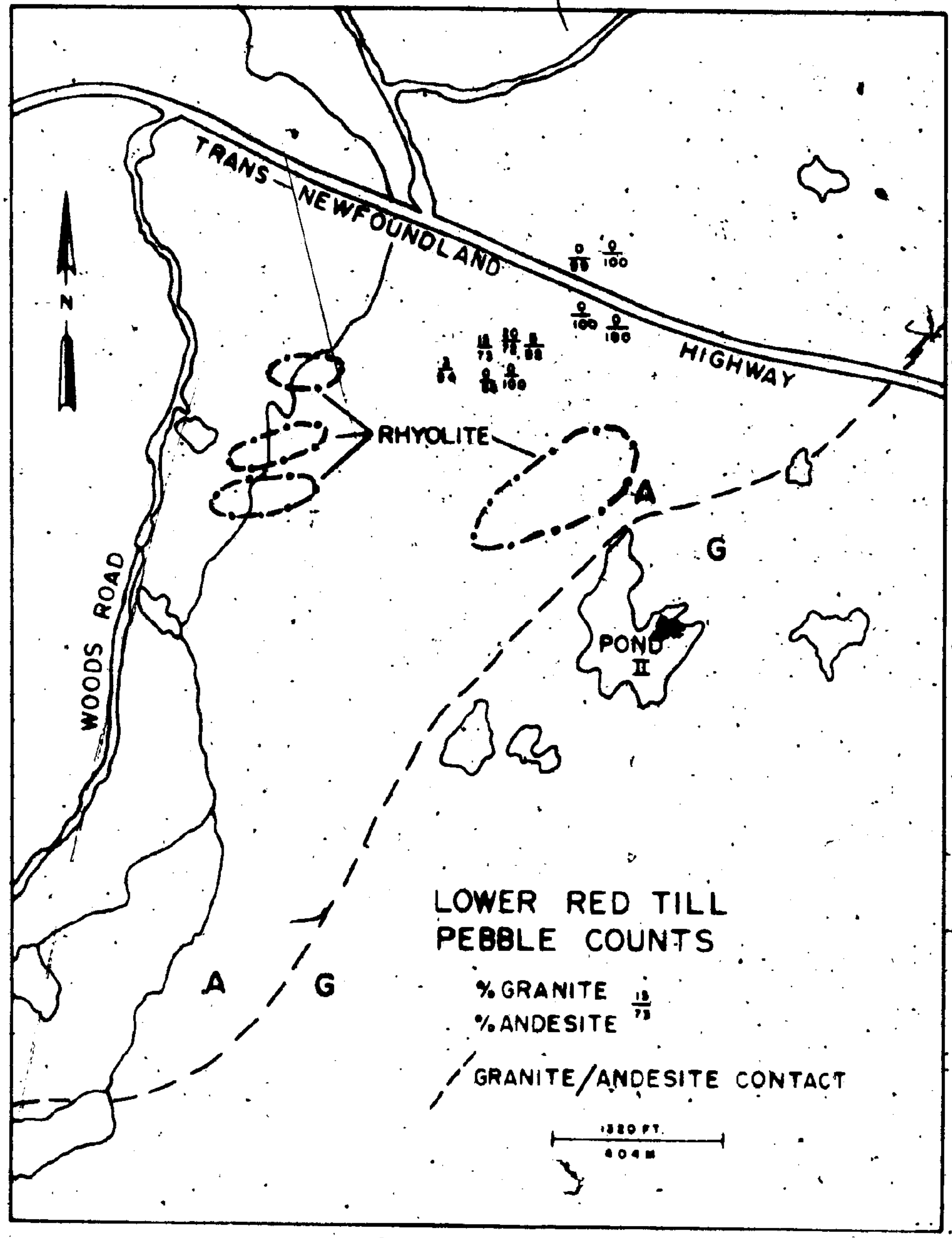


Figure 17: Pebble lithologies in Lower Red Till

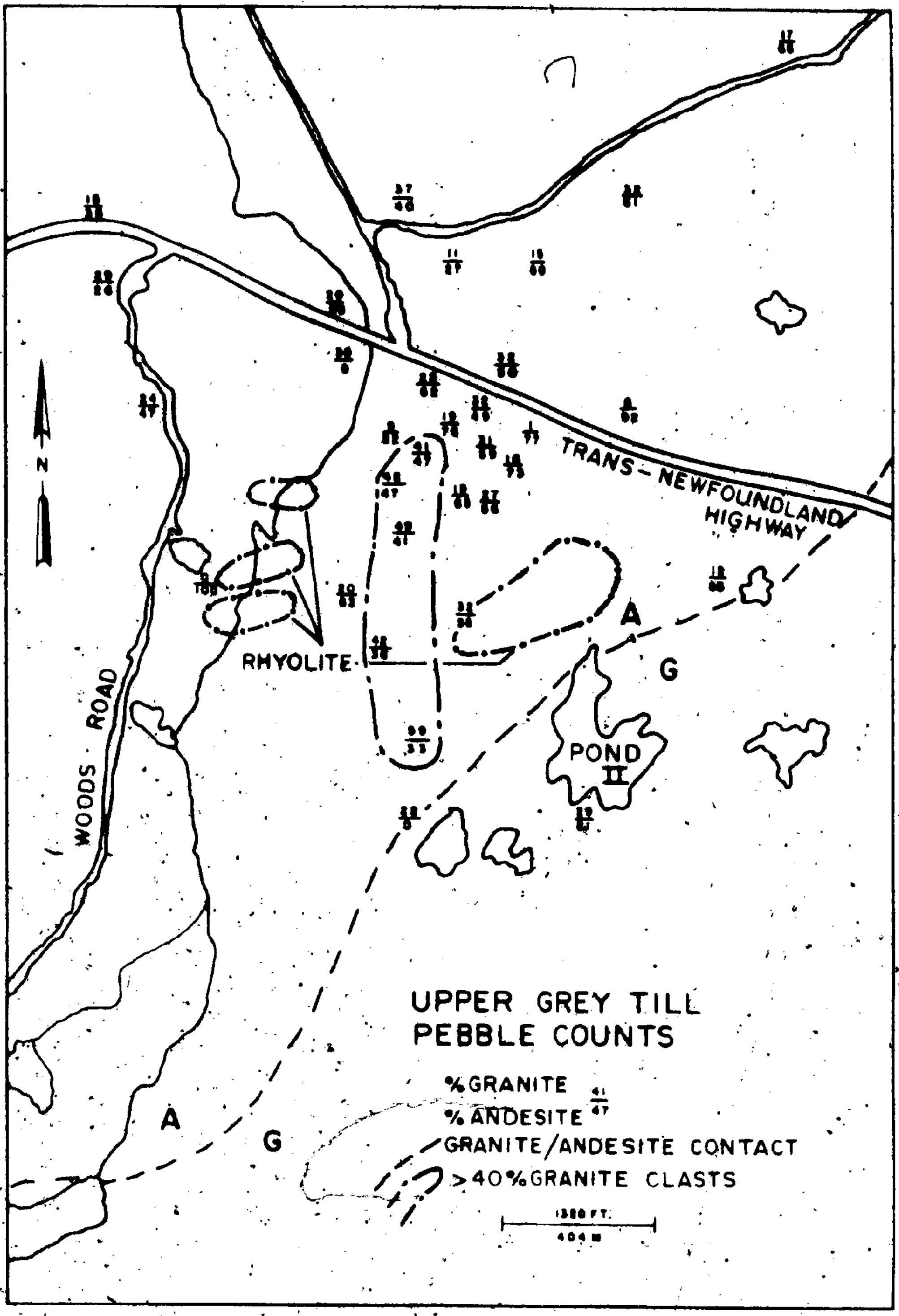


Figure 18: Pebble lithologies in Upper Grey Till

These two photographs were taken 30' apart in a Brinex-Boliden trench in the Main Float Area (Plate 2). Note the dominance of rounded to subrounded granitoid clasts in the Grey till above, and the angular, stained andesite clasts in the Red till, below.

Plates 6 and 7: Till Clast Lithology

Clay Mineralogy

Clay minerals have diagnostic d-spacings in their C-axis direction. The clay sized ($< 2\mu$) mineral assemblage in glacial till can be determined qualitatively by means of an X-ray diffractometer. Oriented clay mineral slides made by pipetting (Carroll, 1970) of four selected samples, two Upper Grey till, (#59 Low and #91B High) and two Lower Red till, (#97 Low and #91B Low) were prepared (see Appendix C) and analyzed on a Philips X-ray Diffractometer, using CuKa radiation, at settings of:

Killovolts - 40
Milliamps - 20
Time Constant - 4 sec.
Range C.P.S. - 4 x 10
20 mm./Min. Chart Speed
Scanning Speed - $1^{\circ} 2\theta$/Min (or 0.25° 2θ/Min)
Scan - see Figure 53

The aims of the clay mineral analyses were to determine: 1) which clay minerals were present in the two till layers, 2) the relative abundance of the various clay mineral types in each till, 3) if the clay minerals themselves will serve as a basis on which to differentiate the till units of the study area, and 4) the possible extent of post-depositional weathering on the mineral assemblage, especially in the Lower Red till.

Results

One untreated slide (Slide "A" - Figure 53) of each sample was scanned from 3° to 30° at a scan speed of 1° 2θ/minute.

Feldspar and illite were identified by peaks on the untreated slide diffractograms at 3.17 Å and at 10 Å, 5 Å and 3.35 Å, respectively (Beaumont, 1971), (Figure 19). Chlorite was identified by 14 Å, 7 Å, 4.7 Å and 3.5 Å peaks.

To test for the presence of Montmorillonite in the samples, another slide (Slide "B" - Figure 53) was placed overnight in a dessicator, into which had been poured 200 mls. of ethylene glycol, and heated overnight in an 80° C oven (Figure 20). Glycolation causes a shift of the major Montmorillonite peak from 14 Å to about 17 Å. The glycolated slides were scanned from 3° to 15° at a scan speed of 1° 2θ /minute. No shift of the peak was observed on the diffractogram of any of the slides, therefore, Montmorillonite is not present in the samples.

Since Kaolinite and Chlorite cannot be differentiated in an untreated sample slide due to overlapping peaks at 7 Å and 3.5 Å (Biscaye, 1964), three techniques were applied to the slides ("A", "C" and "D" - Figure 53) to determine if Kaolinite indeed occurred in the samples (Biscaye, 1964). A slow scan (Slide "A" - Figure 53) at 0.25° 2θ /minute was run on the original untreated slide. Chlorite has its major peak at 3.54 Å and Kaolinite at 3.58 Å, and these usually appear as one broad peak at the regular scanning speed (Biscaye, 1964). This method revealed only one large peak at 3.54 Å for all of the samples (Figure 21), therefore Chlorite and not Kaolinite is probably present in the samples. To further verify this interpretation, a third slide (slide "C" - Figure 53) of each sample was placed in a muffle furnace, heated to 600°C for one hour and immediately scanned from 2° - 15° at the same instrument settings as for the original untreated slide (Carroll, 1970). Kaolinite becomes amorphous when heated

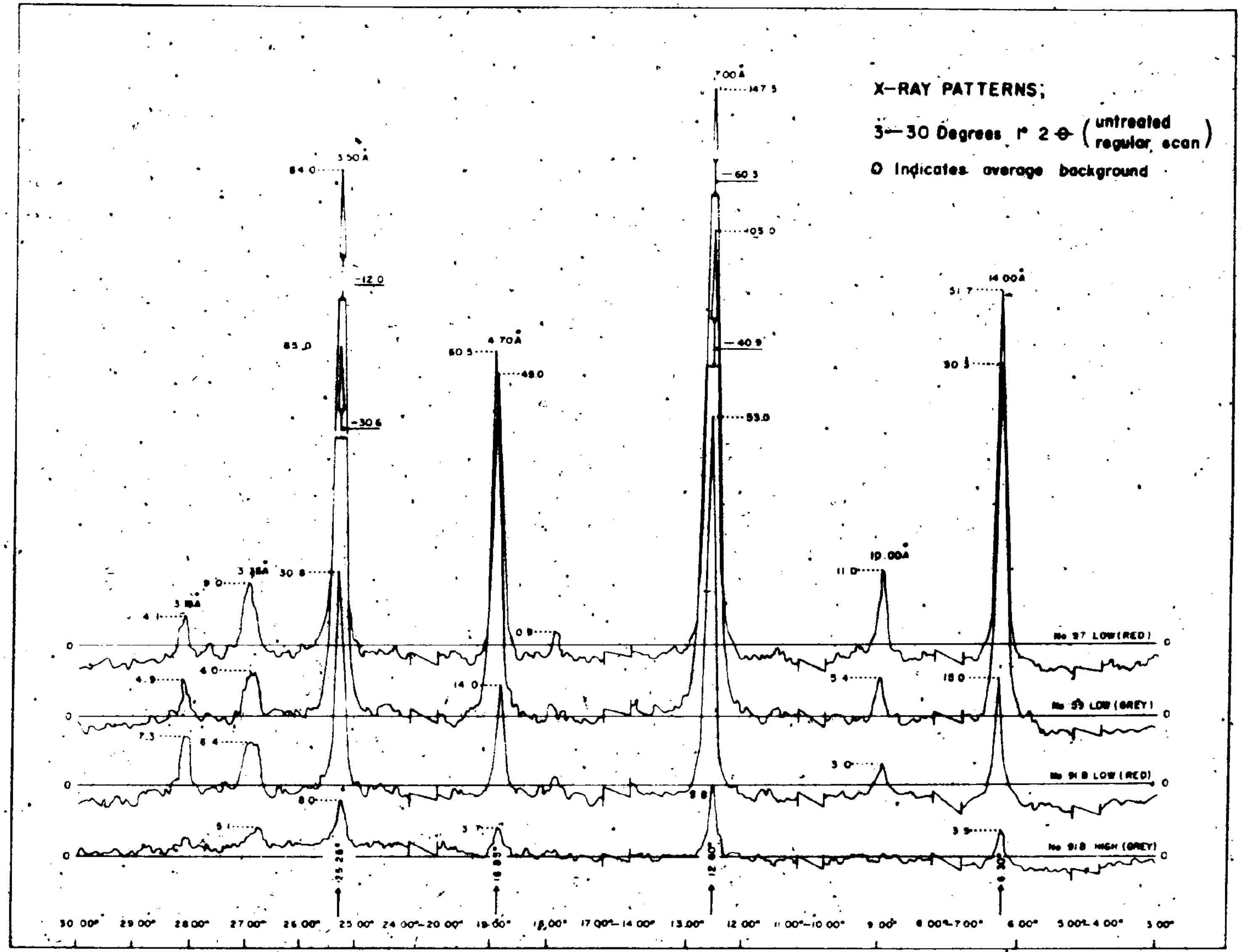


Figure 19. X-ray Diffractogram, Untreated Regular Scan.

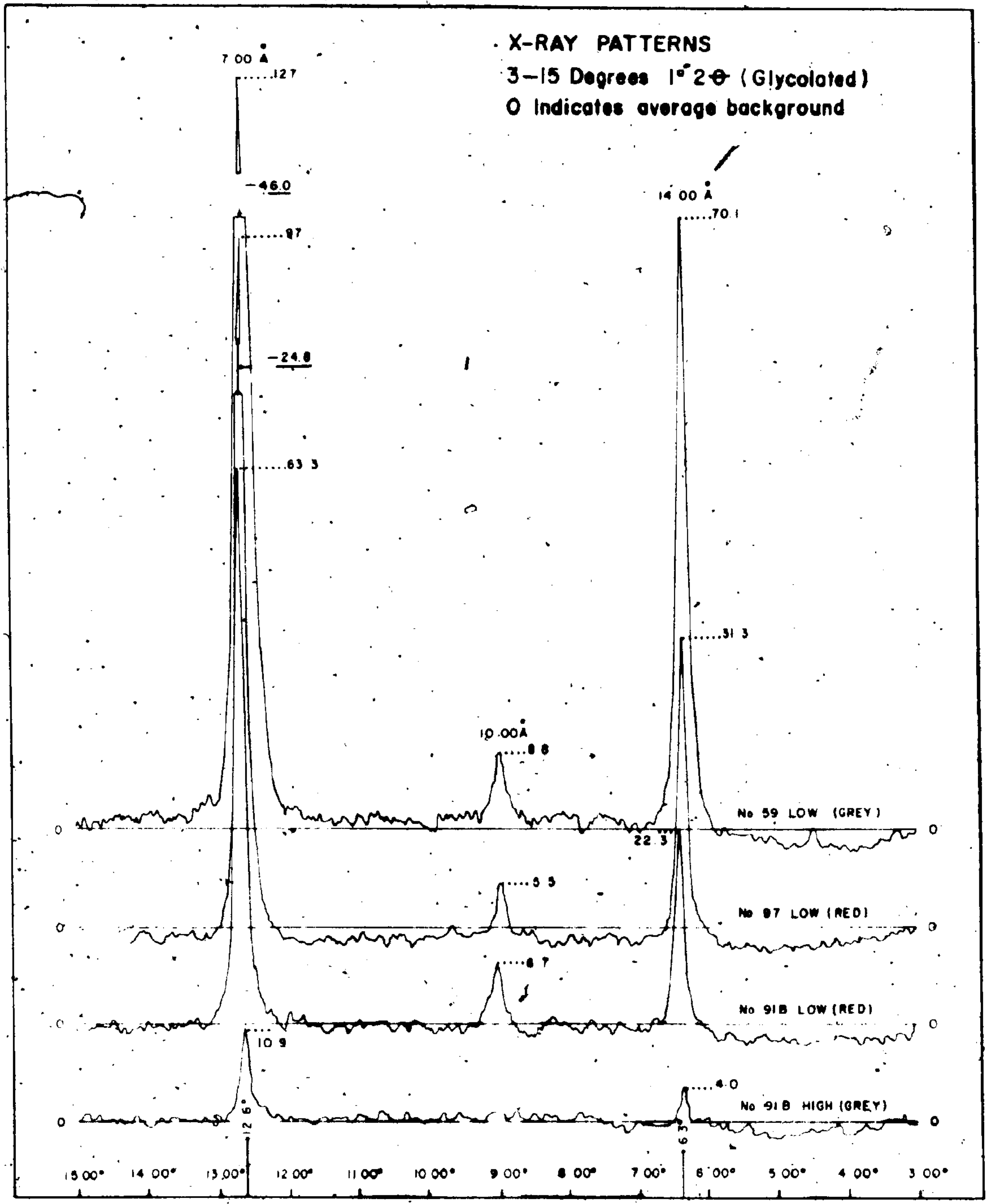


Figure 20. X-ray Diffractogram, Glycolated Regular Scan.

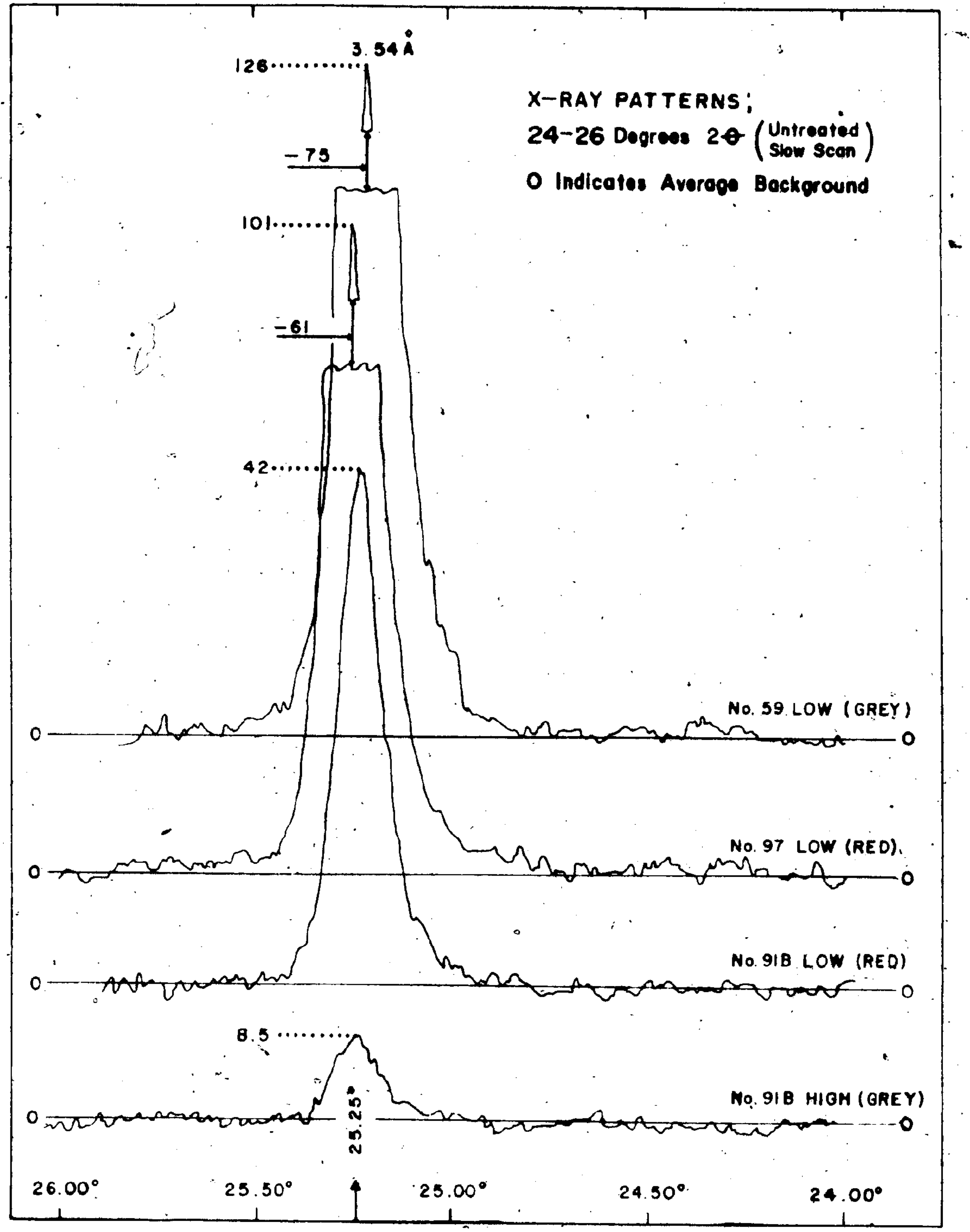


Figure 21. X-ray Diffractogram, Untreated Slow Scan.

to 600°C. If a peak remains after heat treating the slide, then Chlorite must definitely be present in the sample. The results were erratic and inconclusive. Samples 59 Low and 91B Low definitely contain Chlorite as indicated by a strong 14 Å peak after heat treatment. However, samples #91B High and 97 Low became amorphous possibly indicating a Kaolinite presence not shown by the slow scan method (Figure 22).

To resolve this discrepancy, a fourth slide (slide "D" - Figure 53) of each was acid treated for one hour in an 80°C oven (Biscaye, 1964). The 3.5 Å Chlorite peak should diminish or completely disappear, since the acid selectively dissolves Chlorite but leaves the Kaolinite unscathed. In all cases, the 3.54 Å peak was either greatly diminished or disappeared, proving conclusively that Chlorite and not Kaolinite is present in the samples (Figure 23).

Quantitative Analysis

While there is no general agreement as to the most accurate method of quantitative analysis of clay mineral assemblages Biscaye (1965) advocates a simple means of approximating the content of the various clay minerals in a sample. His method, which cannot be expected to produce results better than ± 10%, involves measuring the areas encompassed by the first order diffractogram peak produced by each clay mineral in the assemblage (Table 5). One hundred per cent of the clay in these samples is assumed to be made up of illite and chlorite, although small K feldspar peaks do occur on all of the diffractograms at 3.18 Å. A measurement of the relationship of the

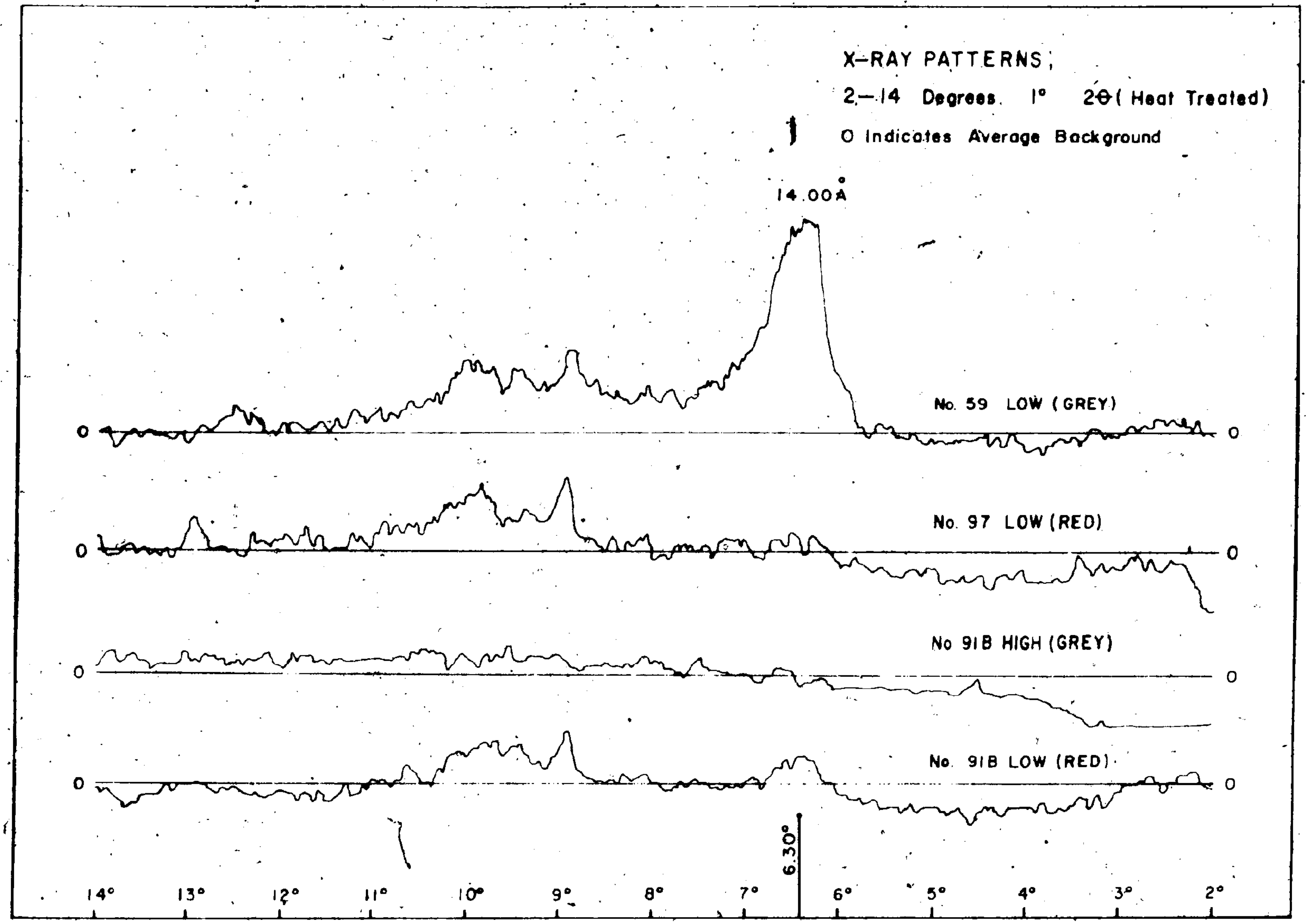


Figure 22. X-ray Diffractogram, Heat Treated.

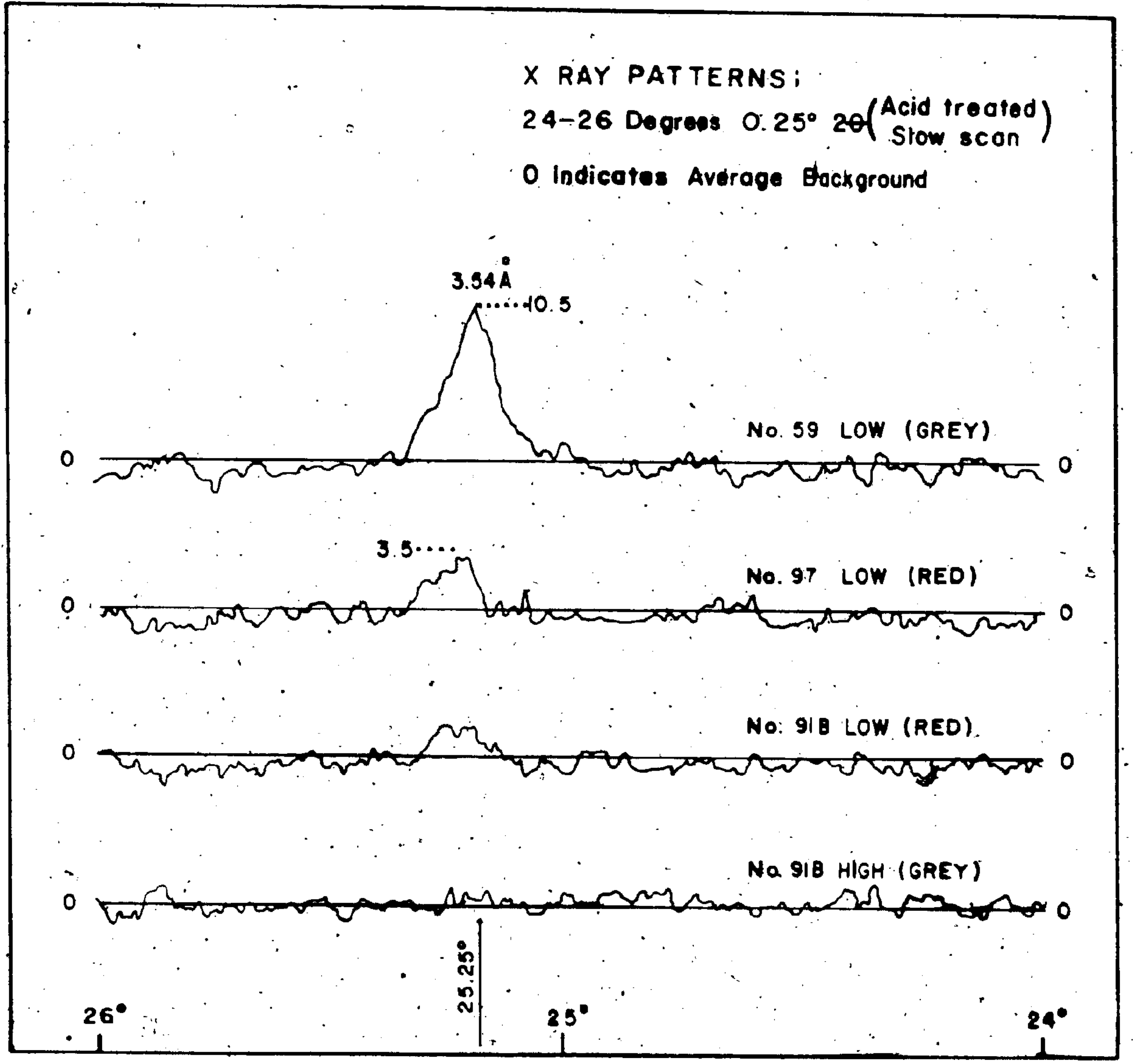


Figure 23. X-ray Diffractogram, Acid Treated Slow Scan.

TABLE 5 : QUANTITATIVE CLAY MINERALOGY DETERMINATION

TILL UNIT	SAMPLE #	% ILLITE	% CHLORITE
Grey	59 Low	6.9	93.1
Grey	91B High	-	100.0
Red	91B Low	14.2	85.8
Red	97 Low	13.9	86.1

Illite and Chlorite dominant peak areas, should then reflect the relative proportion of the two minerals in the samples. The dominant peak of Chlorite occurs at 7 Å and for Illite at 10 Å, on the untreated slide diffractogram (Figure 19).

Table 5 indicates that illite may be slightly enriched in the Lower Red till. Lundquist (1965) has postulated that illite in glacial clay may represent re-deposited older sediments (i.e., pre-glacial regolith). The dominance of chlorite in the samples is a reflection of the chloritized bedrock of the region.

Basing broad correlations on only four analyzed samples is never a good practice, however, some differentiation of the two till units in the study area (especially in the main float area, from whence the four samples were collected) seems justified, on the basis of this work. Also of importance here is the fact that both tills are enriched in Chlorite, which would seen to support the work of Bayrock and Pawluk (1966), concerning the local provenance of the "fine fraction" of basal till.

Gravel, Sand, Mud Content

The results of the textural analyses (Appendix F) performed on 164 of the bulk till samples collected are summarized in Table 6 and are plotted on a ternary diagram of gravel, sand and mud (G.S.M.) content in Figure 24. The mean (G.S.M.) content of both till units derived from Table 6 also appear in Figure 24.

It is deduced from the ternary diagram that both tills have similar mud content, but are somewhat dissimilar in their gravel and sand components. Nevertheless, the greater gravel (2-16 mm.) content of the Lower Red till, and the greater sand (0.062-2 mm.) content of the Upper

TABLE 6 : GRAVEL, SAND, MUD CONTENT

Till Unit	Sediment Type	$\bar{X}$%	S	$E\bar{X}$	N.
Grey	16-2 mm. Gravel	42.6	13.01	1.07	144
Grey	2-0.0625 mm. Sand	40.3	5.42	1.21	144
Grey	>0.0625 mm. Mud	17.0	8.86	1.01	144
Red	16-2 mm. Gravel	53.7	10.27	2.35	20
Red	2-0.0625 mm. Sand	31.4	7.09	1.62	20
Red	>0.0625 mm. Mud	15.7	5.93	1.32	20

$\bar{X}$% - mean per cent.

S - standard deviation.

$E\bar{X}$ - standard error of the mean.

N - number of samples.

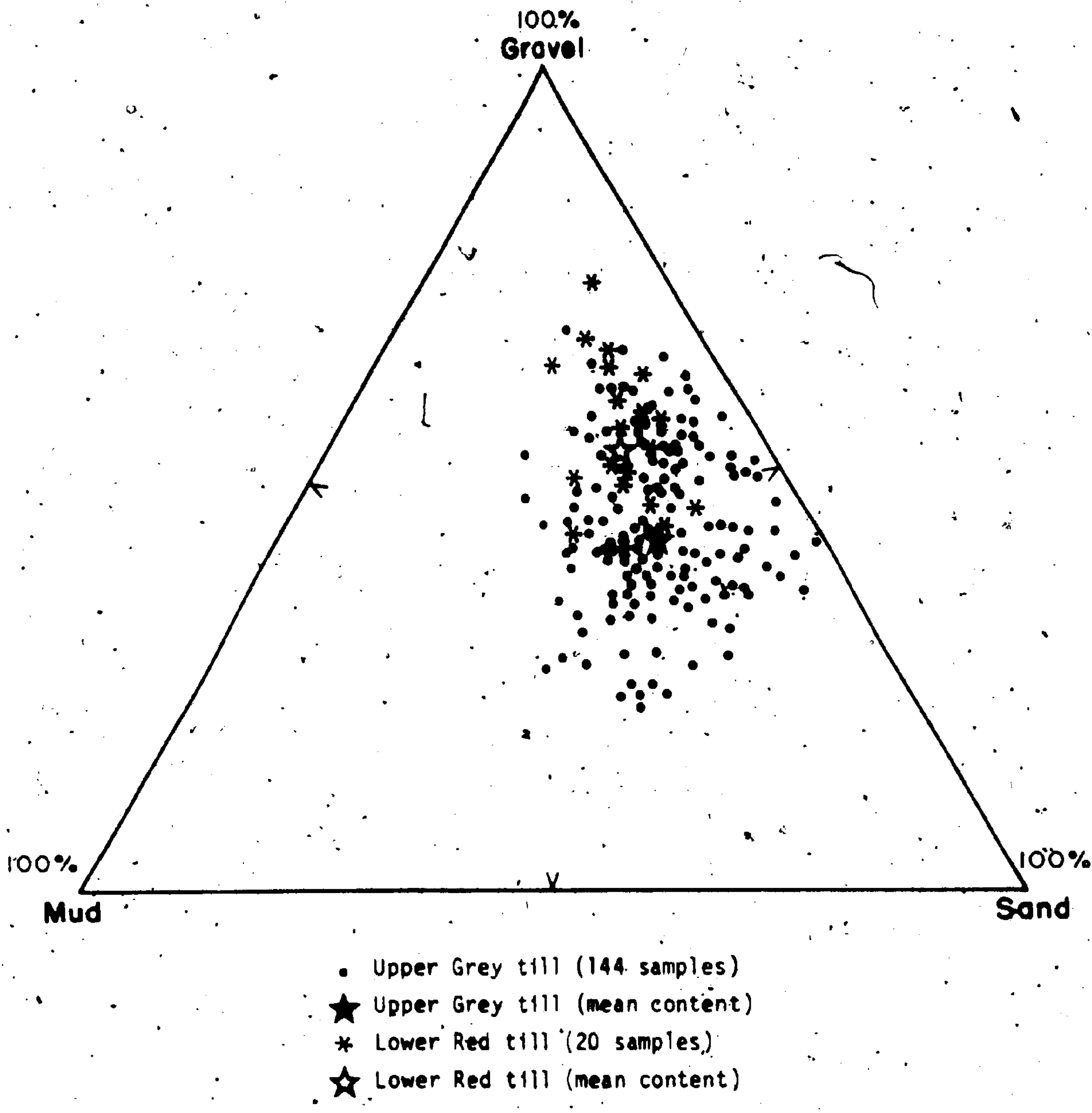


Figure 24. Gravel, Sand, Mud Ternary Diagram.

Grey till probably do not represent significant criteria on the basis of which, alone, to differentiate the two units. However, this work does indicate that the two tills have somewhat different textures and the similar mud content of both units adds supporting evidence for their emplacement by two discrete ice advances, rather than from the same ice sheet.

Sand, Silt, Clay Ratios

Table 7 summarizes the results of sieve and pipette analyses performed on 10 Upper Grey till and 10 Lower Red till samples from the main float zone (Figure 2). The results are also plotted on a ternary sand, silt, clay diagram (Figure 25).

These results indicate that no differentiation of the two tills can be made on the basis of sand, silt, clay proportions. Again, however, good supporting evidence that both tills were emplaced as discrete till units rather than the Lodgement and Ablation facies of the same till sheet is seen by the high content of "fines" in the tills.

Reworked and Incorporated Till Blocks

During the trenching phase of the study, subrounded blocks of Lower Red till were observed to occur in the Upper Grey till (Figure 26). The distinct contacts which occurred between these blocks and the enclosing grey till matrix and their differing clast lithology from that of the grey till are interpreted to indicate that they are discrete "ripped-up" blocks (Schollen) of Lower Red till material, rather than the results of differential weathering, or the former occurrence at the sites of large, weathered float clasts.

TABLE 7 : GRAVEL, SAND, SILT, CLAY CONTENT

Till Unit	Sediment Type	$\overline{X}$%	S.	$E\overline{X}$	N.
Grey	16-2 mm. Gravel	38.8	10.12	3.20	10
Grey	2-0.062 mm. Sand	40.9	8.35	2.64	10
Grey	0.0625-0.002 Silt	17.2	5.16	1.63	10
Grey	>0.002 Clay	3.0	2.54	0.80	10
Red	16-2 mm. Gravel	49.8	9.65	3.05	10
Red	2-0.062 mm. Sand	33.5	5.45	1.72	10
Red	0.062-0.002 mm. Silt	13.5	6.64	2.10	10
Red	>0.002 Clay	3.1	2.15	0.68	10

$\overline{X}$% - mean per cent.
S. - standard deviation.
$E\overline{X}$ - standard error of mean.
N. - number of samples.

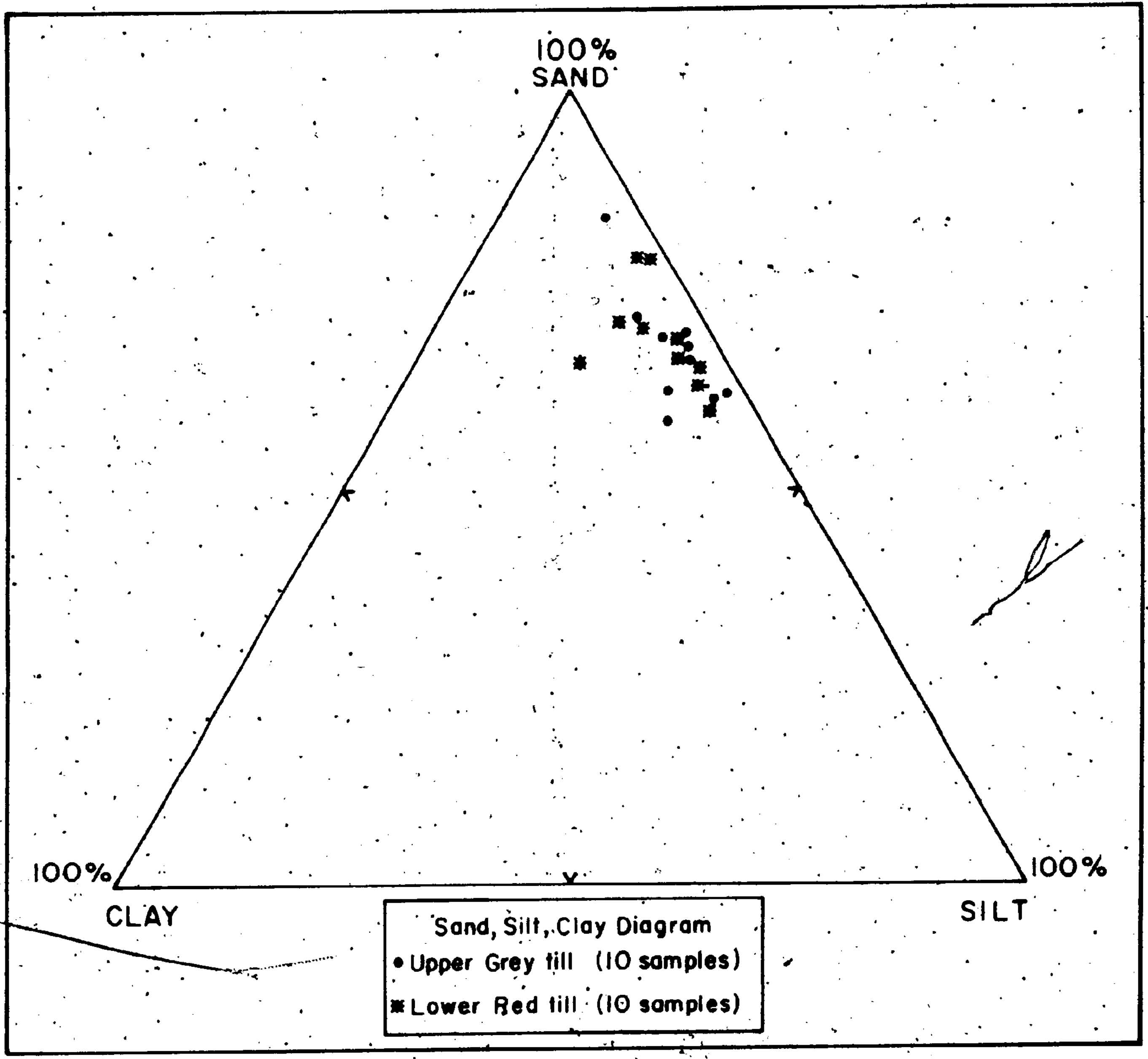


Figure 25. Sand, Silt, Clay Ternary Diagram.

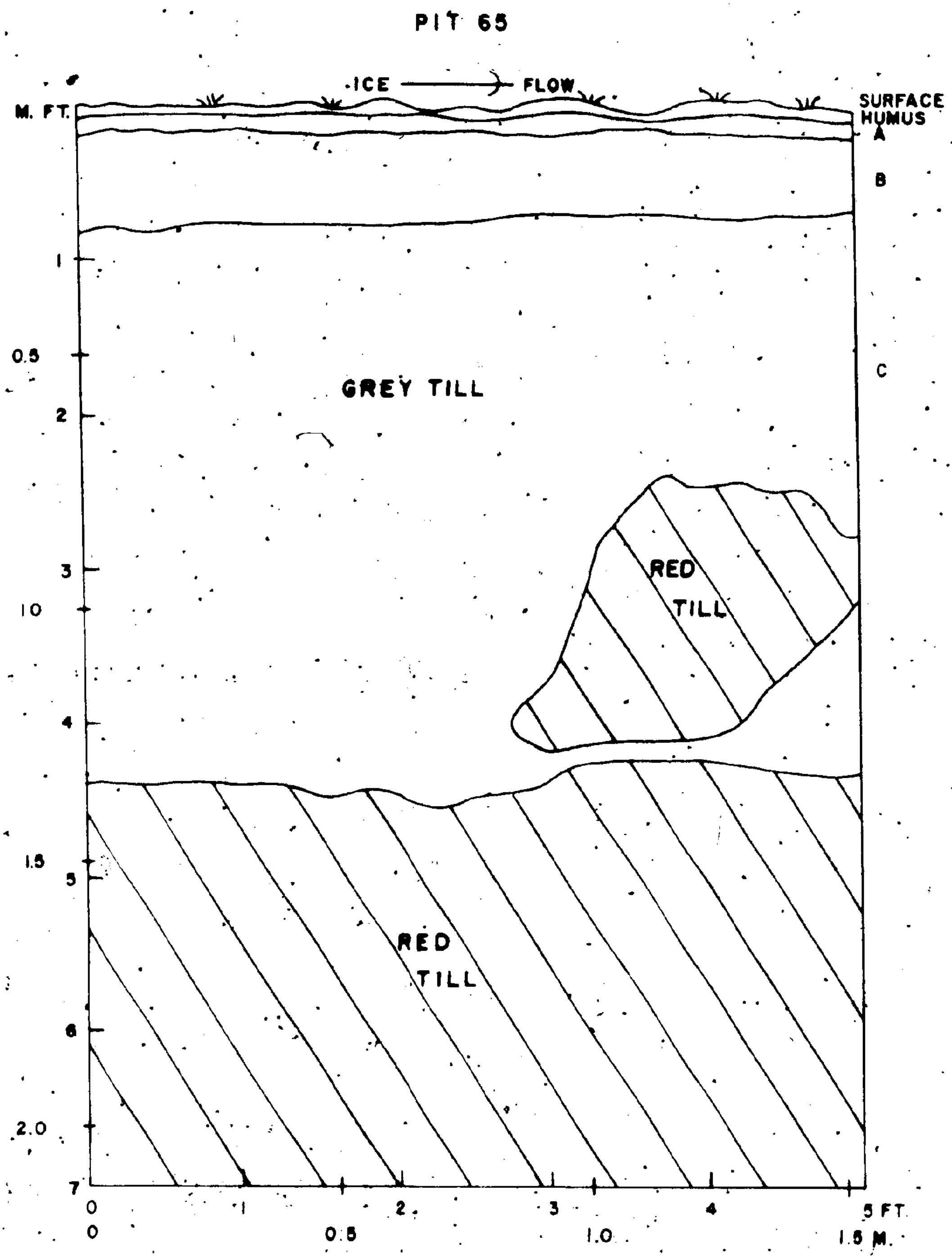


Figure 26 - Diagram of trench #65 showing block of Lower Red Till emplaced in Upper Grey Till

The occurrence of these blocks is conclusive evidence that two till sheets, derived from separate ice advances, are present in the study area.

Geochemistry

A complete discussion of the geochemistry of the two till units appears in Chapter V, and it is sufficient here to mention that the two till units are easily differentiated on the basis of their widely varying concentrations of trace elements.

Dispersion Fans

As outlined in Chapter III (General Principles of Drift Prospecting), the discovery of mineralized float in glacial drift is prime evidence that bedrock mineralization occurs in the vicinity.

The sulphide float of the Sheffield Lake - Indian Pond area is dominantly confined to a small area straddling the Trans-Newfoundland Highway ~~#1~~, denoted as the "Main Float Zone", on Figure 2. The float, as described in Chapter II, ranges from weakly pyritized, chloritized andesite fragments to massive pyrite - chalcopyrite clasts.

It has been pointed out that the float clasts occur in great profusion in the Lower Red till (Malmquist, 1961), but only sparsely in the Upper Grey till of the main float zone.

The occurrences of sulphide float in the Lower Red till are plotted on Figure 27. They indicate a good fan shape pointing to a source area South West of TB-65 (Figure 12).

The float occurrences in the Upper Grey till, (Figure 28) are always of secondary, reworked derivation. The effect of the second ice advance and till deposition in the vicinity has been, then, to mask, smear and

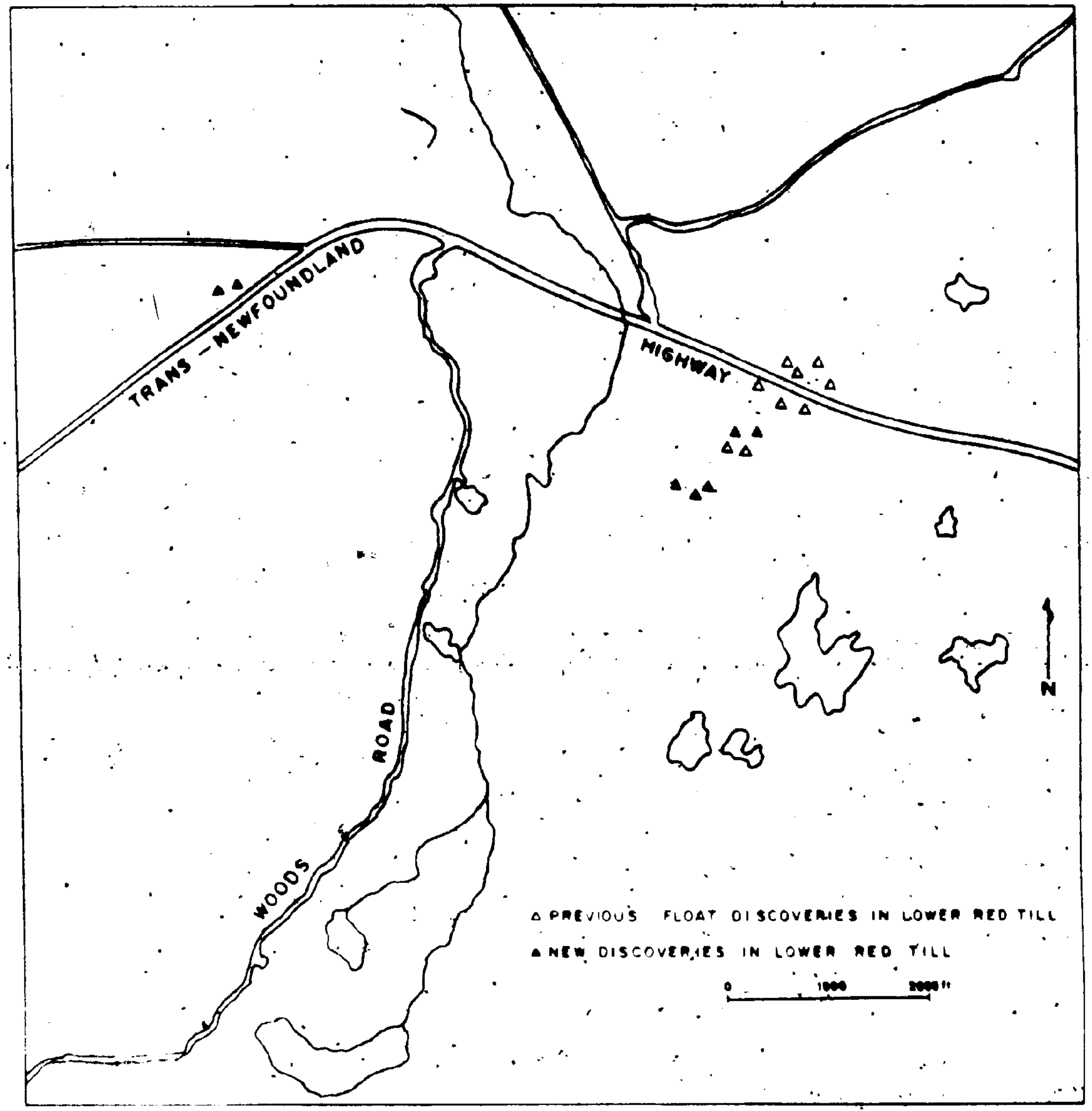


Figure 27 - Distribution of float in Lower Red Till of Main Float Zone

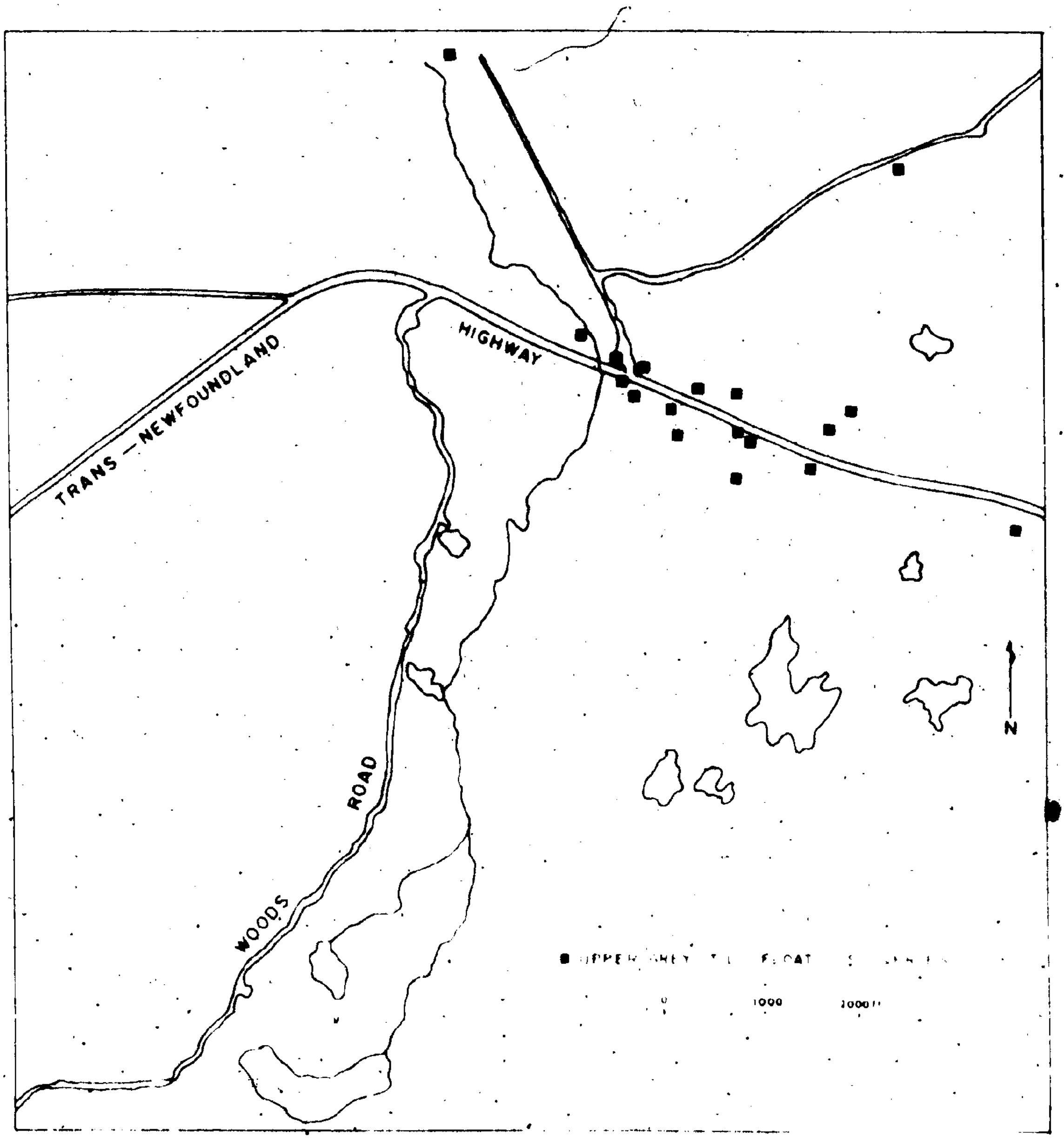


Figure 28 - Distribution of float in Upper Grey Till of Main Float Zone

attenuate the primary dispersion fan as it occurs in the Lower Red till. Much of the confusion of previous workers (Malmquist, 1961) concerning the tracing of the float clasts in this region can be linked directly to these events.

The Ablation, Lodgement Till Hypothesis

Figure 29 indicates the mode of deposition of Lodgement and Ablation Till from the same ice advance, and their superposition after ablation of the ice (Flint, 1971). Since the two till units that occur in the Sheffield Lake - Indian Pond area (Figure 11) have been previously interpreted as the lodgement and ablation facies of the same till sheet (Malmquist, 1961), a re-interpretation of them as two discrete till units emplaced by two separate ice advances needs to be verified.

Lodgement and ablation till (Figure 29), often referred to as ground ablation moraine by Scandinavian workers (Embleton and King, 1968), are thought to represent two completely different modes of deposition and have been formerly mistaken for evidence of two ice advances (Drake, 1971).

Table 8 lists the common characteristics of lodgement and ablation till and of the Lower Red and Upper Grey tills of the study area. From this comparison, the Lower Red till apparently has all of the features of lodgement till, which would seem to support the lodgement, ablation hypothesis.

However, a comparison of lodgement till features and those of the Upper Grey till reveals some important similarities. Although the Upper Grey till is somewhat friable, is non fissile, has many clasts of distant provenance (see section on Sedimentology) and is relatively thin, all features of ablation till; its properties also include some compaction

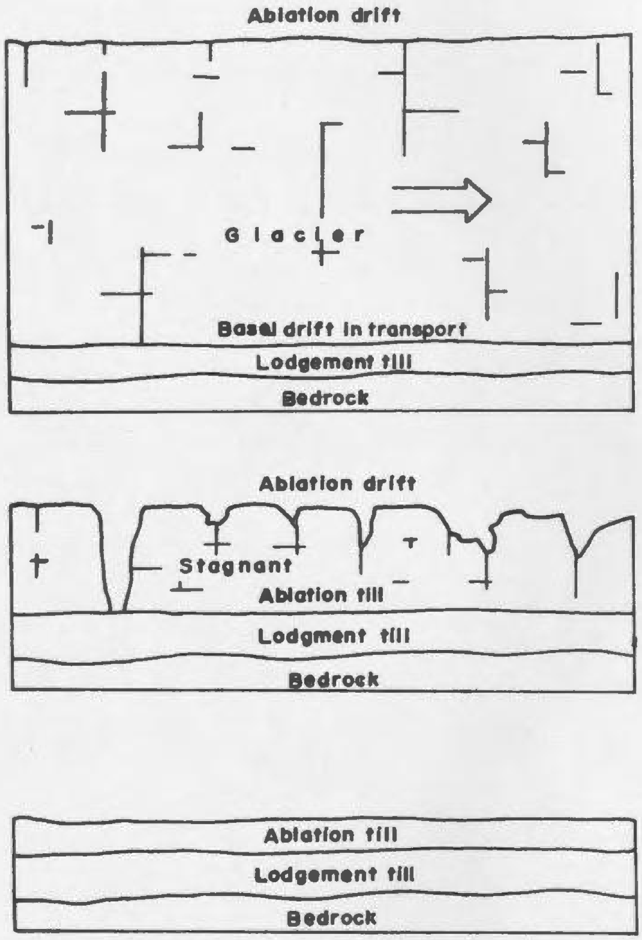


Figure 29 - Origin of lodgment and ablation till. A. Basal drift in transport over bedrock giving rise to a lodgment till. B. During period of ablation, ice near a glacial margin melts beneath a cover of glacial drift and an ablation till is deposited. C. Post-glacial condition. A layer of ablation till is found over a lodgment till. From Flint (1971).

(pits in this unit with vertical walls have remained open for more than a year), subrounded clasts, a high mud content, two strong, superimposed fabrics and, conclusively, discrete "ripped up" and incorporated blocks of Lower Red till material within itself (Figure 26). Furthermore, the Lower Red till has been shown to be discontinuous beneath the Upper Grey till. Thus, extensive areas of Upper Grey till are superimposed directly on bedrock; a difficult phenomenon to rationalize with an Ablation Till interpretation for the Upper Grey Till (see Figure 29).

These features, then, probably indicate that the Upper Grey till is not the ablation till facies of the same ice sheet that emplaced the Lower Red till. The deposition of the Upper Grey till, probably from relatively thin ice, is evidenced by the lack of fissility of the till. Reworking of the Lower Red till (which was in the frozen state) resulted in the removal of any soil horizon that may have developed and an unknown amount of "C" horizon material as well.

The Ablation, Lodgement Hypothesis has been shown, then to be untenable from these finding. The results are interpreted to indicate the presence of 2 distinct lodgement tills deposited during independent ice advances.

The Englacial, Basal Till Hypothesis

Alternatively, it has been suggested that the Upper Grey and Lower Red tills of the Sheffield Lake-Indian Pond area might represent the Englacial and Basal facies of deposition from a single ice sheet (A. Dreimanis, Personal Communication, 1975).

There is an apparent overlap between englacial till (Dreimanis,

1975) and ablation till, in that both derive from the same process, glacier ablation. Nevertheless, features characteristic of englacial till differ sufficiently from those of ablation till so that a rather indistinct boundary may be drawn between the two.

A comparison of the characteristics of englacial till with those of the Upper Grey till appears in Table 8. The table illustrates the apparent dissimilarities between englacial till features and those of the Upper Grey till. In particular, the presence of incorporated blocks (Schollen) of Lower Red till in the Upper Grey till, and the discontinuous distribution of the red till beneath the contiguous grey till, are conclusive evidence that the grey till is not the englacial facies of the same till sheet represented by the Lower Red till.

The Ablation, Lodgement and the Englacial, Basal Hypotheses have been shown, then to be inconsistant with these finding. The results are interpreted to indicate the presence of two distinct lodgement tills deposited during independent ice advances.

Evidence for Two Ice Advances

In 1926, A.P. Coleman, in one of the first studies of the glacial history of Newfoundland, was convinced that the island had been glaciated on at least two separate occasions during the Pleistocene. He cited as evidence for this interpretation the occurrence at Curling (near Corner Brook), of gravelly till both underlying and over lying a marine shell-bearing bed. He further states that the second advance was less severe than the first, from which it was separated by a period of climatic amelioration.

ABLATION TILL*	UPPER GREY TILL	ENGLACIAL TILL**	LOWER RED TILL	LODGEMENT TILL*
- Friable	- Somewhat friable	- Friable	- Non-friable	- "Plastered on"
- Non compact	- Some compaction	- Non compact	- Compact	- Compact
- Non fissile	- Non fissile	- Some fissility	- Fissile	- Fissile
- May be stratified	- Non stratified	- Often stratified	- Non stratified	- Non stratified
- Undeformed	- Undeformed	- Often slumped and faulted	- Undeformed	- Undeformed
- Mud absent	- 17% mud	- Low mud content	- 15.7% mud	- Some mud content
- Usually thin	- 10+ feet thick	- Usually thin	- 30+ feet thick	- Variable thickness
- Large areal extent	- Large areal extent	- Discontinuous occurrence common	- Patchy occurrence	- Continuous sheet
- Angular clasts	- Subrounded clasts	- Angular clasts	- Angular clasts	- Angular clasts
- Of distant provenance	- Local and distant provenance apparent	- Of distant provenance	- Local provenance	- Local provenance
- Lacks a fabric	- 2 good fabrics	- Rude fabric (Often transverse)	- Strong Fabric	- Strong fabric
- Random imbrication	- "Up-ice" imbrication	- Flat lying a-b plane	- "Up-ice" imbrication	- "Up-ice" imbricati
- Few striated clasts	- Striated clasts common	- some striated clasts	- Some striated clasts	- Some striated clasts
	- Incorporated blocks (schollen) of lower red till			

Table 8. A comparison of Ablation, Englacial and Lodgement Till characteristics with those of the Upper and Lower Tills in the study area. (*Flint, 1971; Embleton and King, 1968: ** Upham, 1891; Dreimanis, 1975)

MacClintock and Twehhofel (1940) in their classic study of the glacial history and deposits of Newfoundland, also allude to more than one glacial episode. Their interpretation, like that of Coleman, rested primarily on the discovery of intercalated till and fossiliferous marine clay beds in the Bay St. George area on the west coast of Newfoundland and also near Baie Verte, on the north coast. The sequence and interpretation near Baie Verte is indicated below:

22 ft.	Glacial-Fluvial Outwash	- ?, 2nd ice retreat
	Till	- ?, 2nd ice advance
	Marine Clay	- 6', 1st ice retreat
	Till	- 3', 1st ice advance

The sequence of deposits on the Central Plateau near Buchans was interpreted as indicating that after retreat of the major ice sheet, ice tongues pushed down the valleys and deposited terminal moraines.

MacClintock and Twenhofel (1940) also point out that no drift older than Wisconsinan is found in Newfoundland.

Flint (1951) interpreted the Wisconsinan glacial deposits of Newfoundland as indicating radial flow from a centre near Buchans followed by the formation of smaller more local ice caps, which presumably were responsible for local pulses in the ice front.

Jenness (1960) describes an extensive end moraine deposit in Eastern Newfoundland which resulted either from a lengthy stand of retreating Wisconsinan Ice at that position or, more likely, from a final re-advance to that position from further inland.

Lundquist (1965), in a study of striae sets in the Sheffield Lake - Indian Pond Region, concluded that there was an increasing topographic influence upon ice movement as the major Wisconsinan ice sheet waned and that a last readvance occurred in the area from an isolated ice mass near the Sheffield Lake - Indian Pond plateau (see Introduction). He notes, that there are many signs of a general stage of equilibrium or temporary readvance during the ablation of the major ice sheet.

Prest (1970), on the basis of flow indicators, states that during the waning of the island ice cap complex, ice-flow patterns developed with erratic, shifting active centres of ice flow.

Brookes (1969), described marine clays intercalated between layers of till on the Port au Port Peninsula, indicating a readvance.

Grant (1970) recognized similar till deposits beneath and above fossiliferous marine clays dated at 10,900 B.P. on the Northern Peninsula and from this he named the Ten Mile Lake readvance.

O'Donnell (1973) states that as the major Wisconsinan ice cap waned, small local ice caps were formed in the High Central Plateau area and sporadic topographically controlled advances, pulses and surges were widespread. He also reports two till fabric directions in the Gullbridge area but attributes them to the more topographically controlled late ice rather than to a readvance.

Tucker (1973) records multi directional striae just to the east of the Sheffield Lake - Indian Pond area which he interprets as indicating late, topographically controlled ice flow.

Rogerson and Tucker (1973) have found evidence in the St. Vincent area of the Southern Avalon Peninsula of a glacial readvance. A lower till unit of unknown thickness is overlain by a marine outwash delta and it, in turn, by a layer of till 10 feet thick.

All of these researchers, then, present evidence of either topographically controlled late Wisconsinan ice or a period of readvance during the late Wisconsinan glacial period. The widespread evidence of a period of readvance preserved as crossing striations, increased drift thicknesses and intercalated marine and/or glaciofluvial deposits with glacial till are convincing. The conclusive evidence for two ice advances-superimposed till sheets-however, has not previously been reported in central Newfoundland.

In the Sheffield Lake - Indian Pond area, two distinct superimposed till units do occur. The hypotheses that they are the ablation - lodgement facies or the englacial - basal facies of the same ice advance have been shown to be untenable. They may be interpreted, then, as corresponding to the readvance postulated to have occurred during the waning stages of the Wisconsinan ice sheet in Newfoundland. Alternatively, the possibility exists that the Lower Red till is much older than the Upper Grey till which may be the only major Wisconsinan deposit in the area. Coleman (1926) postulated that very old (Kansan?) tills occur in Newfoundland and the deeply oxidized and indurated Lower Red till might then conceivably date from a pre-Wisconsinan glaciation.

CHAPTER V.

GEOCHEMISTRY

Introduction

In 1957, S.V. Ermengen stated that,

> "A study of the literature available reveals that relatively little has been written on geochemical prospecting in parts of the world which have been submitted to continental glaciation during Pleistocene time."

His observation, probably true eighteen years ago, certainly does not apply today. A rapidly increasing dossier of case histories has been documented in various journals and two books on the subject of geochemical exploration in areas of Pleistocene continental glaciation (Kvalhiem, 1967; Jones, 1973) have been published to date.

The number of geochemical prospecting projects has surged ahead in the formerly glaciated areas of Fennoscandia, Ireland, and mainland Canada, particularly in the last decade. However, insular Newfoundland has until recently (Hornbrook and Davenport, 1972) been ignored by exploration geochemists, even though the glacial history, deposits, and post-glacial conditions are thought to closely resemble those of the more intensively prospected areas mentioned above, and even though techniques developed in these other areas should be particularly applicable here.

Sampling

It is a rather obvious dictum that where float boulders occur in large numbers in glacial drift the finer grained matrix of the drift must also include detrital float fragments. This syngenetic halo of fine detrital grains has been referred to by Kauranne (1958) as a micro-float train, as a microboulder fan by Bolviken (1967), and by Wennervirta (1968) as a glaciogenic fan.

Since the fine grained (200 mesh) fraction of glacial till is postulated to have only been transported a very short distance (Bayrock and Pawluk, 1966) a study of its elemental composition "up ice" should reveal, even more precisely than the macroscopic float clasts, their common provenance in the subcropping bedrock.

It is also apparent that in areas of deep overburden the optimum sampling depth is within the unweathered, undisturbed glacial till material (the "C" zone of the podzol profile) where detrital sulphide grains are almost insoluble in the reducing conditions that predominate there (Scott and Byers, 1964; Kauranne, 1967; Forgeron, 1971 Parslow, 1972). Of importance, as well, is the determination of elemental variations with depth in the overburden as a further criterion for source determination, since elemental concentrations in both the horizontal and vertical components of the micro-float fan should increase in proportion to the proximity of the suboutcropping source (Figure 5). This purpose is best served by the collection of profile samples at regular intervals in a pit opened into the glacial drift (Ermengen, 1957; Hawkes and Webb, 1962; Hyvarinen 1967; Brotzen, 1967; Halonen, 1967; Kauranne, 1967; Wennervirta, 1968; Larsson and Nichol, 1971; Gunton and Nichol, 1974).

In the Sheffield Lake - Indian Pond area, 108 trenches were dug from which 167 bulk samples were collected for geochemical analysis (Appendix C). Samples at two depths (designated High and Low) were collected from 28 of the trenches, and at 6 selected sites profile samples (designated A, B, C, etc.) were collected at one foot vertical intervals. In all cases only "C" horizon parent till material was collected. At two locations sample pits bottomed on andesite bedrock and in each case bedrock samples were collected for geochemical analysis (Table 1).

Pre-Treatment and Analyses

Critical to any geochemical exploration program is the choice of a suitable analytical method. The geochemist must consider (1) the size fraction of the sample (2) the number of samples and elements to be analyzed (3) the pre-treatment and extraction techniques to be used (4) the reliability, ease of implementation, and detection limit of the method and (5) the accuracy and precision to be expected from the method.

As outlined in the general principles of Drift Prospecting (Chapter III) most geochemical exploration programs in glaciated terrain concentrate on the unweathered "C" zone of the glacial till, and specifically on the -80 mesh fraction of the till. Gunton and Nichol (1974) have pointed out, however, that the clay-and-silt-sized fractions (-230 mesh) must be removed to avoid the variable effect they can have on elemental concentrations.

The Sheffield Lake - Indian Pond area samples were first wet sieved to remove the -230 mesh (0.063 mm) fraction. The +230 mesh fraction was then dried, and sieved on an 80 mesh stainless steel screen to obtain the -80 to +230 mesh fraction. This fraction was then split into 3 subsamples for geochemical analyses. (Appendix C). From prior analyses of float samples (Table 1) Cu, Pb, Zn, Mn, Co, Ni, Fe, and S were chosen to be the tracer elements analyzed.

Studies are available on the merits of one pre-treatment extraction over another (Foster, 1971). Generally, the methods available can be divided into Total and Partial extractions.

A total extraction technique is performed by fusion or by the addition of strong, hot acid to the sample which results in complete sample dissolution. This method is best adapted to lithogeochemical surveys, since it extracts even the silicate complexed-and strongly bonded-metal in the sample.

A partial extraction technique is performed with weak or dilute acid which takes into solution only discrete sulphide grains and the relatively loosely bonded and absorbed metals in the sample. This partial dissolution is best adapted to the study of unconsolidated sediments (e.g., glacial till) when the survey is directed toward the pinpointing of anomalous metal concentrations which should reflect the presence of sulphide minerals rather than silicate bonded metal.

However, some partial extraction methods (e.g., cold buffer THM extractions) are often insufficinet to delimit anomalous areas in glaciated terrain, where anomalies may be only 10 ppm above threshold. A balance must be struck then between a too weak partial extraction and a too strong total digestion when glacial till is the sampling medium.

In this investigation Ward's (1969) extraction method (HOT 16N HNO_3) was first tested but later rejected. It was very time consuming, required specialized equipment, and failed to produce the degree of precision desired.

A boiling dilute acid (10/1, 1N HNO_3 16N HCl) (F. Goudie, Personal Communication, 1974) was found to be superior for partial digestion of the -80 + 230 mesh fraction since neither nitric (HNO) nor hydrochloric (HCl) acid decompose the more stable rock-forming silicates (Levinson, 1974), but they do leach all forms of sulphide minerals.

Elemental analyses were performed by Atomic Absorption Spectrophotometry (A.A.S.). The advantages of A.A.S. are its sensitivity, precision, reliability, and speed (Brotzen, et al., 1967). One special appeal of A.A.S. in exploration geochemistry is the fact that, from one sample digestion, as many as 40 elements can be determined, thus resulting in a considerable saving in cost while at the same time providing a wealth of information (Levinson, 1974).

In this study, each subsample was analyzed for Cu, Pb, Zn, Co, Ni, Mn, and Fe on a Perkin-Elmer Model 303 Spectrophotometer using standard procedure (Figure 54), after a 1½ hour hot acid digestion (10/1, 1N HNO_3 16N HCl).

Elements to be analyzed in the digestion solution by A.A.S. must be in the atomic state. This is readily achieved by aspirating the solution at a controlled rate into a flame fueled by a mixture of air and acetylene. A light beam at one of the characteristic wavelengths (i.e., 2139A for Zn) of the element of interest is directed through the flame, into a monochromator and into a detector which measures the intensity of the light beam. The amount of light absorbed by the flame when a sample is being aspirated is proportional to the concentration of the element in the sample. This reading is then compared with readings obtained from standard solutions of known concentration, and the concentration in ppm of the element in the sample is attained.

Sulphur content of 77 of the samples was determined using a LECO Sulphur Analyzer which is generally thought to be the best method of sulphur analysis (Foscolos and Barefoot, 1970). The method involves the combustion of the sample in a stream of oxygen in a high frequency furnace. As the sample is combusted, all sulphur compounds are volatilized, primarily as sulphur dioxide. The SO_2 is carried by the oxygen to the titration vessel where it is absorbed by bubbling through a dilute HCI solution, which also contains free iodine. The absorbed SO_2 is titrated with standard LIO_3 using starch indicator, and the amount of SO_2, hence sulphur in the sample, is determined.

In exploration geochemistry, precision (which is the ability to produce and repeat the same result) is often more important than accuracy (which is the approach to the true value), at least in the initial stages of a project (Levinson, 1974). Precision and accuracy by A.A.S. are thought to be better or comparable to any other method of trace element analysis (Brotzen et al., 1967).

For precision determination, within each batch of 22 samples 2 were weighed, digested, and analyzed twice each; also within each batch, 2 control samples (#59L and #67), of high and low elemental concentrations (determined in the first batch) were always included resulting in each being analysed 10 times. Samples were analysed at random, that is, all of the samples from one till unit or within a small part of the project area were never analysed in one batch (Table 9). As a check of accuracy and precision 30 representative samples were sent to Atlantic Analytical Services, (Springdale, Newfoundland) and were analysed by A.A.S. for Cu, Pb, Zn, Ni, Co, Mn, and Fe; comparative results appear in Table 10. Generally, good agreement is apparent from this comparision, with the possible exceptions of the Zn and Ni values where the Atlantic Analytical Services determination are generally lower than those recorded by the author.

All of the sulphur analyses were performed over a 48 hour period

Table 9. Precision of Atomic Absorption Analyses

	Sample #			$\overline{X}$	S	$E\overline{X}$	N.
*	67	ppm.	Cu	16.5	2.0	0.7	10
		"	Pb	6.9	1.5	0.5	10
		"	Zn	37.0	8.9	3.1	10
		"	Co	4.1	0.8	0.3	10
		"	Ni	11.1	3.2	1.2	10
		"	Mn	189.0	11.4	4.0	10
			%Fe	0.75	0.13	0.04	10
*	59L	ppm.	Cu	164.6	13.9	4.9	10
		"	Pb	7.4	1.2	0.4	10
		"	Zn	98.8	5.8	2.0	10
		"	Co	21.5	1.2	0.4	10
		"	Ni	17.3	1.5	0.5	10
		"	Mn	628.0	100.6	33.5	10
			%Fe	2.63	0.57	0.20	10
	6	ppm.	Cu	19.0	5.7	4.0	2
		"	Pb	9.0	0	0	2
		"	Zn	51.0	12.7	9.0	2
		"	Co	3.0	0	0	2
		"	Ni	28.0	2.8	2.0	2
		"	Mn	329.0	12.7	9.0	2
			%Fe	1.45	0.21	0.15	2
	31	ppm.	Cu	47.5	3.5	2.5	2
		"	Pb	7.5	0.7	0.5	2
		"	Zn	20.0	0	0	2
		"	Co	2.0	0	0	2
		"	Ni	24.5	0.7	0.5	2
		"	Mn	152.5	0.7	0.5	2
			%Fe	0.45	0.21	0.15	2
	47	ppm.	Cu	24.0	5.7	4.0	2
		"	Pb	6.5	2.1	1.5	2
		"	Zn	30.5	0.7	0.5	2
		"	Co	6.5	0.7	0.5	2
		"	Ni	8.5	3.5	2.5	2
		"	Mn	256.5	4.9	3.5	2
			%Fe	1.00	0.14	0.10	2

Table 9 Continued

Sample #			$\overline{X}$	S	$E\overline{X}$	N.
66L	ppm.	Cu	8.0	0	0	2
	"	Pb	8.5	2.1	1.5	2
	"	Zn	17.0	1.4	1.0	2
	"	Co	3.5	0.7	0.5	2
	"	Ni	4.0	1.4	1.0	2
	"	Mn	125.0	7.0	5.0	2
		%Fe	0.50	0	0	2
70A	ppm.	Cu	151.0	2.1	1.5	2
	"	Pb	175.0	0	0	2
	"	Zn	202.0	3.5	2.5	2
	"	Co	30.0	0	0	2
	"	Ni	26.5	2.1	1.5	2
	"	Mn	575.0	35.3	25.0	2
		%Fe	5.60	0.10	0.10	2
79	ppm.	Cu	9.5	0.7	0.5	2
	"	Pb	5.5	0.7	0.5	2
	"	Zn	18.5	0.7	0.5	2
	"	Co	20.5	2.1	1.5	2
	"	Ni	7.5	0.7	0.5	2
	"	Mn	189.5	2.1	1.5	2
		%Fe	0.75	0.07	0.05	2
92L	ppm.	Cu	185.0	0	0	2
	"	Pb	13.0	0	0	2
	"	Zn	37.5	3.5	2.5	2
	"	Co	39.5	0.7	0.5	2
	"	Ni	26.5	2.1	1.5	2
	"	Mn	681.0	26.1	18.5	2
		%Fe	12.1	0.10	0.10	2
94H	ppm.	Cu	16.5	2.1	1.5	2
	"	Pb	8.0	1.4	1.0	2
	"	Zn	24.5	0.7	0.5	2
	"	Co	8.0	0	0	2
	"	Ni	25.0	0	0	2
	"	Mn	175.0	14.1	10.0	2
		%Fe	0.85	0.07	0.05	2

Table 9 Concluded

Sample #			$\overline{X}$	S	$E\overline{X}$	N.
96L	ppm.	Cu	37.5	3.5	2.5	2
	"	Pb	9.5	0.7	0.5	2
	"	Zn	90.0	14.1	10.0	2
	"	Co	18.5	0.7	0.5	2
	"	Ni	15.0	0	0	2
	"	Mn	725.0	35.3	25.0	2
		%Fe	2.20	0	0	2
102A	ppm.	Cu	38.0	0	0	2
	"	Pb	5.5	0.7	0.5	2
	"	Zn	29.0	1.4	1.0	2
	"	Co	7.0	1.4	1.0	2
	"	Ni	14.0	1.4	1.0	2
	"	Mn	136.5	2.1	1.5	2
		%Fe	1.90	0.07	0.05	2
102D	ppm.	Cu	25.0	2.8	2.0	2
	"	Pb	8.5	0.7	0.5	2
	"	Zn	16.0	0	0	2
	"	Co	3.5	0.7	0.5	2
	"	Ni	15.5	0.7	0.5	2
	"	Mn	112.5	3.5	2.5	2
		%Fe	1.30	0	0	2

* Control Samples

$\overline{X}$ Mean

S Standard Deviation

$E\overline{X}$ Standard error of the mean using the standard procedure of Foscolos and Barefoot (1970). As in the A.A.S. work, the samples were analyzed at random and each tenth sample run was a blank containing accelerator and flux only. Two control samples (#86 and #59L) were analyzed periodically until the S content of each had been determined 10 times.

Subsamples of 20 representative samples from the area were separated in TETRABROMOETHANE (S.G. = 2.92) into heavy and light fractions, again following standard procedure (Allman and Lawrence, 1972) (Appendix C). All of the heavy separates and 11 of the light fractions were then analyzed by the A.A.S. method for the elements listed formerly.

Good estimates of the accuracy of A.A.S. and Leco determinations, except those done by Atlantic Analytical Services (Table 10) were difficult to obtain since no unconsolidated glacial sediment standards are available, as are rock standards. As well, the acid dissolution used in the study was adjudged too weak to leach the silicate bound metal in rock standards. Nevertheless, an attempt was made using Geological Survey of Canada rock standards U.M.2 and U.M.4 to obtain accuracy figures for the A.A.S. and Leco methodologies. Values obtained in the A.A.S. analyses of rock standards U.M.2 and U.M.4 appear with the published trace element values in Table 11. An acceptable degree of agreement between the values is apparent, however, in all cases the published values are somewhat higher than those obtained by the author. This discrepancy can be traced to the weak acid dissolution used by the author in the pre-treatment of the standard samples.

Statistics

It is in vogue to apply statistical manipulations to geoanalytical data to "better" define anomalous areas (Le Peltier, 1969). Levinson

Table 10.

ACCURACY AND PRECISION OF ATOMIC ABSORPTION ANALYSES
A RAW DATA - COMPARISON OF VALUES OBTAINED IN THIS STUDY AND BY ATLANTIC ANALYTICAL SERVICES LTD.

		AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*
	Sample	Cu	Cu	Pb	Pb	Zn	Zn	Co	Co	Ni	Ni	Mn	Mn	%Fe	%Fe
	1	8	8.0	5	4.0	12	21.0	5	5.0	5	20.0	170	152.5	0.70	0.57
	14	5	2.5	5	4.5	10	14.0	5	3.7	7	15.0	150	135.0	0.50	0.45
	50	12	17.5	5	6.0	15	20.5	5	8.8	5	12.5	215	225.0	1.10	1.00
**	59L	160	164.6	15	7.4	100	98.8	25	21.5	25	17.3	850	628.0	2.80	2.63
	63L	22	22.5	5	2.0	20	27.5	5	2.1	5	6.0	225	212.0	1.10	0.85
	65H	18	17.5	5	6.0	13	17.0	5	4.5	5	6.0	140	140.0	0.90	0.80
	65L	25	30.0	5	9.5	20	30.0	5	5.0	10	6.0	230	250.0	2.00	1.80
	66L	8	8.0	5	8.5	10	17.0	5	3.5	5	4.0	135	125.0	0.65	0.50
**	67	15	16.5	5	6.9	25	37.0	5	4.1	5	11.1	190	189.0	0.90	0.75
†	6203	7	-	25	-	90	-	15	-	30	-	295	-	1.20	-
	70A	165	151.0	175	175.0	340	202.0	40	30.0	15	66.5	590	575.0	7.50	5.60
	70B	60	62.5	65	62.5	200	187.0	30	26.5	15	19.0	560	540.0	3.30	3.80
	70C	15	15.0	15	19.0	48	62.5	12	8.8	10	12.5	330	300.0	1.30	1.00
	87	27	30.0	5	3.0	10	19.0	18	19.0	5	10.0	460	500.0	0.60	0.56
	89L	15	15.0	5	3.0	18	28.0	5	7.5	5	6.0	190	180.0	0.86	0.86
	91B-H	42	48.0	10	8.0	20	26.5	10	6.4	10	15.0	230	240.0	1.80	1.30
	91B-L	20	22.5	10	7.0	25	28.5	10	6.5	10	26.0	350	310.0	3.30	3.00
	92B-A	380	300.0	20	19.0	50	50.0	15	10.5	15	14.5	595	550.0	10.00	10.00
	92B-B	50	54.0	30	37.0	35	80.0	10	7.5	15	12.5	440	332.5	4.70	4.50
†	6204	7	-	15	-	390	-	12	-	20	-	185	-	1.10	-
	92B-C	42	52.5	25	23.5	25	31.5	12	7.5	15	15.0	330	275.0	3.00	3.40
	92B-D	37	37.5	10	6.5	18	24.0	15	12.5	5	10.0	285	260.0	1.30	1.10
	92B-E	35	40.0	5	6.5	18	24.5	10	2.5	5	15.5	255	135.0	1.20	1.10

Table 10. Concluded

ACCURACY AND PRECISION OF ATOMIC ABSORPTION ANALYSES

A RAW DATA - COMPARISON OF VALUES OBTAINED IN THIS STUDY AND BY ATLANTIC ANALYTICAL SERVICES LTD.

	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*	AT.A.	*
Sample	Cu	Cu	Pb	Pb	Zn	Zn	Co	Co	Ni	Ni	Mn	Mn	%Fe	%Fe
93H	8	7.5	5	7.0	16	23.5	5	2.5	5	30.0	150	135.0	0.80	0.60
93L	7	7.5	5	6.0	8	15.5	5	7.5	5	6.0	135	130.0	0.60	0.50
94L	22	24.0	10	16.0	20	25.0	5	7.5	5	20.0	220	240.0	1.00	0.90
95L	8	7.5	5	7.5	10	85.0	5	5.0	5	10.0	140	120.0	0.60	0.50
96L	42	37.5	10	9.5	48	90.0	18	18.5	10	15.0	800	725.0	1.70	2.20
97H	35	33.0	8	5.5	30	63.0	15	11.5	10	15.0	390	450.0	3.30	3.40
+ 6205	5	-	5	-	20	-	5	-	5	-	135	-	0.45	-
102-A	38	38.0	10	5.5	20	29.0	5	7	10	14.0	145	136.5	2.00	1.90
103	310	231.0	10	7.0	35	36.0	65	50.0	15	18.5	960	900.0	3.10	2.80
104	65	60.0	10	6.0	35	39.5	15	8	20	15.0	510	480.0	3.60	3.60

AT.A. - Atlantic Analytical Services Determinations

* - Thesis Determinations

\+ - Blanks run by AT.A.

** - Control Samples Analyzed 10 x

Table 11: ACCURACY OF CHEMICAL ANALYSES

		U.M.2**	$\overline{X}$*	U.M.4**	$\overline{X}$*	N.
ppm.	Cu	950	875	540	490	5
"	Pb	N.A.	-	N.A.	-	5
"	Zn	32	28	64	57	5
"	Co	120	105	70	54	5
"	Ni	3850	2700	2514	1500	5
"	Mn	619	575	1161	1088	5
%	Fe	10.06	10.00	9.94	9.50	5
%	S	0.94	0.98	0.44	0.46	3

$\overline{X}$* - mean of values obtained by the author

N. - number of analyses

** - published values in Faye (1972)

Table 12: PRECISION OF LECO SULPHUR ANALYSES

SAMPLE	$\bar{X}$ ppm.	S	E$\bar{X}$	N
*86	496.20	37.39	11.82	10
*59L	72.20	10.79	3.41	10
67	Trace	-	-	3
91BL	393.66	9.81	5.66	3
92L	2530.00	21.21	15.00	2
97H	197.50	3.54	2.50	2

X - mean

S - Standard Deviation

N - number of determinations

EX - Standard error of the mean

* - Control samples

(1974) points out that geochemical anomalies, and numerous mines, were found long before computers came into being, and since then as well by virtue of the proper interpretation of available geochemical data. Hawkes and Webb (1962) stress that statistical methods should be used solely as a disciplinary guide and never as a replacement for qualitative appraisal.

The Sheffield Lake Indian Pond geochemical data is presented, insofar as possible, as "real" data (Shilts, 1973) with a minimum of transformation by statistical manipulation.

Background is defined as the normal abundance of an element in barren earth material (Hawkes and Webb, 1962). Threshold is defined as the upper limit of normal background fluctuation or, statistically, as the mean plus twice the standard deviation. An anomaly is defined as a deviation from the norm of those values which lie beyond threshold on a frequency distribution curve of the data.

Each element has its own distinctive background, threshold, and possibly anomalous values. In the Sheffield Lake - Indian Pond area two till units are present. Samples from each unit will have separate background, threshold, and anomalous values for each element (see below):

Ground Surface

"C" zone Grey Till (e.g., Zn Threshold 400 ppm)

Red Till (e.g., Zn Threshold 1,300 ppm)

Bedrock

Page 107 was not in the original scans

Elemental Geochemistry and Results

Krauskopf (1967) points out that the process of chemical weathering of sulphides 1) gets the metal ions into solution or into stable insoluble compounds, 2) produces relatively acid solutions, and 3) converts sulphides to sulphates.

Optimum conditions for sulphide dissolution naturally occur above the zone of permanent saturation (the water table), however, descending oxygenated waters can extend oxidation to depths far below the phreatic surface (Hawkes and Webb, 1962). Gravenor and Stupavsky (1974) state that oxidation in tills can be found at depths of three metres or more.

In polymetallic sulphide orebodies the oxidation of one mineral is often favoured over that of others in sulphide aggregates. Thus, in a deposit consisting of chalcopyrite and pyrite, the chalcopyrite is oxidized preferentially to the pyrite (Hawkes and Webb, 1962).

In the final stages of chemical weathering of sulphides, the suboutcropping ore has become desulphurized and disburdened of most heavy metals (Kreiter, 1968), leaving only those sedentary compounds derived from the weathering of the silicate gangue.

Regardless of the order in which sulphides oxidize, they usually go through a sulphate stage (Kreiter, 1968). Most metal sulphates dissolve readily in water. The greater the acidity of the groundwater, the stronger is its leaching action, and the more saturated it becomes with soluble sulphates. As a result, many elements are "washed out" of the primary, suboutcropping sulphides with a marked tendency toward dispersion governed only by the migration propensities of the element involved.

Nickel (Ni)

General Occurrence

Nickel is a SIDEROPHILE (to a lesser degree chalcophile) element usually associated in sulphide deposits with Copper, Cobalt and Platinum (Hawkes and Webb, 1962). It occurs, primarily as Pentlandite - NiS (to a lesser extent as Millerite - NiS and Niccolite NiAs) which is labile in oxidizing conditions and quickly alters to nickel sulphate.

Nickel is a less mobile element than Cobalt but is more so than Copper (Canney and Wing, 1966); however, its moderately high mobility (Hawkes and Webb, 1962) is often limited in the epigenetic environment because of its affinity for coprecipitation or sorption from solution by hydrous manganese and iron oxide precipitates and by clay minerals (Hawkes and Webb, 1962; Jenne, 1968; Boyle et al., 1965).

Nickel is a useful tracer element to the Drift Prospector primarily because of its high mobility. Due to this property a much larger Ni anomalous area can occur in till than that produced by the less mobile elements (i.e. Pb).

A standard method of Ni analysis by A.A.S. is available in the literature and Ni lends itself to dissolution in the hot, HNO_3 - HCl acid extraction previously outlined (Goudie, Personal Communication, 1974).

As a first approximation to the regional background of an element in the "C" zone of a podzol developed on glacial till, average data on the underlying bedrock of the study area can be utilized. As described in Chapter II the bedrock of the area of most intensive study within the Sheffield Lake - Indian Pond area consists dominantly of andesite (or dacite) with granitoid lithologies in the "up-ice" direction.

Results

Thurlow (1973) in a study of barren andesite sequences associated with the nearby Buchans orebodies (which have been described as being deposited in the same environment as the Sheffield Lake - Indian Pond andesites by Williams, 1967) reported Ni concentrations of 19 - 29 ppm. The analysis of two andesite samples from the study area (by the same partial extraction technique used for the till samples) yielded values of 30 ppm (outside the zone of maximum float accumulation) and 55 ppm (slightly "up-ice" from the main float zone) (Figure 2).

The "C" zone of the glacial till directly overlying these rocks would be expected to have a background value considerably lower than that of the bedrock (Ermengen, 1957; Mehrtens <u>et al</u>, 1973) unless sulphide mineralization, which included an appreciable amount of NiS, was in the suboutcropping bedrock.

The Lower Red till in the Sheffield Lake - Indian Pond area has a background ($\overline{X}$) value of 22 ppm Ni and a threshold ($\overline{X}$ + 2S) of 60 ppm. The lone anomalous value of 67 ppm. ($\overline{X}$ + 2S+) occurs in sample #70A - (Figure 30).

A second overlying till unit would be expected to show somewhat lower background values, (a dilution factor) even taking into account the migration propensity of Ni. In the Upper Grey till the background 20 ppm, is surprisingly close to that of the Lower Red till. This is probably a reflection of the mobility of Ni in the epigenetic

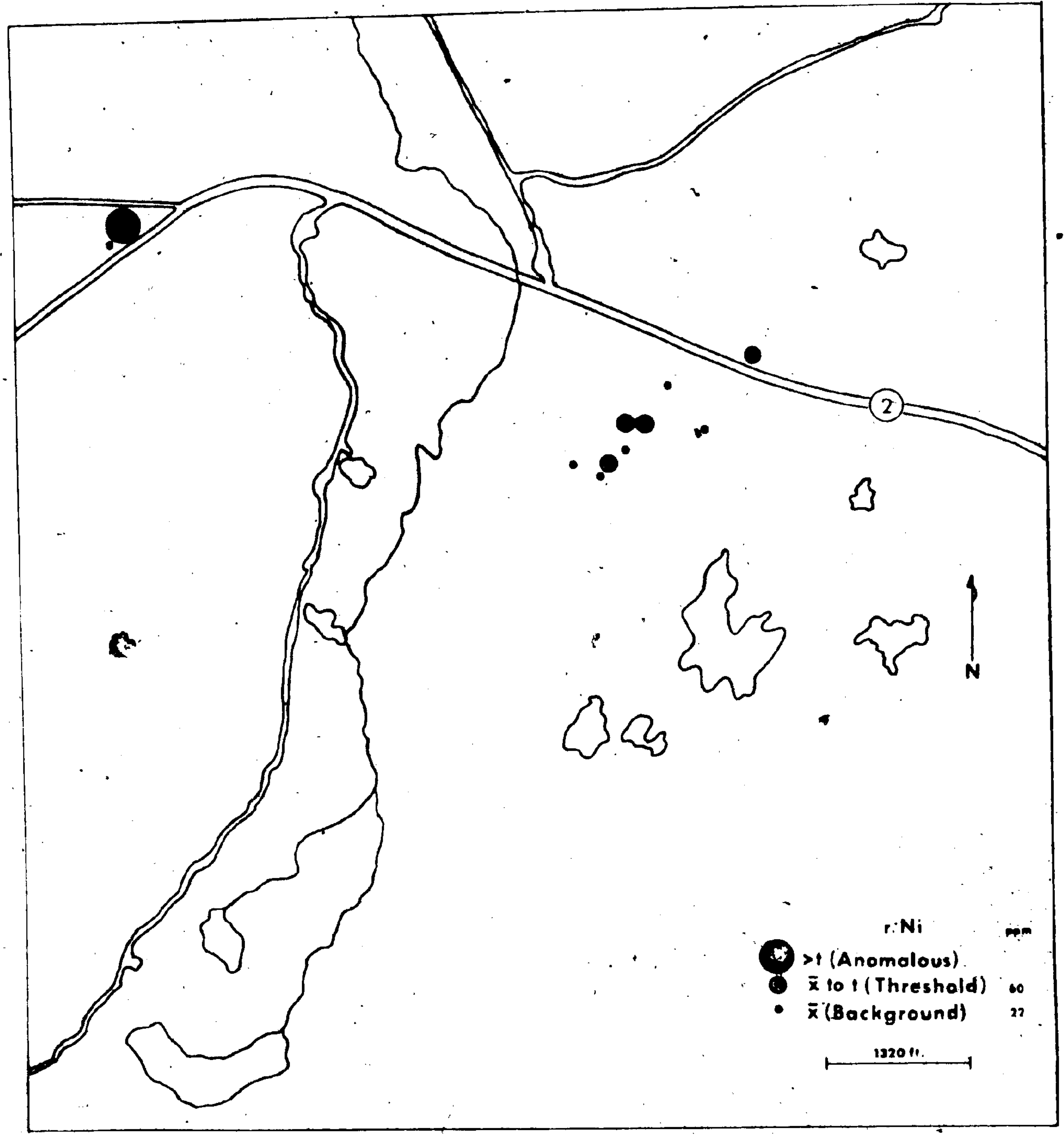


Figure 30 - Distribution of Ni in Lower Red Till

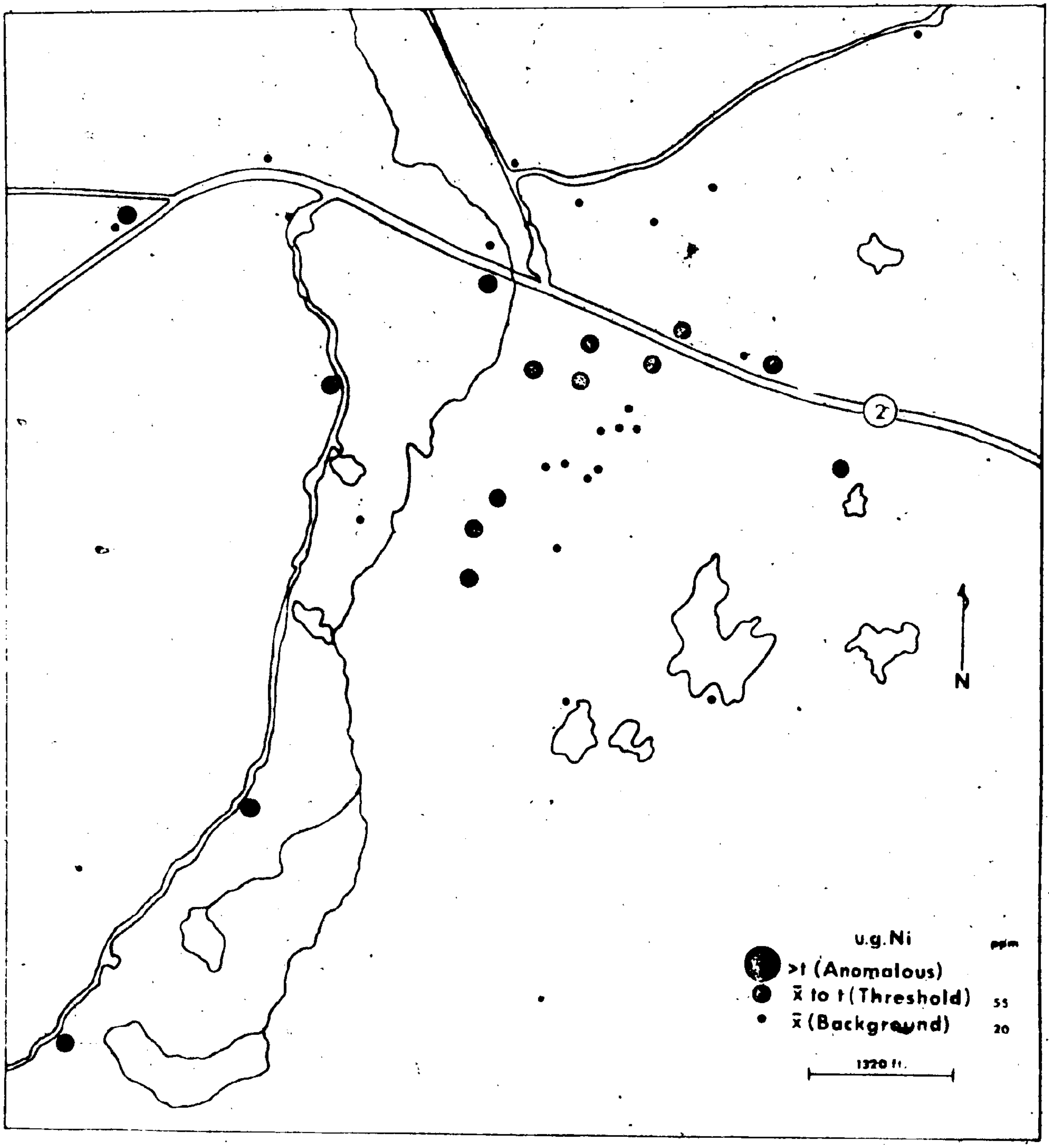


Figure 31 - Distribution of Ni in Upper Grey Till

environment. The threshold is 55 ppm. Two anomalous values of 68 and 63 ppm. occur to the east of the zone of main float occurrence (Figure 31).

In the study area then, Ni, which should be in anomalous quantities in the main float zone and, therefore, be a good tracer element and help delimit the float source, does not do so. It must be assumed, therefore, that the source sulphide mineralization is deficient in this element.

Cobalt (Co)

General Occurrence

Cobalt is a Siderophile (to a lesser degree chalcophile) element usually associated in sulphide deposits with iron, copper, nickel, arsenic, and silver. It occurs primarily as cobaltite - CoAsS or smaltite - $CoAs_{3-x}$, both of which are labile in an oxidizing environment and soon alter to cabalt sulphate in the secondary environment (Kreiter, 1968).

Cobalt is considerably more mobile than copper or nickel (Canney and Wing, 1966); however, its relatively high mobility is often limited in the epigenetic environment by the presence of arsenic which retards its migrdtion by fixing cobalt sulphate in the mineral erythrite - ($Co_3(AsO_4)_2.8H_2O$)(Kreiter, 1968).

The elemental distribution and concentration of Co in till is also restricted by co-precipitation or adsorption in the secondary Fe or Mn products of weathering and also by clay minerals (Hawkes & Webb, 1962; Jenne, 1966; Govett, 1973; Govett <u>et al.</u>, 1974; Levinson, 1974).

Cobalt is ubiquitous as a trace element in sulphide deposits and is, therefore, a useful indicator element to the Drift Prospector. A standard method of Co analysis by A.A.S. is available in the literature, however, Co is not readily attacked by dilute acids particularly dilute HNO_3. Foster (1971) points out that Co is attacked more vigorously by HCl than by HNO_3 particularly if the acid is heated. The boiling HNO_3 - HCl acid extraction, utilized, although not the optimum medium for Co dissolution was considered sufficient for the purpose of this study.

Results

The average concentration of Co in andesites similar to those in the Sheffield Lake - Indian Pond area (Thurlow, 1973) is in the range of 21 to 30 ppm. In the 2 analyzed samples of bedrock andesite from the Sheffield Lake - Indian Pond area Co values were 47 and 29 ppm. A somewhat lower background value than this would be expected in overlying glacial sediments unless bedrock sulphide mineralization containing Co occurs in the vicinity.

The Lower Red till in the study area has a background ($\overline{X}$) value of 21 ppm. Co and threshold ($\overline{X}$ + 2S) value of 64 ppm. The lone anomalous value ($\overline{X}$ + 2S+) of 70 ppm. occurs in sample 97-Low (Figure 32).

Background ($\overline{X}$) is only 6 ppm. Co in the Upper Grey till, which probably reflects the scavenging of Co by limonite and clay minerals in the Red till, thus restricting its dispersion into the overlying unit. The threshold ($\overline{X}$ + 2S) value is 20 ppm. Three anomalous values do occur in the Grey till at sample sites 69, 87 and 103, all of which are in the main float occurrence area (Figure 33).

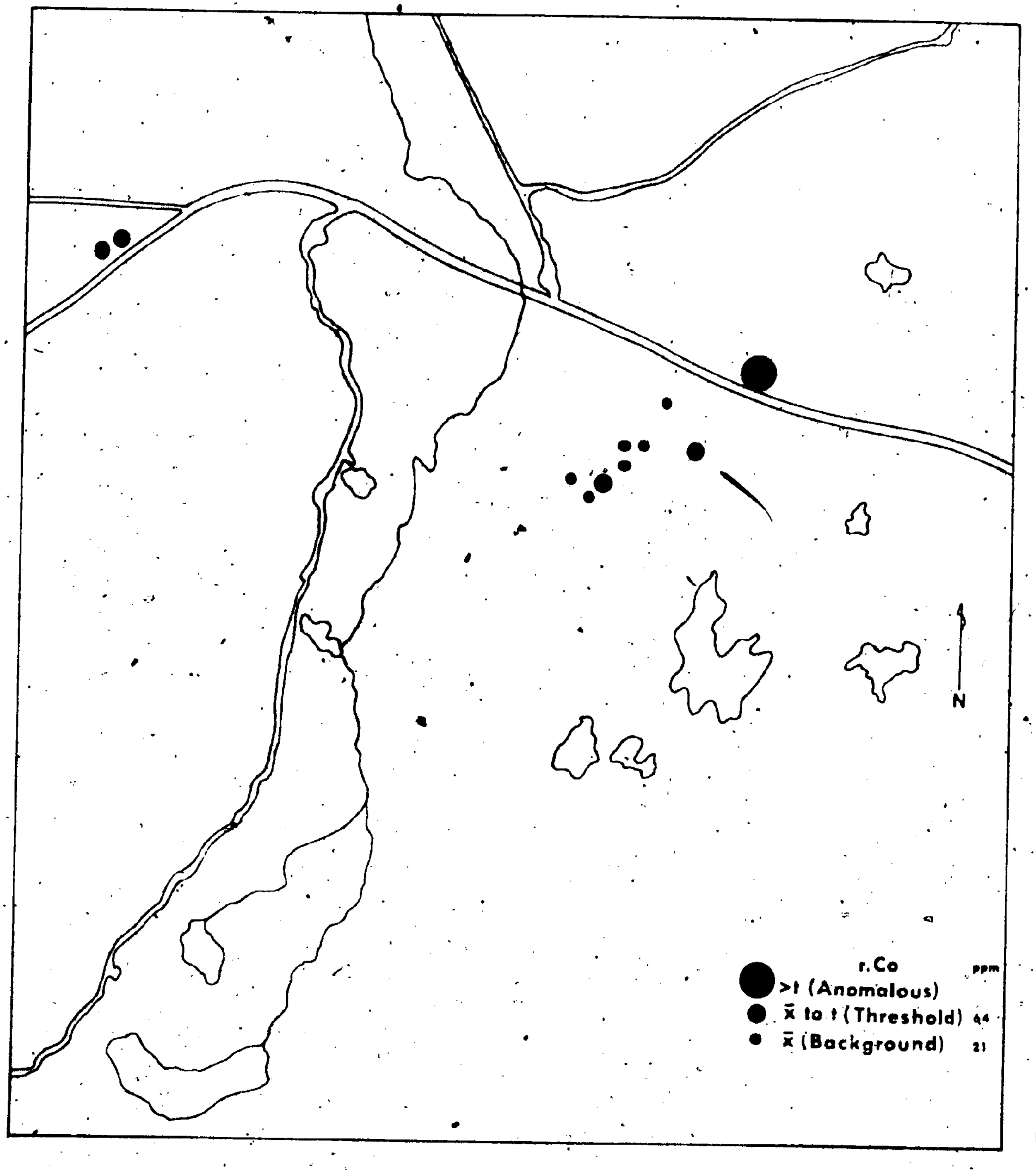


Figure 32 - Distribution of Co in Lower Red Till

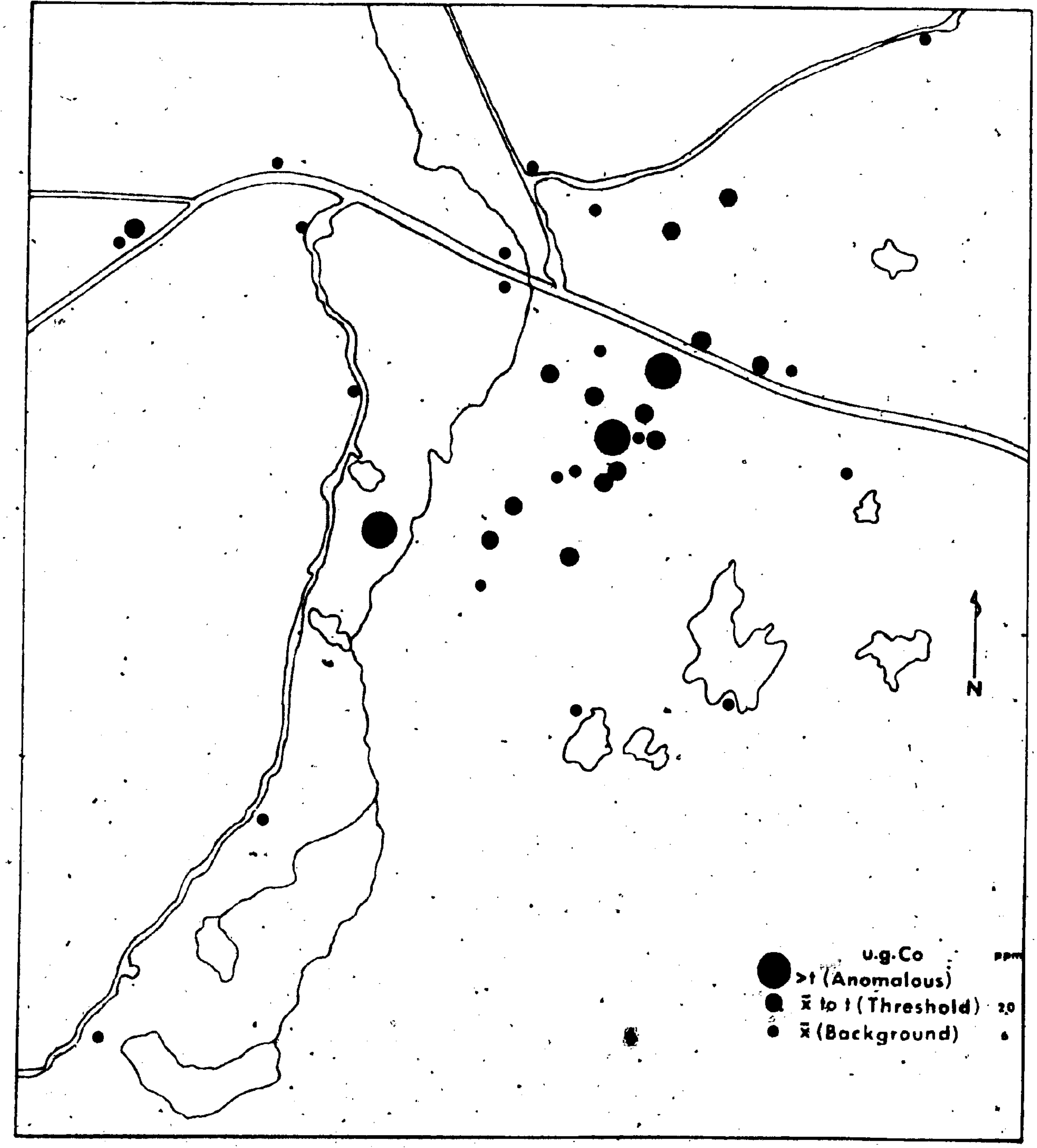


Figure 33 - Distribution of Co in Upper Grey Till

Cobalt, then, probably is a very worthwhile tracer element in the Sheffield Lake - Indian Pond area since it outlines the main float area. Its use is hindered somewhat by low background contrast due to its affinity for limonite sorption and possibly to some extent, by the acid dissolution used in the study.

Copper, Lead, and Zinc

General Occurrence

The "old standbys" of exploration geochemists the world over are of primary importance to this study since all three elements have been reported as occurring in the float, but only Cu is present in economic quantities (up to 8.2%, Malmquist, 1961).

Copper, lead and zinc are Chalcophile elements, usually associated with each other in sulphide deposits and variously with Mo, Ag, Au, Co, Ni, Fe, Mn and As. (Hawkes and Webb, 1962). Chalcopyrite - $CuFeS_2$ and bornite - Cu_5FeS_4 are the ore minerals most often mined for copper although their oxidized equivalents, malachite $Cu_2(Co_3)(OH)_2$, cuprite Cu_2O_7), etc., are locally important. The two primary ores of copper have been reported in the Sheffield Lake - Indian Pond float (Malmquist, 1961). Both minerals are labile in oxidizing conditions and quickly are weathered to sulphate or carbonate.

Galena - PbS, is the most important ore mineral of lead. In oxidizing conditions galena is weathered to relatively insoluble anglesite - $PbSO_4$.

The most important ore mineral of zinc is sphalerite - ZnS, a labile mineral. It quickly alters under oxidizing conditions, first to the sulphate phase, possibly due to bacterial action (Starkey, 1966) and then to simthsonite - $ZnCO_3$, which is often visually mistaken for limonite.

The three elements have widely varying migration propensities. Zinc, the most mobile, has amphoteric properties (Ermangen, 1957; Hawkes and Webb, 1962; Riddell, 1967; Garrett, 1969). However, the high mobility of Zn, is restricted by adsorption on iron and manganese hydrated oxides (Hawkes and Webb, 1962; Boyle et al, 1966; Krauskopf, 1967; Shilts, 1971; Govett et al, 1974); by chelation with organics, and because Zn is preferentially sorbed into lattice positions by clay minerals (Hawkes and Webb, 1962; Shilts, 1971).

Although the mobilities of Zn, Co, and Ni, are somewhat greater than that of Cu (Ermangen, 1957; Hawkes and Webb, 1962; Canney and Wing, 1966; Levinson, 1974) the latter is still considered to be a relatively highly mobile element in acid environments (Kreiter, 1968; Morrissey and Romer, 1973), especially below pH 5.5 (Hawkes and Webb, 1962). The mobility of Cu, however, like Zn, is restricted in the epigenetic environment, by chelation with organics (Horsnail and Elliott, 1971), sorption with clay minerals (Hawkes and Webb, 1962) and coprecipitation, occlusion and absorption with Mn and Fe hydroxide precipitates (Hawkes and Webb, 1962; Canney and Wing, 1966; Jenne, 1966; Horsnail and Elliott, 1971; Shilts, 1973).

The least mobile of the three elements in the epigenetic environment is lead. The sulphide form, galena, is relatively unstable and weathers easily to the sulphate form which is insoluable in water (Hyvarinen, 1967, Riddell, 1967; Keller, 1968; Kreiter, 1968; Mehrtens *et al*, 1973). As well as its demonstrated insolubility and, therefore, low mobility, its dispersion is even further restricted by the same scavengers that affect Zn and Cu–organics, clays and limonite (Hawkes and Webb, 1962). For these reasons then, Pb is often relatively enriched in the epigenetic till environment near its suboutcropping bedrock source, as a result of the leaching of the more mobile constituents of the deposit.

Copper, lead and zinc are useful tracer elements to the Drift Prospector primarily because of their varying mobilities and their economic potential. Zinc, the most mobile, can indicate anomalous areas at the reconnaissance level of exploration. Copper, being less mobile, is important in the follow-up phase in that its anomalous area is smaller in area, and lead, the least mobile, is generally effective in delimiting the source area in the detailed phase of the study, since its anomalous concentrations are only located close to bedrock mineralization.

Standard methods of Cu, Pb and Zn analysis by A.A.S. which are capable of high precision and accuracy with a minimum of expense and time per analysis are available in the literature. Copper, zinc and lead are easily dissolved in the hot HNO$_3$-HCl acid extraction previously outlined (F. Goudie, Personal Communication, 1974).

Results

Bedrock background values for these elements in similar andesites (Thurlow, 1973) are: Cu=53-72 ppm., Pb=24-25 ppm. and Zn=83-91 ppm. The corresponding values from the two Sheffield Lake - Indian Pond andesite samples are Cu=15 and 120, Pb=3 and 6, and Zn=14 and 30 ppm.

L

The Pb background value in the Lower Red till samples is 25 ppm., well above the 3-6 ppm. in the bedrock samples from the vicinity. The threshold value is 120 ppm. One anomalous value of 175 ppm. occurs at sample site 70A (Figure 34).

Zinc in the Lower Red till has a background value of 63 ppm., also well above the 14-30 ppm. occuring in the andesite bedrock. The threshold value is 168 ppm. Again sample 70A has the lone anomalous value (200 ppm.).

Copper has a background value of 92 ppm. and a threshold value of 254 ppm. The anomalous value of 281 ppm. occurs in sample 92B (Figure 36).

Dreimanis (1960) has stated that a 200 ppm. value for Cu in till reflects a 2% concentration of that element in its bedrock source. These results, therefore, suggest the abundance of Cu in the bedrock of the vicinity. It must be considered then that sample site 92B is close to but probably still some distance "down-ice" from the bedrock source of the Cu-rich float boulders.

Both Pb and Zn are enriched in sample 70A which is some distance "down-ice" from the main float occurrence, however, as will be discussed in a later section, this anomaly is probably a spurious one, due to the high Mn concentration associated with it.

The Upper Grey till in the region has background values of 7 ppm. for Pb, 34 ppm. for Zn and 29 ppm. for Cu. The corresponding threshold values are 14 ppm., 83 ppm. and 93 ppm. (Figures 35,37,39).

Contamination from outside sources is often an important consideration in glacial drift studies, especially for Pb. Lead enrichment

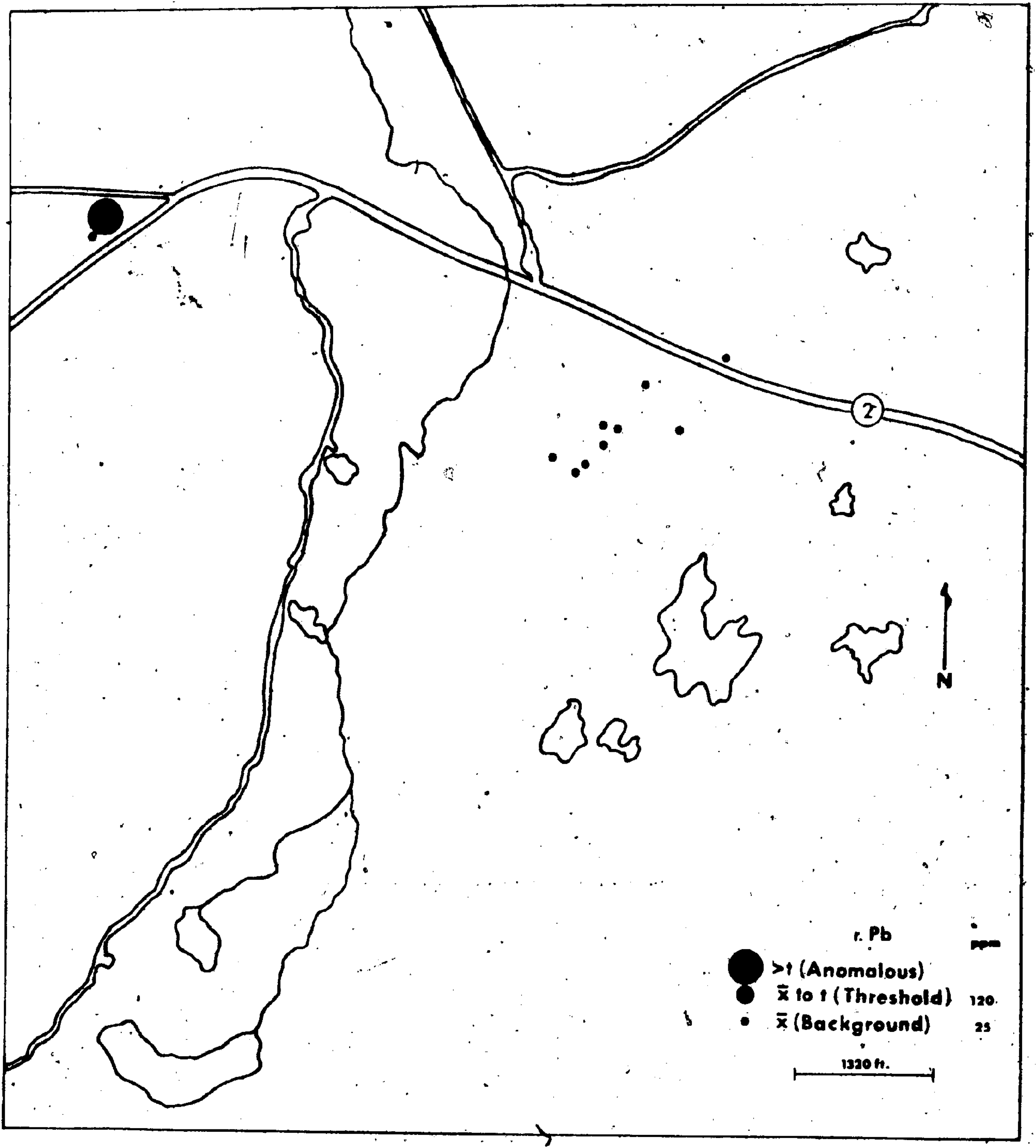


Figure 34 - Distribution of Pb in Lower Red till

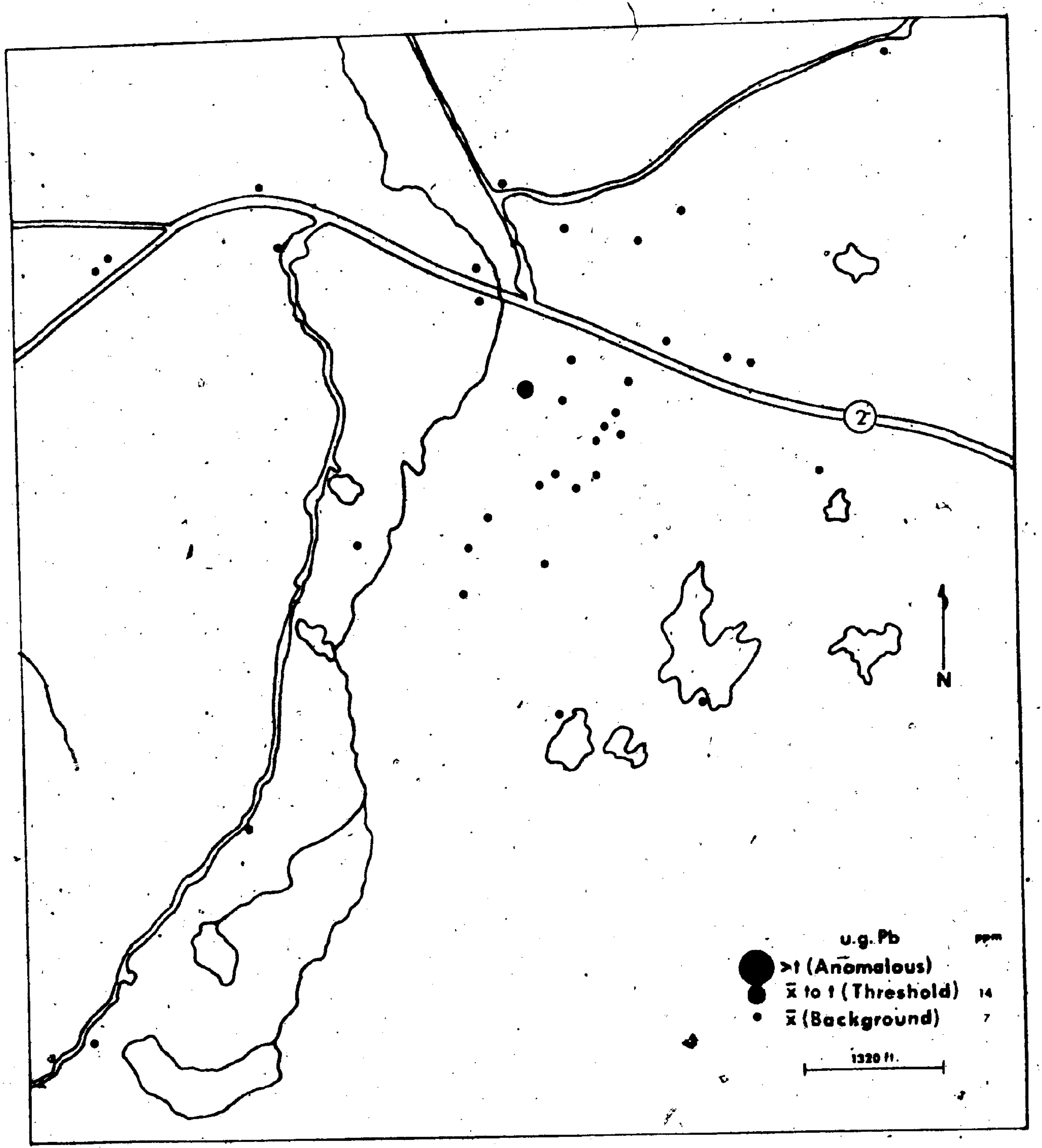


Figure 35 - Distribution of Pb in Upper Grey Till

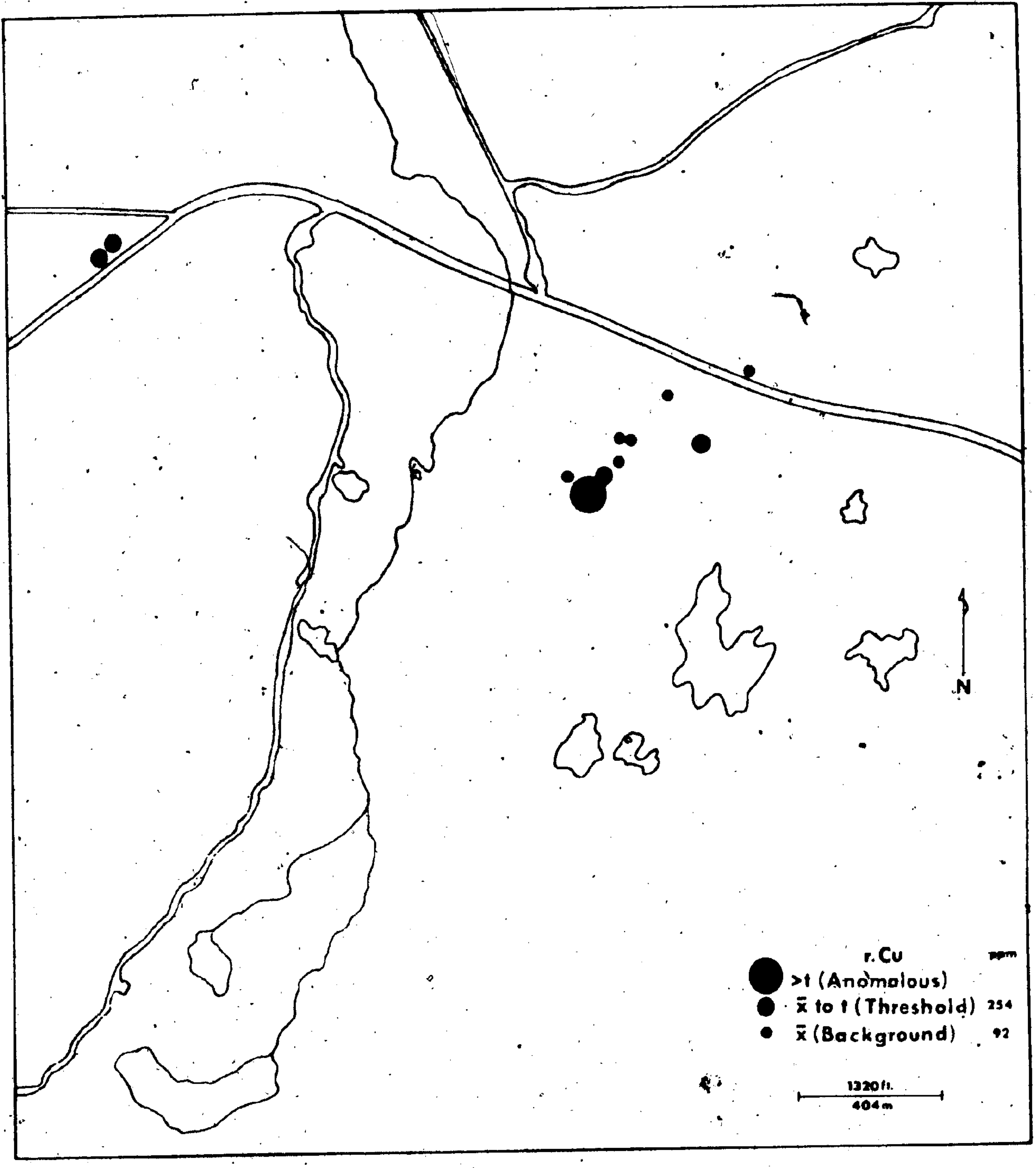


Figure 36 - Distribution of Cu in Lower Red Till

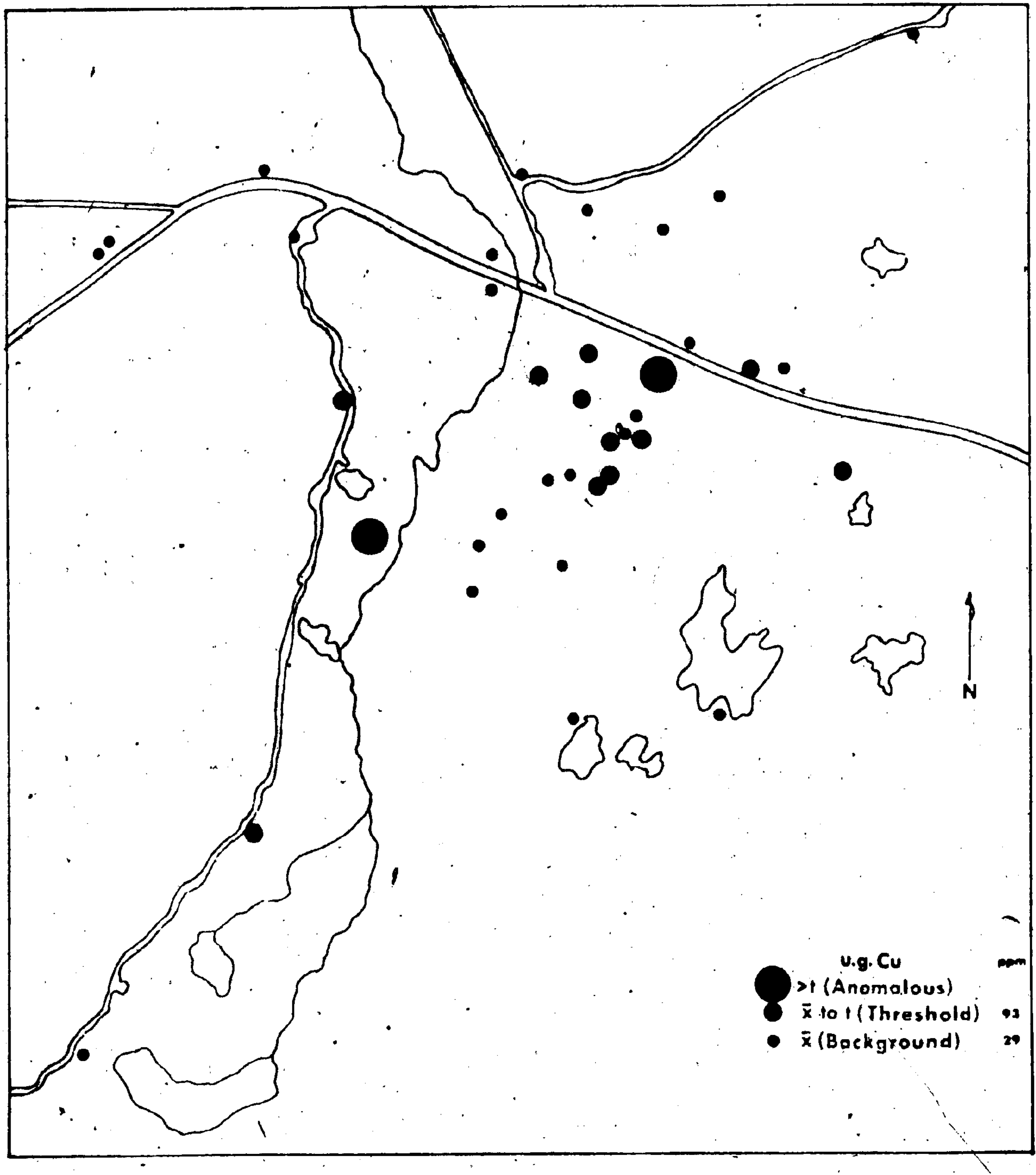


Figure 37 - Distribution of Cu in Upper Grey Till

can occur up to hundreds of feet from highways as a result of automobile exhaust and the Pb content of fuels (Levinson, 1974). As mentioned, in the introduction, the study area is bisected by the old trans-Newfoundland highway (#2) - the only road across the province until 1967, and so Pb contamination must be considered as possible in the samples collected in the area.

Lead contamination, if present in the area, would be expected to give erratically high Pb values in the Upper Grey till. Apparently, such contamination has had little or no effect here, probably because the samples were taken from the "C" horizon in the till, below the zone where downward percolating meteroric water has had any effect on the Pb concentration.

Values slightly above Pb threshold occur at 7 locations in the study area, however, none of these seem to define any one anomalous area, and therefore they must be considered as insignificant erratic highs (possibly due to contamination).

Anomalous Zn concentrations occur in 5 samples from the Upper Grey till, 3 of which (#96H, 89H and 69) are in the main float area (Figure 39). The smearing, masking, and dilution effect of the second ice advance in the region is here again demonstrated due to their relatively low concentrations.

Three samples from the Upper Grey Till have anomalous Cu values. Number 26 (200 ppm.) is located to the north east of the main float occurrence. Other samples in this area have relatively high C[illegible]lues so this area bears further investigation. This is particularly true in light of Dreimanis (1960) conclusion concerning Cu values in till,

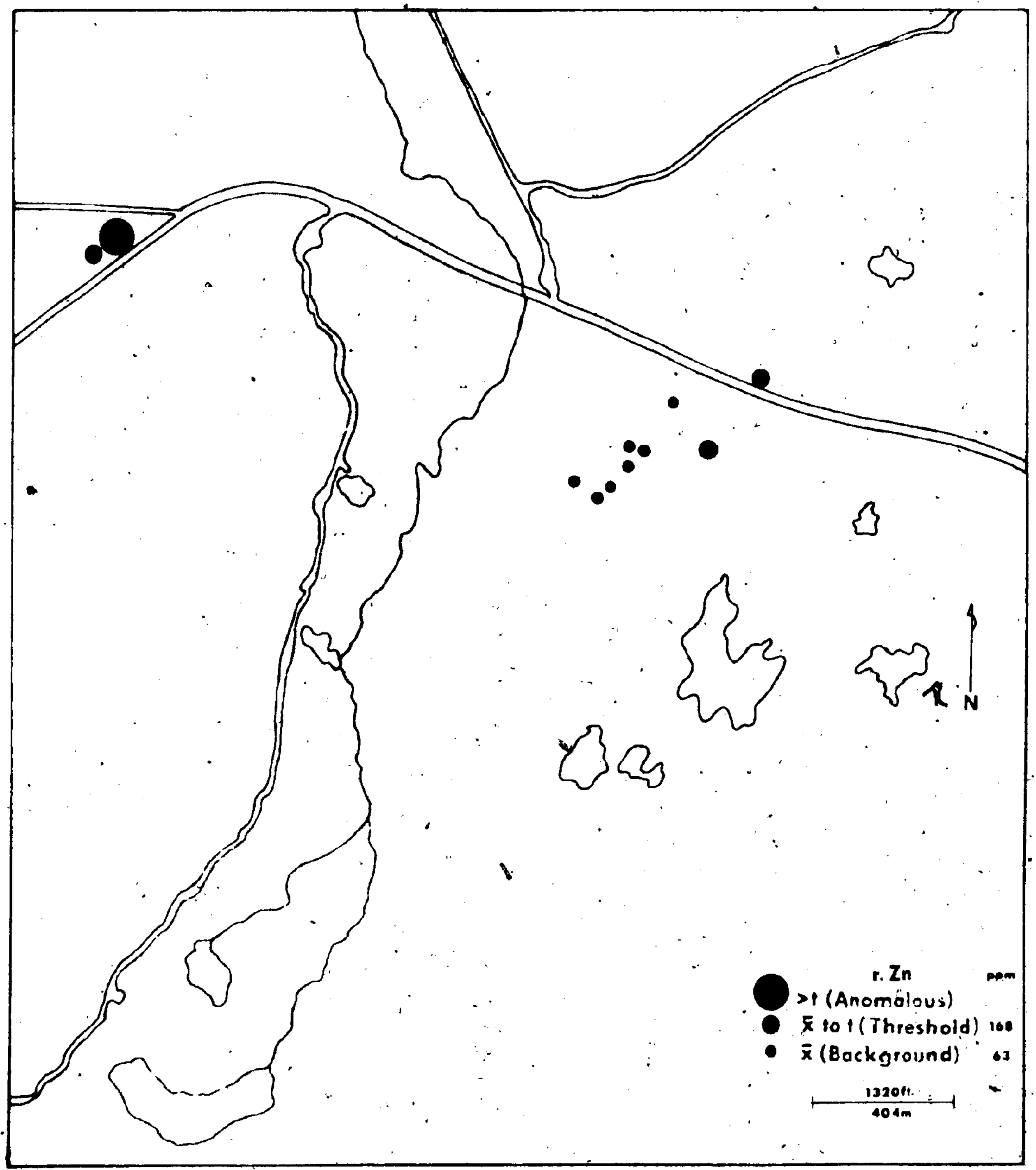


Figure 38 - Distribution of Zn in Lower Red Till

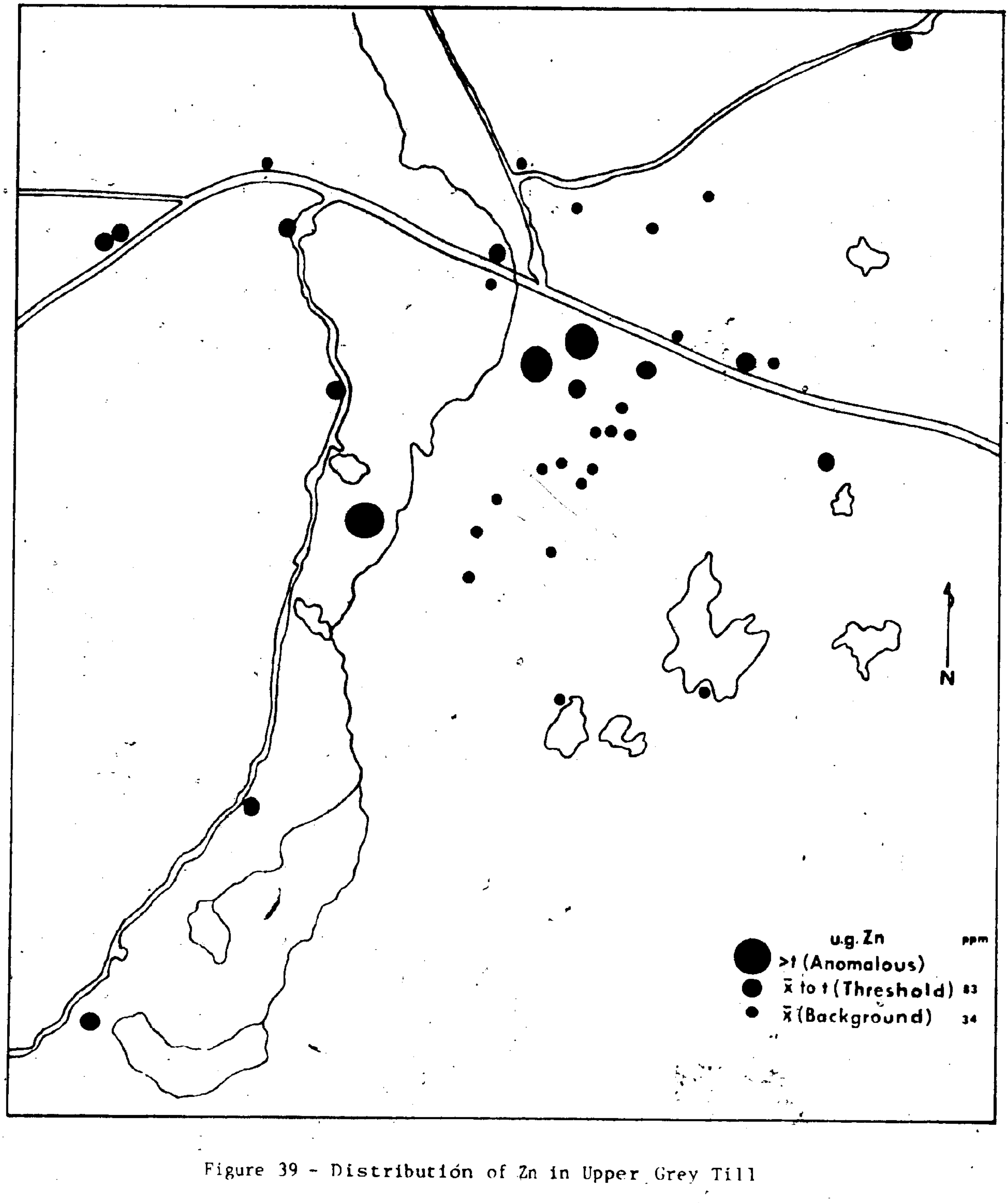


Figure 39 - Distribution of Zn in Upper Grey Till

mentioned previously. Numbers 69 and 103 are also anomalous in Cu (98 and 231 ppm respectively). Both are in the main area of float occurrence. Number 103, because of its high value and proximity to red till outcrop, (50 feet to the East) must be considered to represent reworked Lower Red till material. Number 69 is well "up-ice" from 103 and possibly its high value can be more easily linked to a proximal bedrock source.

The Cu and Zn values in the Upper Grey till and Lower Red till then, generally outline the main float occurrence area. Lead values are, however, erratic in the grey till and might be traced to contamination.

From the above results, it is suggested that overburden drilling in the vicinity of #26 and "up-ice" from 92B (near #69) would be an obvious next step to delimit the float source. (Figure 12).

Manganese (Mn)

General Occurrence

Hydrous oxides of Mn and Fe are nearly ubiquitous in glacial sediments, both as partial coatings on other minerals and as discrete oxide particles. Some 36 oxidic manganese minerals are recognized as opposed to only about a half dozen iron oxides. Dominant among the concretionary Mn minerals in unconsolidated sediments are lithiophorite, birnessite and hollandite (Jenne 1968). Other Mn minerals of importance include pyrolusite - MnO_2, braunite - $(Mn, Si)_2O_3$, psilomelane - $(Ba,H_2O)_2 Mn_5O_{10}$ and rhodocrosite - $MnCO_3$.

Manganese is a lithophile element which is often associated with massive sulphide deposits (usually in pyrite and sphalerite) (Boyle et al, 1966). It is readily oxidized even under only slightly oxidizing conditions (i.e. below the water table) (Hawkes and Webb, 1962) to dioxide or hydroxide forms. However, the primary importance of Manganese hydroxides to the Drift Prospector is their great capacity for co-precipitating or scavenging cations of Co, Cu, Zn, Ni, Pb, Au, Ag, etc. from solution. (Hawkes and Webb, 1962; Boyle et al, 1965; Brotzen, 1967; Hornsnail and Elliott, 1971; Shilts, 1973; Govett, 1973; Meyer and Evans, 1973; Govett et al, 1974; and others.)

Manganese and iron oxides control the fixation of many elements in glacial till. Since they often occur as coatings on other minerals, they can exert chemical activity far out of proportion to their total concentrations (Jenne, 1968). Brotzen (1967) has pointed out the strong correlation between Mn and Fe concentration and that of heavy metals in unconsolidated sediments. Boyle et al (1968) reported similar results from a stream sediment survey in New Brunswick.

The presence of Mn compounds is considered significant in exploration - both as a pathfinder element and as a means of enhancing minor metal anomalies (Govett et al, 1974). However, the scavenging ability of Mn compounds can produce spurious anomalies of other elements in glacial sediments (see discussion of sample #70A in the section on Mode of Occurrence.)

Manganese is readily attacked by the dilute acids used in the pre-treatment of samples in this study, and standard procedures of Atomic Absorption Spectrophotometric analysis are available in the literature.

Results

Unmineralized andesites associated with the Buchan's orebodies analyzed by Thurlow (1973) were found to contain approximately 1239 ppm. Mn after a strong acid digestion. The two andesite samples analyzed in the Sheffield Lake - Indian Pond area, by means of the partial extraction outlined formerly, yielded values of 163 and 680 ppm. Mn respectively. The higher of the two values was obtained from an andesite sample collected near the main float area.

The Lower Red till overlying these rocks would be expected to have background values lower than those of the andesite. The background value for Mn in the Lower Red till is 491 ppm. and the threshold value is 1338 ppm. Sample #97 low is anomalous (1700 ppm) (Figure 40).

In the Upper Grey till the background value is considerably lower than that of the red till (254 ppm), indicating the low mobility of Mn in the epigenetic environment. The threshold is 530 ppm. Samples #69 and #103 from the main float area have anomalous values of 625 and 900 ppm., respectively. Samples #12, situated near Sheffield Lake, and #48 and #49 straddling the trans-Newfoundland Highway a mile east of the main float zone, are also anomalous, with values of 800, 585 and 750 ppm., respectively.

It must be interpreted then, that the significance of Mn in the study area is twofold. First, Mn, as well as Fe Oxides which were always present in the samples (Table 14) are apparently capable of concentrating the other elements of interest. Second, because of the generally high concentrations it exhibits in the Lower Red till (Table 13) and in the Upper Grey till of the main float zone, Mn must be

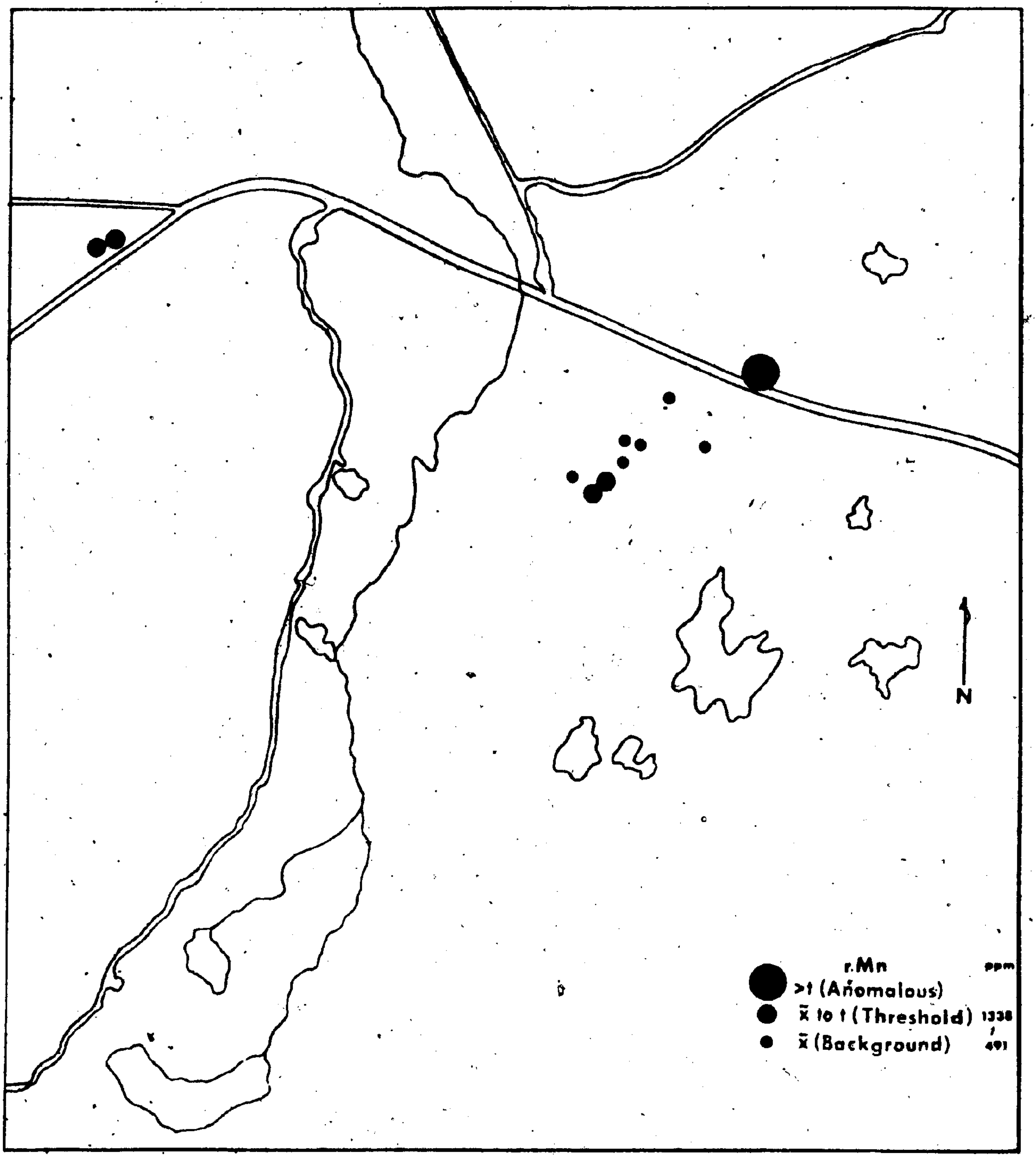


Figure 40 - Distribution of Mn in Lower Red Till

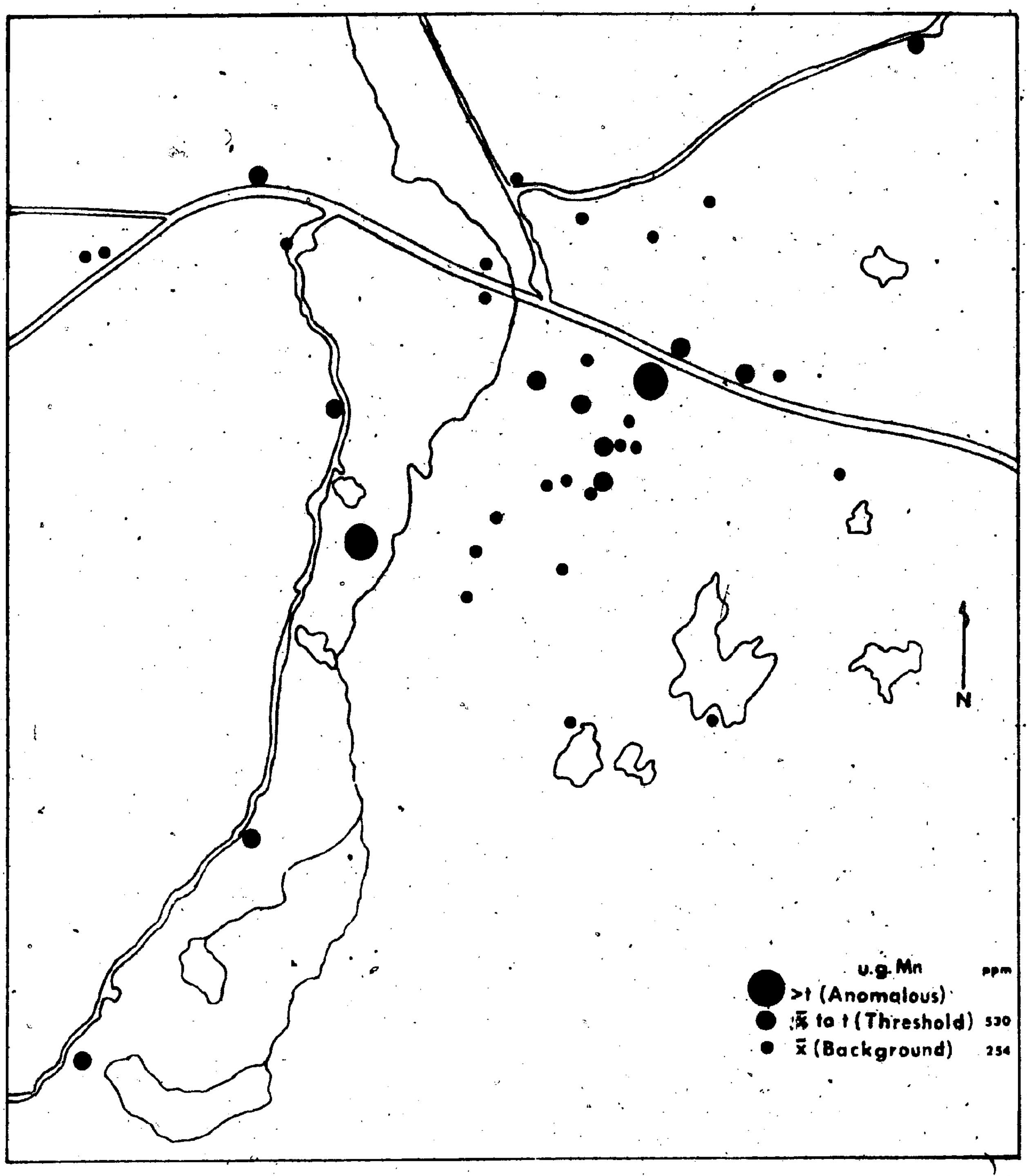


Figure 41 - Distribution of Mn in Upper Grey Till

considered a very important tracer element in the Sheffield Lake - Indian Pond area.

Iron (Fe)

General Occurrence

Iron is a siderophile element which usually occurs in sulphide deposits primarily as pyrite - FeS_2, marcasite - FeS_2 pyrrhotite - $Fe_{1-x}S$, and chalcopyrite - $CuFeS_2$, all of which are labile minerals. The oxidation of the polymorphous iron sulphides, pyrite and marcasite, produces an acid environment that promotes the migration not only of the iron, but of many associated elements as well (Kreiter, 1968; Hunt, 1972). The oxidation process also results in the production of elemental sulphur and in the formation of higher valency oxides or hydroxides (Hawkes and Webb, 1962; Hunt, 1972). Predominant among these secondary products of iron sulphide decomposition are hematite - Fe_2O_3, amorphous ferric iron - $Fe_3(OH)_3$, or, one or both of two $FeO(OH)$ polymorphs, goethite and lepidocrocite. The last three minerals, which are hydrated oxides, cannot be readily identified on sight and are therefore commonly labelled as limonite, a non-committal group name (Keller, 1968).

The hydrous iron and manganese oxides are of particular concern to the Drift Prospector because 1) they coprecipitate with a suite of other elements, 2) during and after precipitation they have an affinity for scavenging elemental cations with which they come in contact, 3) they limit the mobility of all other elements normally associated with sulphide deposits, even under the low pH conditions caused by Fe oxidation which otherwise would promote migration, 4) spurious anomalies can result from 1) through 3) above, (Hawkes and Webb, 1962; Canney and Wing, 1966; Jenne, 1968; Brotzen, 1967; Mehrtens et al, 1972; Govett, 1973; Nichol, 1973; Levinson, 1974).

Because hydrous Fe oxides in glacial sediments generally occur as coatings on silicate minerals, their scavenging propensity is increased far out of proportion to their concentration due to the expanded reactive surface attained.

Nevertheless, although the hydrous oxides must be used with caution by the Drift Prospector, they are important tracer elements for sulphide mineralization (Govett et al, 1974), and the bonus of their scavenging ability serves to enhance the generally low threshold contrast normally encountered in glacial till samples. In fact, Hawkes and Webb (1962) point out that,

> "most of the metal of clastic patterns, including anomalous metal, is contained in secondary minerals, principally in the clay minerals and hydrous oxides."

Jenne (1968) states that the principal control on the fixation of heavy metals in soils is the hydrous oxides of Mn and Fe, and that possibly the sorption of heavy metals by clays can be traced to limonite coatings on these minerals as well.

It is apparent then, that if a series of geochemical samples are to be taken in an area, they should include only one sorbent (organics, clays or oxides) (Shilts, 1971) and that sorbent should be the hydrous oxides of Mn and Fe which are ubiquitous in all soil horizons (except possibly, the leached A_e in a podzol) (Jenne, 1968). The organics are most easily avoided by sampling only "C" horizon material and organics and clays are readily removed by wet sieving the samples (Appendix C).

Iron exhibits low mobility in the epigenetic environment, due to its rapid precipitation as limonite and hematite. Even so, high Fe values (in the percent range) are to be expected in glacial till because virtually every rock type overidden and eroded by ice contains Fe as oxides, hydroxides, sulphides, silicates, etc. However, only near increased bedrock concentrations of one or more of the many Fe minerals (e.g. a sulphide deposit) should the values be appreciably higher than expected.

Limonitic precipitates and their adsorbed ions are easily digested in the dilute hot acid leach used for this investigation and a standard method of Fe analysis by A.A.S. is available in the literature.

Results

Andesites from the Buchans area contain 6.6 to 8.4% Fe (Thurlow, 1973). Comparable rocks from the Sheffield Lake - Indian Pond area (digested by weaker reagents) have indicated values of 4.8% in the main float area and 1.7% outside that zone (Table 1).

The Lower Red till overlying the main float zone andesite is enriched in Fe but has a slightly lower concentration than the bedrock. The background value is 4.65% and the threshold, 11.2%. An anomalous value of 12.1% occurs in sample 92L, a short distance "up-ice" from the main float occurrence (Figure 42).

The Upper Grey till would be expected to have much lower Fe concentrations than the Lower Red till because of the low mobility of Fe. A background value of 1.1% and a threshold of only 2.4% seems to

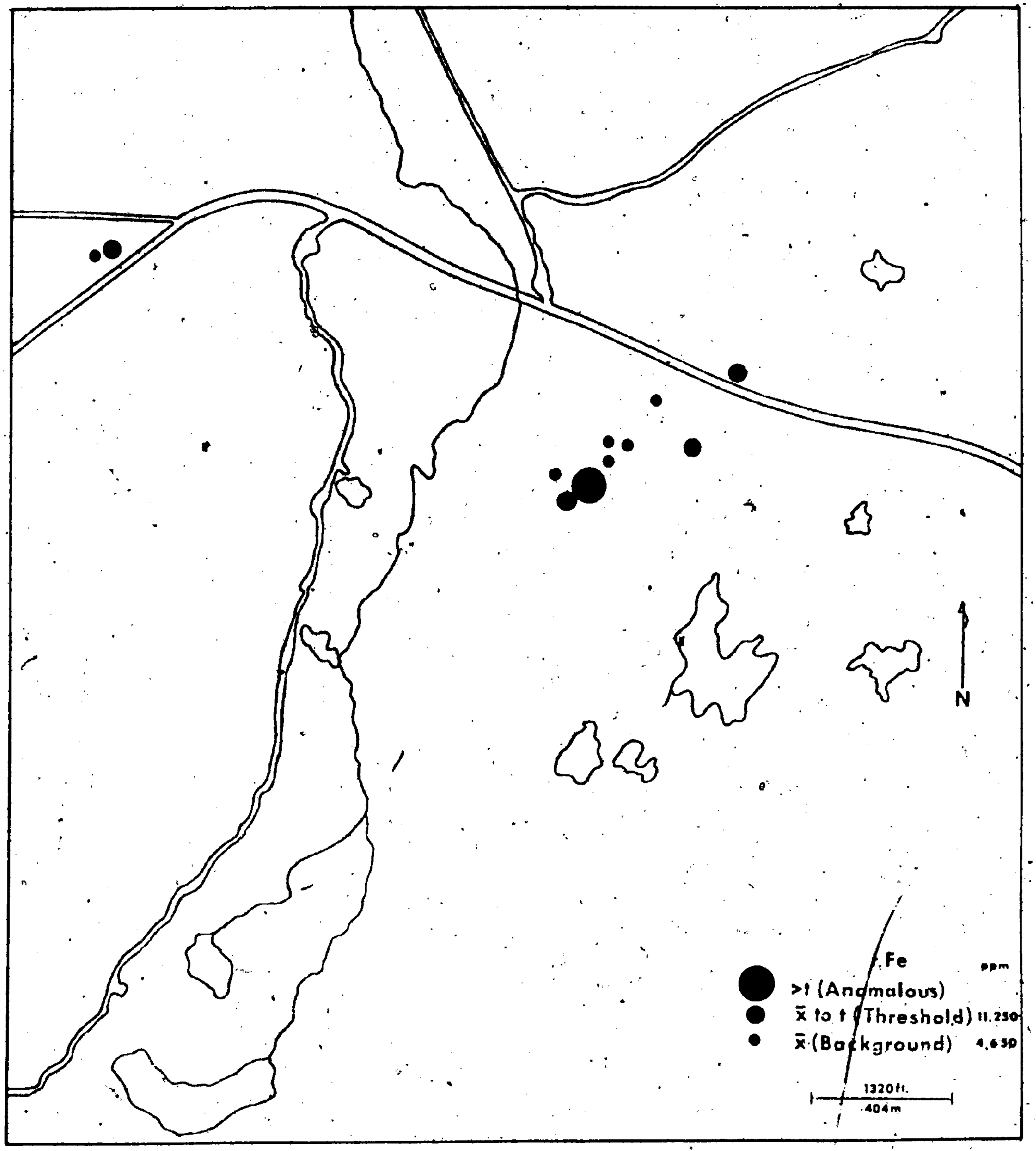


Figure 42 - Distribution of Fe in Lower Red Till

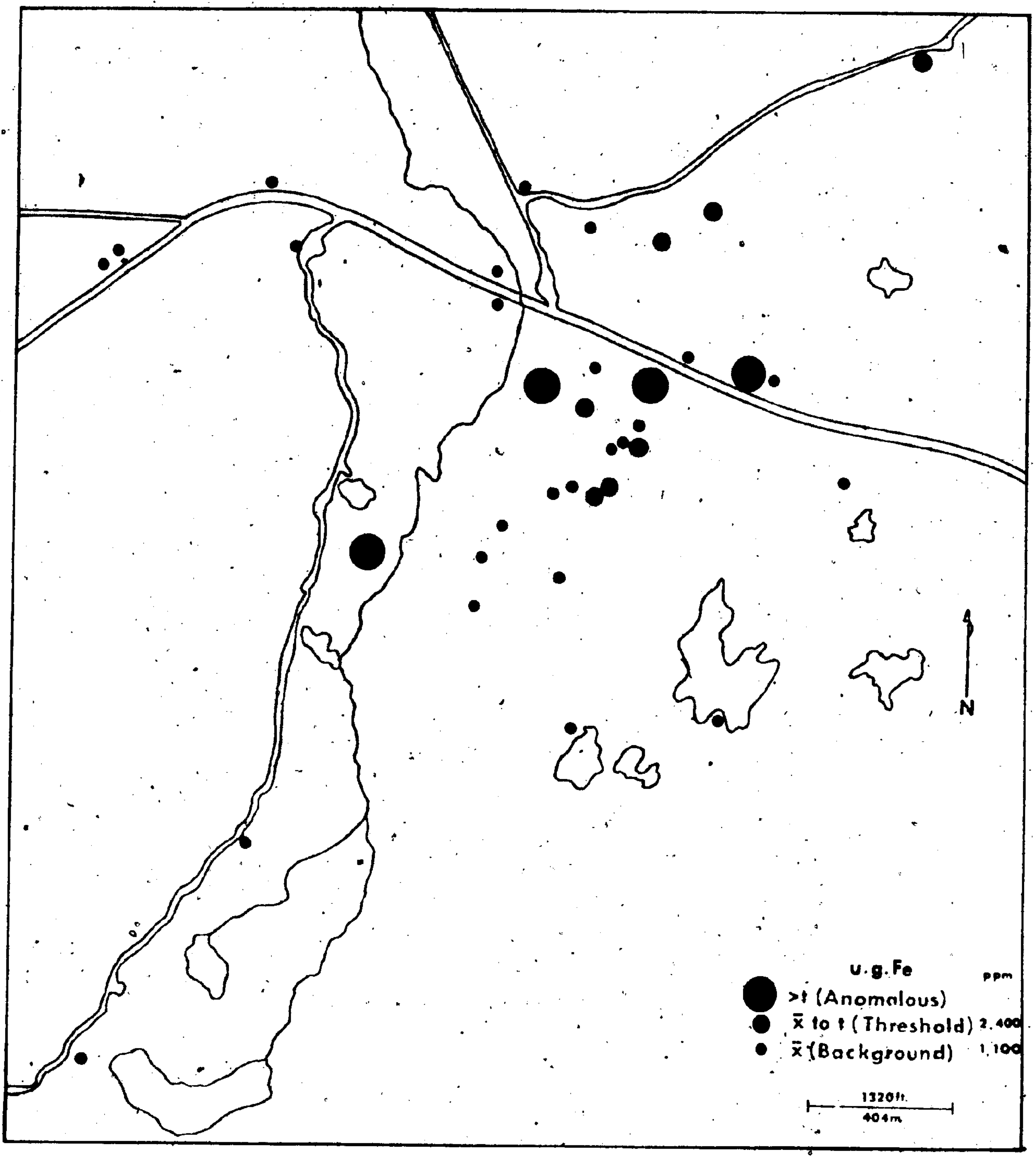


Figure 43 - Distribution of Fe in Upper Grey Till

bear out this dictum. Four anomalous value occur in the main float area (Figure 43). These anomalous values for samples #69, #96, #97 and #103, stretch along the dominant early ice flow direction, and outline the suboutcrop and outcrop of the Lower Red till amazingly well. Two other anomalous samples #75 and #100, occur to the east and north east of the main float area, respectively.

Iron, then, is a very worthwhile tracer element in the Sheffield Lake - Indian Pond area. The dominant metallic mineral in the float samples is pyrite (Table 1). Therefore, high iron concentrations would be expected in till overlying and "down-ice" from the suboutcropping bedrock source, since the main dispersion mechanism in the area seems to be mechanical rather than hydromorphic (see section on Mode of Occurrence).

Sulphur (S)

General Occurrence

> "Sulphur, although the one element common to all sulphide deposits, has been neglected in exploration geochemistry in favour of the more specific metals derived from the ore minerals forming the exploration target" (Meyer and Peters, 1973).

Sulphur is a chalcophile element, and occurs in Cu sulphide deposits primarily as pyrite - FeS_2, marcasite - FeS_2, pyrrhotite - $Fe_{1-x}S$, bornite - Cu_5FeS_4, chalcopyrite - $CuFeS_2$ and possibly in associated sphalerite - ZnS and galena - PbS (Hawkes and Webb, 1962).

The weathering of sulphides produces transient elemental sulphur which seldom persists in the epigenetic environment. Most of the inorganic sulphur in soils is in the sulphate form (Starkey, 1966;

Hunt, 1972). As oxidation of sulphides progresses the parent deposit is gradually desulphurized (Kreiter, 1968) and the sulphate thus produced is, in part, adsorbed by silt and clay particles and, more importantly by Mn and Fe hydrous oxides (Meyer and Peters, 1973). Another product of sulphide oxidation is sulphuric acid which drastically lowers the pH to 2.5 or less (Levinson, 1974) and thereby increases the mobility of all of the associated sulphide elements and sulphur (Krauskopf, 1967). The sulphate form exhibits extremely high mobility especially under low pH conditions and for this reason it is an important tracer element to the Drift Prospector.

It is a fairly obvious dictum that where metal sulphides occur in some quantity in bedrock, the overlying soil or till in the vicinity can be expected to contain anomalous quantities of a soluble, mobile element like sulphur.

In 1971 Brinex conducted a survey of the sulphur content of soils in their Newfoundland Halls Bay concession area (Peters, 1971). The samples were analyzed for Fe, Cu, and S. Where an anomalous value for S coincided with one for Cu then copper mineralization in the form of chalcopyrite was suspected. Conversely, when a S anomaly coincided with an Fe anomaly, then pyrite mineralization was suspected in the underlying bedrock. This hypothesis was tested in areas of known mineralization and a good degree of success was attained. However, several S anomalies were found to be unrelated to either Fe or Cu anomalies and their occurrences are inadequately explained by Peters (1971). Quite possibly they are due to the sampling method used, whereby organic rich humus was included in the samples. Since plants require sulphur in varying amounts as a nutrient they tend to concentrate it, thus more erratic concentrations would be expected in humus than in the "C" horizon, due solely to botanical differences.

Gunton and Nichol (1974), using the sulphur content of the -80, +230 mesh fraction of basal till, likewise had good success in outlining bedrock mineralization. They found that values in the range of 1.0% sulphur in the till were anomalous.

The use of sulphur as a pathfinder element in drift prospecting studies has been hindered by the lack of a quick, accurate, and reliable method of analysis. With the advent of the LECO SULPHUR ANALYZER in geochemical prospecting however, this obstacle has been largely removed (Foscolos and Barefoot, 1970; Peters, 1971; Hausen et al, 1972; Meyer and Peters, 1973) (Appendix C).

Results

The analyzed samples of andesite bedrock from the Sheffield Lake - Indian Pond area contains 0.34% and 14.5% S. The lower value represents the andesite sample collected outside the main float area. Three float boulders from the area contain between 23.6% and 39.1% sulphur (Table 1) and Malmquist (1961) reports the S content in one clast as 42.9%.

The overlying Lower Red till of the area has a background value of only 579 ppm S, but a much higher threshold value of 2110 ppm. Sample 92L is anomalous (2530 ppm). These relatively low values probably indicate the removal of the highly mobile sulphate ion by circulating acid groundwater with only a very small proportion of the S remaining adsorbed to limonite, or occuring in discrete sulphide grains.

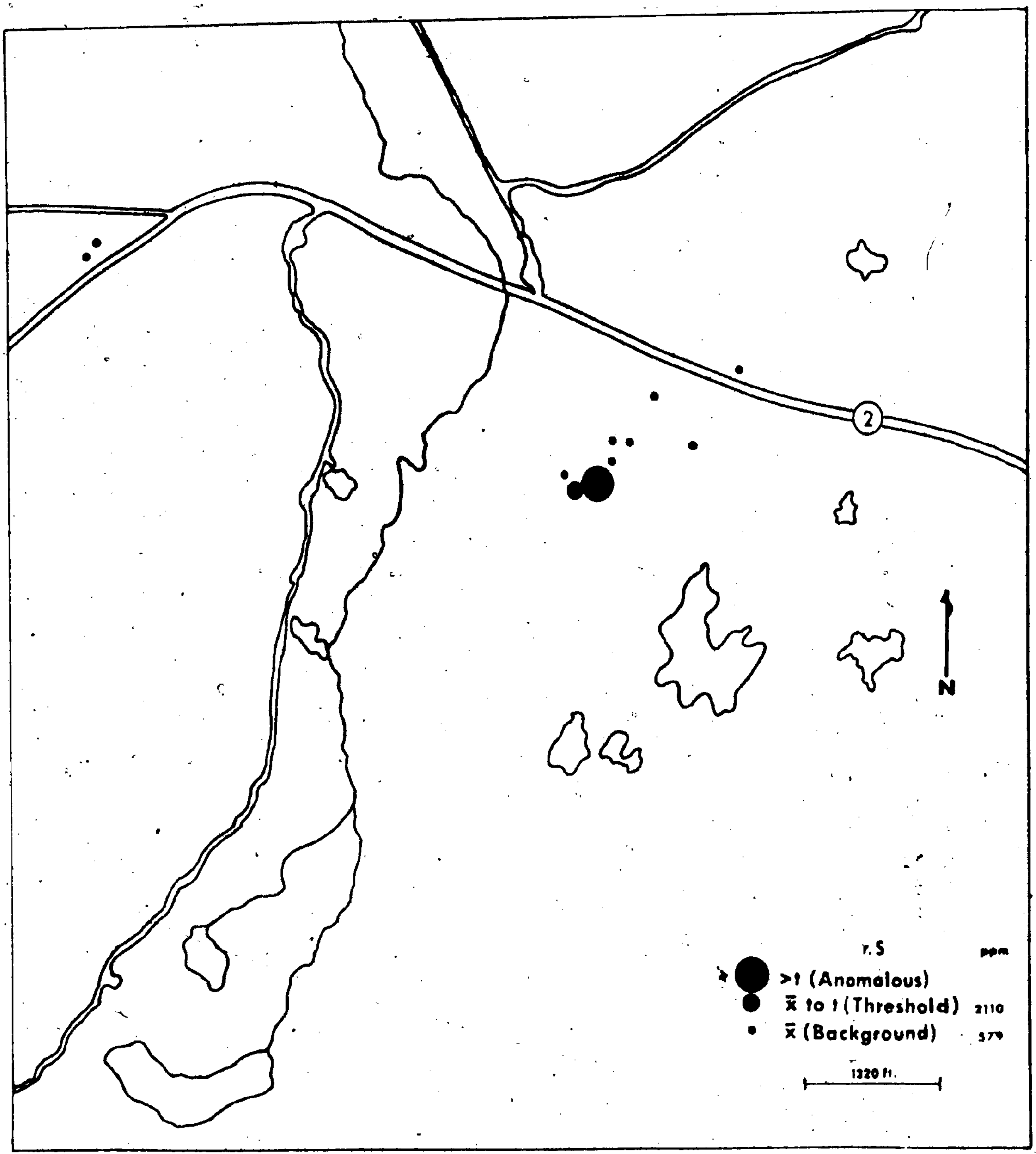


Figure 44 - Distribution of S in Lower Red Till

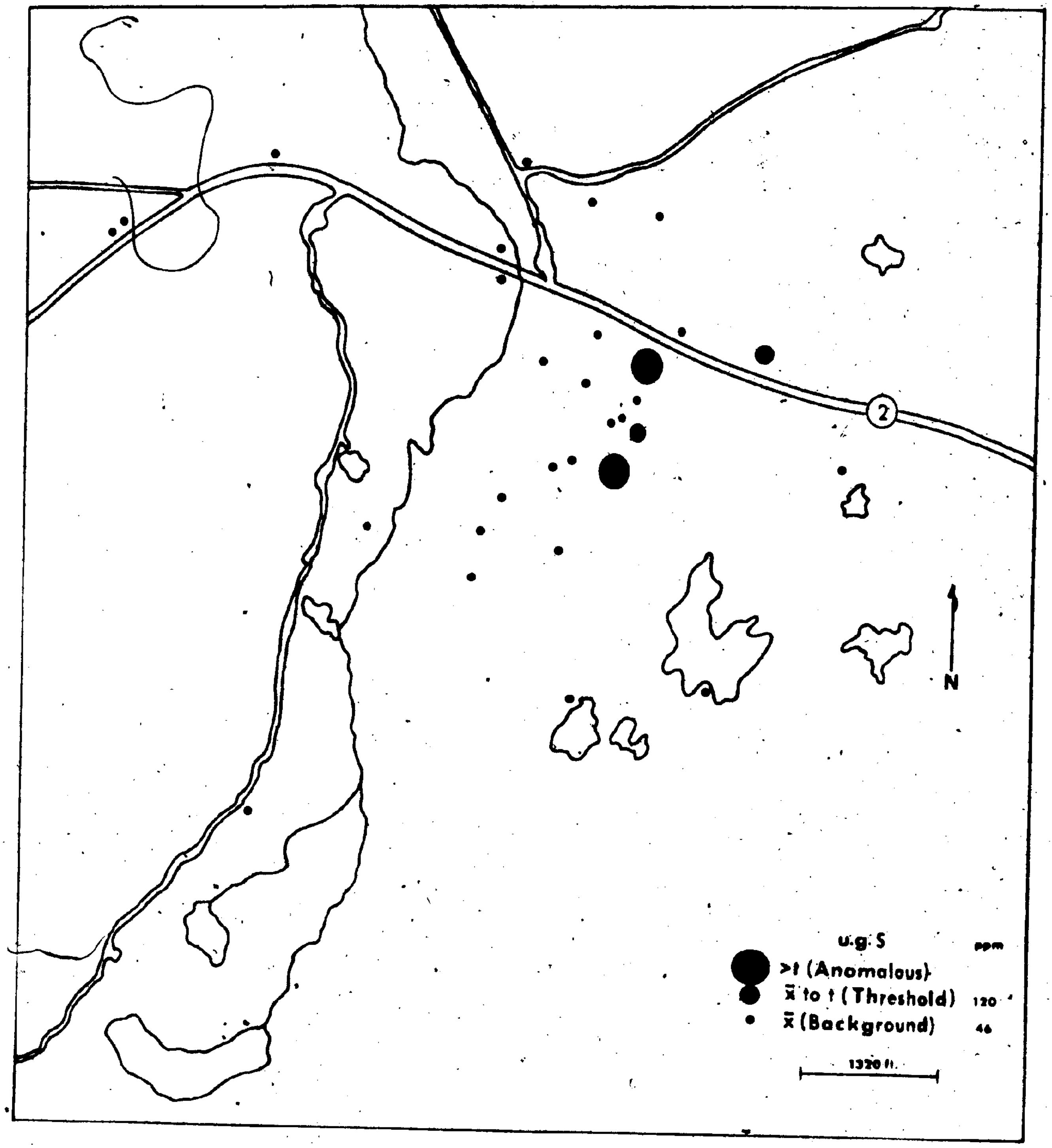


Figure 45 - Distribution of S in Upper Grey Till

The Upper Grey till has a background S level of only 46 ppm, and a threshold value of 120 ppm. Anomalous values occur in samples #92H (153 ppm) and #103 (245 ppm). Again the extremely high mobility of S is indicated, although both of the anomalous values occur in the ~~main~~ float zone.

Summary

Manganese, the only litholphile element studied, is rapidly oxidized in the till and almost as quickly co-precipitated with ferric hydroxide or precipitated in neutralized groundwater as occlusions on various mineral clasts in the till. It is a good pathfinder element in that it is enriched in both till units in the main float zone.

Nickel, cobalt and iron, the siderophile elements studied, have widely varying mobilities and efficacy as tracer elements in the Sheffield Lake - Indian Pond region. Nickel is probably not a worthwhile tracer here because of its low concentration in the bedrock source of the float clasts. Manganese and iron hydrated oxides are particularly adept at scavenging soluble cobalt sulphate liberated from the sulphide source in the Sheffield Lake - Indian Pond area and thus its high mobility is, in part, restricted. Nevertheless, cobalt is another good tracer element here since the only anomalous values for Co are found in the main float zone. The low mobility usually exhibited in the epigentic environment by Fe holds true in the study area. However, due to the predominant mechanical dispersion (e.g. float clasts) very high Fe values are encountered over the whole length of Red till outcrop and in the superimposed grey till in the main float zone. Because of the pyrite rich source in the area, and the low mobility of Fe, it must be considered an indispensible tracer element for the purposes of this study.

The chalcophile elements, Cu, Pb, Zn and S represent a tremendous range of elemental mobility in the Sheffield Lake - Indian Pond tills. The extremely high mobility of S has resulted in much lower concentrations of this element in the tills than expected from the andesite and float concentrations. However, S still outlines the main float area with high or anomalous concentrations and higher concentrations are seen in a few locations "up-ice" of the main float occurrences in the grey till. Zinc, the next most mobile of the chalcophile elements studied, is hindered as a tracer element because of the presence of Fe and Mn scavengers which restrict its mobility and because the suboutcropping float source (as ascertained from float analyses is indigent in Zn). Even so, Zn must be considered as a relatively worthwhile tracer element, since the highest concentrations are found either in the tills of the main float area or a short distance "down-ice" from there.

Copper, which is considered to be less mobile than Zn or S in till is, however, the main element of interest in the Sheffield Lake - Indian Pond area. The concentrations encountered, particularly in the float boulders and Lower Red till, warrant further work "up-ice" from sample site #92B which was anomalous in Cu.

Lead, the least mobile of the chalcophile elements studied, has not proved to be a good pathfinder element in the Sheffield Lake-Indian Pond area. This can be primarily attributed to a paucity of Pb in the bedrock source (as ascertained by float analyses) and possibly

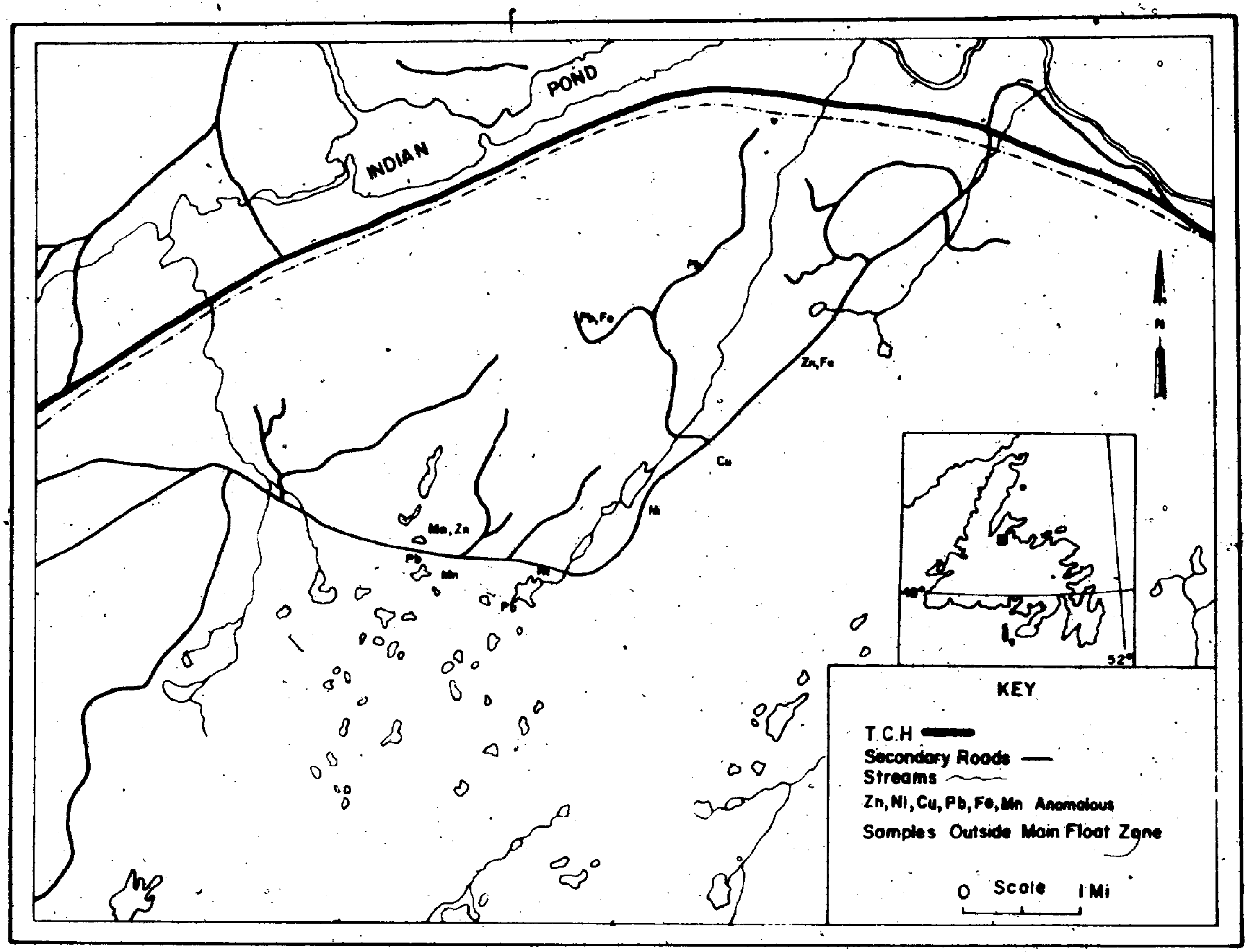


Figure 46. Anomalous Concentrations Outside Main Float Zone.

also to its very immobile nature, whereby it should occur in anomalous concentration in the till of the IMMEDIATE vicinity of the suboutcropping deposit, but should rapidly diminish down-ice from it. Since no pits were opened immediately over suboutcropping sulphides, till enriched in Pb was not found.

It is important to note here that the weathering of the float boulders themselves is not the source of the anomalous trace element concentrations in the two till units. The anomalous values for Cu, Fe and S, the three most important tracers (since the float analyses reveal that high concentrations of these 3 elements exist in the bedrock source), do not correspond to the areas where hundreds of sulphide float clasts are concentrated in the tills, but rather are generally up-ice from them. (Fredriksson and Lindgren, 1967) obtained similar results from a survey in Finland.

Profile Samples

Six of the 108 pits dug in the trenching and sampling phase of the Sheffield Lake - Indian Pond project were profile sampled to 1) determine elemental variations with depth, and in that way to find the optimum sampling depth in the "C" horizon and to 2) trace the micro-float train in its vertical, as well as its horizontal, component (Hawkes and Webb, 1962) (Figure 5).

Pits #46 and #64 were 10 and 8 feet deep, respectively. Only the Upper Grey Till was encountered in each (Table 13). Pit #64 was located within the main float area, while #46 was approximately two miles to the East (Figure 12).

TABLE 13: ELEMENTAL CONCENTRATIONS IN PROFILE SAMPLES

					PPM. Cu	ppm. Pb	ppm. Zn	ppm. Co	ppm. Ni	ppm. Mn	% Fe	ppm. S
#46	Grey	H	Depth	-1'	16	7	21	5	6	183	1.2	N.A.
	Till	G	with	2'	20	5	38	10	6	263	1.0	N.A.
	"	F	refer-	3'	15	5	20	6	6	228	1.0	N.A.
	"	E	ence	4'	23	7	28	7	18	240	0.6	N.A.
	"	D	to	5'	23	4	24	8	10	218	0.9	N.A.
	"	C	top	6'	18	5	23	5	6	232	1.2	N.A.
	"	B	of "C"	7'	18	8	35	8	33	230	0.8	N.A.
	"	A	Horizon	8'	16	6	25	5	10	253	0.9	N.A.
#64	Grey	E	Depth	-1'	23	7	36	8	33	280	1.1	20
	Till	D	with	2'	23	3	18	5	17	110	0.6	97
	"	C	refer-	3'	28	3	28	12	15	273	1.2	20
	"	B	ence	4'	28	10	30	10	25	300	1.0	29
	"	A	to top of "C"	5'	23	5	25	10	12	285	0.9	5
#70	Grey	E	Hori-	1'	1	12	50	8	6	140	0.9	30
	Till	D	zon	2'	8	13	60	8	25	245	1.1	5
		C		3'	15	19	63	9	13	300	1.0	5
	Red	B	Depth	4'	63	63	187	27	19	540	3.8	120
	Till	A	with reference	5'	151	175	202	30	27	575	5.6	284
#70B	Grey	E	to top	1'	5	14	49	5	50	135	0.9	N.A.
	Till	D	of "C"	2'	20	20	92	15	15	488	1.7	14
	"	C	Hori-	3'	45	18	171	19	20	700	3.0	34
	"	B	zon	4'	40	40	155	18	28	400	2.8	5
	Red Till	A		5'	98	16	110	29	26	562	3.5	120
#92B	Grey	E	""	1'	40	7	25	3	16	135	1.1	22
	Till	D	""	2'	38	7	24	13	10	260	1.1	45
	Red	C	""	3'	53	24	32	8	15	275	3.4	292
	Till	B	""	4'	54	37	80	8	13	333	4.5	1481
	"	A	""	5'	300	19	50	11	15	550	10.0	1635
#102	Mixed	F	""	1'	30	10	23	8	10	140	1.4	65
	Red	E	""	2'	28	3	26	5	19	125	1.7	35
	and	D	""	3'	25	9	16	4	16	118	1.3	35
	Grey	C	""	4'	28	7	16	4	6	115	1.5	N.A.
	Till	B	""	5'	35	8	20	4	12	125	1.5	N.A.
	"	A	""	6'	38	6	29	7	14	137	1.9	27

N.A. = Not analyzed.

In pit #64, Cu, Co, Ni, Mn values are generally higher than in pit #46. This could be because of the proximity of pit #64 to the outcrops of the Lower Red till (approximately 400 feet to the east). Possibly the red till occurs below the 8 ft. depth of the pit.

In both pits the Pb, Zn and Fe values are similar. There is no systematic variation in elemental concentrations with depth in either profile, as would be expected in #64 if red till was, indeed, below the base of the pit. These results suggest that in the Upper Grey till any "C" zone sample would be equally representative of the unit as a whole.

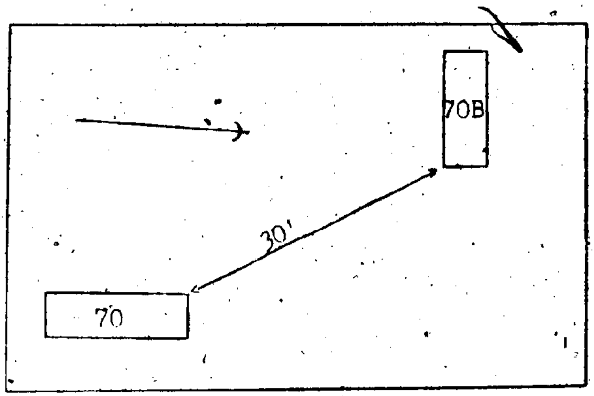
Pit #102 is located 6 miles to the north east of the main float area. The 8 foot deep pit was located on the lee side of, and 200 feet "down-ice" from bedrock outcrop. It was apparent from the mottled nature of the pit walls that grey and red till are mixed at this locality. In fact, a rather angular block of red till could be outlined which appeared to have been "ripped up" from the red till near the base of the pit and incorporated into the overlying grey till. The profile samples were collected so as to avoid this red till block.

The profile samples taken at pit #102 show a very slight increase in Cu and Fe toward the base of the pit (F..>A), (Table 13). All other elemental concentrations are relatively constant throughout the profile with the possible exception of S, which seems to increase in concentration upwards (A..>F) in the profile, reflecting its high mobility.

The reddish till at this site bears little chemical similarity to the Lower Red till in the main float area, as can be seen from

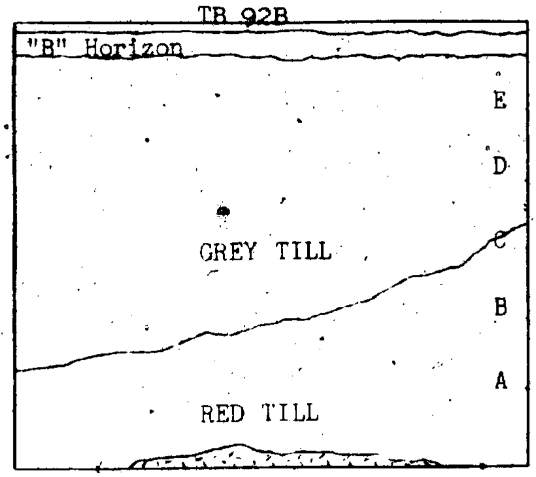
Table 13. It may have been emplaced contemporaneously with the Lower Red Till and been oxidized during an interstadial period as was the Lower Red till. Apparently, it has been diluted with barren rock material incoporated into the till. The grey till at locality 102, however, seems to bear a strong chemical similarity to that in the main float area, as is apparent from a comparison of #64 or #46 with #102 on Table 13.

Pits #70, #70B and #92B all bottomed in Lower Red till. Numbers 70 and 70B were located in the same small bedrock depression about one mile to the west of the main float zone and approximately 30 feet apart. They were 7 and 6 feet in depth, respectively and were dug perpendicular to each other to obtain a 3 dimensional view of the till stratigraphy, as shown below:



The occurrence of Lower Red till in the base of each pit is evidenced by higher concentrations of Cu, Pb, An, Co, Ni, Mn, Fe and S in samples A and B of pit 70, and by Cu, Co, Fe and S in sample A of pit 70B (Table 13). The lack of contrast in elemental concentration for the other 3 elements studied in the red and grey till in 70B might be explained by a greater incorporation of red till material in the grey unit during deposition.

Pit #92B bottomed on chloritized andesite bedrock which contains very minor pyrite disseminations, as shown below.



A sharp break is apparent between the elemental concentrations in the Lower Red, and Upper Grey tills (Table 13). The Lower Red till is enriched in every element analyzed and the concentration, as would be expected, increases as the weakly pyritized bedrock is approached. From the very high concentrations encountered in the Lower Red till in this pit - even allowing for the proximity of bedrock - it is apparent that bedrock Cu sulphide mineralization is to be expected a short distance up-ice from this locality. The high concentrations, especially for Cu, Fe, Mn and S, are not sedentary or residual deposits because the bedrock at the site has no visible mineralization - other than the very minor

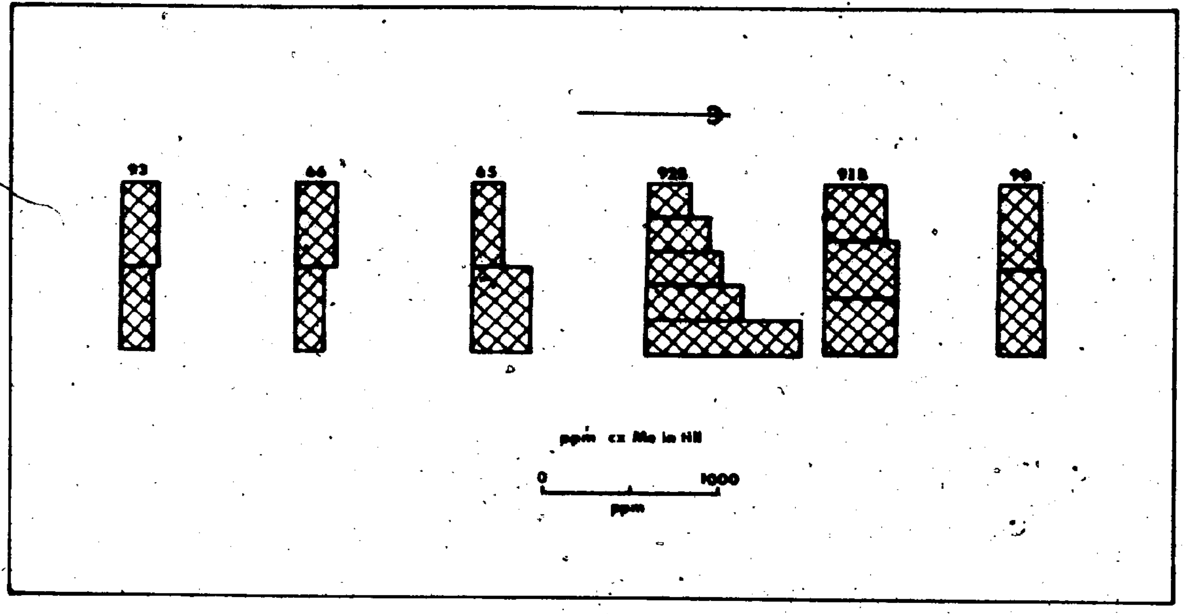


Figure 47. Metal Concentration in Profile Samples.

pyrite alluded to above - which could have been oxidized, and re-precipitated in the "brief" interstadial interval between red and grey till emplacement. It is conjectured then that the hundreds of sulphide float boulders "down-ice" and the high trace element concentrations at pit #92B have a common bedrock source "up-ice" from this sample site.

Mode of Metal Occurrence

The profuse float clasts in the Sheffield Lake - Indian Pond area apparently indicate mechanical (clastic) dispersion as the dominant syngenetic dispersion process in the area, as opposed to hydromorphic dispersion.

Most of the metal comprising clastic dispersion patterns including anomalous metal, is contained in secondary minerals (i.e. hydrous oxides of Mn and Fe) and as discrete primary (sulphide) grains.

As a means of obtaining a reliable prognosis of which of these two modes of occurrence, secondary minerals or primary sulphides, is dominant in the Sheffield Lake - Indian Pond area, the heavy and light fractions of samples from both till units were analysed. Twenty samples selected as representative of both till units and a range of metal content were separated with tetrabromethane in Hutton centrifuge tubes (Figure 48) according to the procedure of Allman and Lawrence, (1972). Each of the heavy separates and eleven of the light fractions were then analysed by A.A.S. using the same methodology as for the bulk samples (F. Goudie, Personal Communication, 1974). The results appear in Table 14. Sample pre-treatment is outlined on Figure 54.

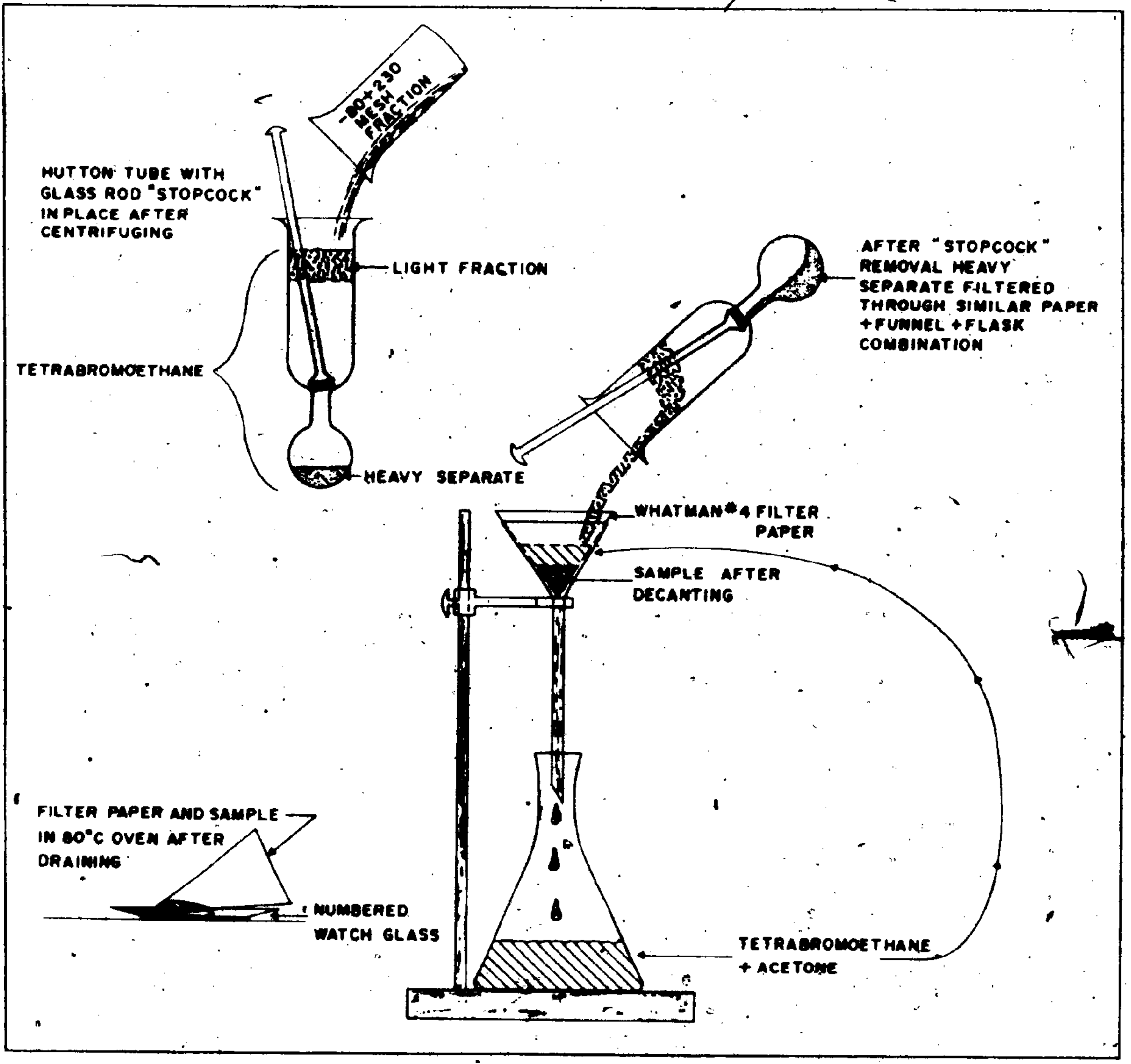


Figure 48. Heavy Mineral Separation

Table 14 : Heavy and Light Mineral Fractions Analyzed by Atomic Absorption Spectrophotometry

No.		ppm. cu	ppm. Pb	ppm. Zn	ppm. Co	ppm. Ni	ppm. Mn	% Fe	Weight per cent light and heavy minerals
1	Hvy.*	27	16	44	25	47	245	2.0	4.6
	Bulk	8	4	21	5	20	153	0.6	-
	Lt.*	N.A.	--	--	--	--	--	--	95.4
15	Hvy.	25	20	46	8	30	255	1.9	4.8
	Bulk	10	4	20	2	9	168	0.8	-
	Lt.	N.A.	--	--	--	--	--	--	95.2
22L	Hvy.	914	17	315	12	35	297	7.5	2.5
	Bulk	208	9	60	3	5	325	2.1	-
	Lt.	N.A.	--	--	--	--	--	--	47.5
59L	Hvy.	218	8	113	60	32	612	4.0	16.9
	Bulk	165	7	99	22	17	623	2.6	-
	Lt.	87	5	110	35	23	585	2.6	83.1
64A	Hvy.	38	17	44	30	19	332	1.9	7.1
	Bulk	23	5	25	10	12	285	0.9	-
	Lt.	N.A.	--	--	--	--	--	--	92.9
65L	Hvy.	50	8	43	8	26	475	3.7	6.5
	Bulk	30	10	30	5	6	250	1.8	-
	Lt.	15	3	14	5	20	138	1.5	93.5
66H	Hvy.	15	19	49	12	7	192	1.4	4.0
	Bulk	8	5	25	4	13	158	0.5	-
	Lt.	N.A.	--	--	--	--	--	--	96.0
67	Hvy.	31	22	72	14	34	332	1.9	6.8
	Bulk	17	7	37	4	11	189	.75	-
	Lt.	12	2	34	5	32	145	0.9	93.2

Table 14 (Continued)

No.		ppm. Cu	ppm. Pb	ppm. Zn	ppm. Co	ppm. Ni	ppm. Mn	% Fe	Weight per cent light and heavy minerals
70A	Hvy.	160	425	244	30	48	282	19.0	5.2
	Bulk	151	175	202	30	27	575	5.6	-
	Lt.	115	175	252	28	28	588	5.7	94.8
86	Hvy.	30	4	34	8	25	213	4.5	6.2
	Bulk	15	9	35	10	13	188	3.5	-
	Lt.	10	8	20	5	13	200	2.9	93.8
89L	Hvy.	40	18	70	25	44	332	2.1	5.9
	Bulk	15	3	28	8	6	180	0.9	-
	Lt.	N.A.	--	--	--	--	--	--	94.1
91AL	Hvy.	28	10	46	13	40	175	2.1	5.3
	Bulk	18	9	20	5	24	105	1.5	-
	Lt.	17	7	36	8	24	205	0.9	94.7
91AH	Hvy.	27	17	36	12	32	122	2.4	3.8
	Bulk	18	7	18	5	11	155	0.9	-
	Lt.	10	3	19	15	30	105	0.8	96.2
92L	Hvy	266	17	70	15	30	463	11.4	8.4
	Bulk	185	13	38	40	27	681	12.1	-
	Lt.	160	12	24	34	25	620	10.1	91.6
92H	Hvy.	95	17	54	21	40	385	3.5	4.9
	Bulk	41	4	31	17	15	450	1.5	-
	Lt.	27	6	73	9	30	282	1.2	95.1
94L	Hvy.	110	17	59	17	23	332	2.4	7.5
	Bulk	24	16	25	8	20	240	0.9	-
	Lt.	8	15	25	6	20	202	0.8	92.5

Table 14 (Concluded)

No.		ppm. Cu	ppm. Pb	ppm. Zn	ppm. Co	ppm. Ni	ppm. Mn	% Fe	Weight per cent light and heavy minerals
95L	Hvy.	18	15	44	21	30	332	1.9	4.6
	Bulk	8	8	85	5	10	120	0.5	--
	Lt.	N.A.	--	--	--	--	--	--	95.4
102A	Hvy.	40	11	37	19	25	87	3.4	4.9
	Bulk	38	6	29	7	14	137	1.9	--
	Lt.	N.A.	--	--	--	--	--	--	95.1
103	Hvy.	125	7	24	50	30	577	3.4	19.0
	Bulk	231	7	36	50	19	900	2.8	--
	Lt.	N.A.	--	--	--	--	--	--	81.0
104	Hvy.	68	7	33	10	26	500	3.9	20.3
	Bulk	60	6	39	8	15	480	3.6	--
	Lt.	55	6	32	9	28	425	0.7	71.7

N.A. = Not analyzed
* = See flow chart (Appendix C)
Hvy. = Heavy mineral fraction (+ 2.92 S.G.)
Lt. = Light mineral fraction (- 2.92 S.G.)
Bulk = -80, +230 Mesh sample

In a few cases (Table 14) the elemental concentration values are somewhat erratic, in that the heavy and/or light fraction values greatly exceed or are less than the bulk sample concentration of the element in the same sample. This is explained by either inhomogeneous sub-sampling or by precision effects. For example, the value for Zn in the bulk sample 59L is less than either the light or heavy fraction value. The value of 99 ppm recorded is the mean of 10 analyses ranging from 90 to 105 ppm, whereas the light and heavy fraction values are single determinations only.

Manganese hydrous oxides are noted for their metal scavenging ability and also for their ability to precipitate on silicate mineral grains, thereby exerting a chemical activity out of proportion to their concentration. A result of this effect is the higher Mn content of the light than heavy fraction of samples #70A, 91A Low and 92Low. (Table14).

Sample #70A, in which the light separate contains almost twice as much Mn as does the corresponding heavy fraction also contains more Zn and is relatively highly enriched in Cu, Co and Pb in the light fraction as well. The co-precipitation of Zn, Cu, Co and Pb, in such quantities with Mn has obviously been the dominant metal fixing process in this sample. Zn and Pb anomalies in #70A, then, must be construed as resulting from the high Mn concentration in the sample and can be interpreted as a spurious anomaly.

Samples #91AL and #92L are also enriched in Mn in the "lights", however, no other element is correspondingly enriched as in the case of #70A (Table 14). In fact higher values occur in the "heavies" for every other element analyzed in these samples.

Mn content of the light fraction of the other eight samples is lower than that in the corresponding heavy fraction which indicates that most of the metal in the Sheffield Lake - Indian Pond samples occurs as discrete sulphide grains, with the Mn and Fe oxides, relegated to a secondary, but important, role.

The role of hydromorphic dispersion in the samples cannot be determined because the complex soluble salts, evolved from this mechanism, were removed during the pre-treatment wet sieving of the samples.

Elemental Correlations

Upon completion of the A.A.S. and Leco analytical programs, the "tracer" element concentration data was punched on separate computer cards according to the format shown in Figure 49. Pearson correlation coefficients were calculated for all of the elements analyzed in both till units, (Wennervirta, 1968; Nichol, 1971; Levinson, 1974) on a IBM 370/155 computer, using Fortran IV language and a program developed by G. Cawthorn (Personal Communication, 1974). The correlation matrices calculated (Table 15) indicate strong correlations between iron and sulphur, copper and iron, and copper and sulphur. Samples of float from the Sheffield Lake - Indian Pond area are rich in pyrite, chalcopyrite and bornite, with traces of galena, sphalerite and pyrrhotite (Table 1). The bedrock source must, therefore, be enriched in these minerals, in approximately the same proportions, and this is reflected by the correlations obtained.

As a test of the significance of the correlations, the confidence

Figure 49. Keypunch Card Format.

TABLE 15

Correlation Matrix for Lower Red Till Data: (13 samples)

Cu	1.0	0.2219	0.2316	0.2469	0.1844	0.3104	0.8727	0.6276
Pb	-	1.0	0.9446*	0.1629	0.4544	0.0606	0.0851	-0.6276
Zn	-	-	1.0	0.2542	0.4075	0.1557	0.0887	-0.1810
Co	-	-	-	1.0	0.6229"	0.9359*	0.3262	0.0847
Ni	-	-	-	-	1.0	0.5069	0.2615	0.0399
Mn	-	-	-	-	-	1.0	0.3025	0.0566
Fe	-	-	-	-	-	-	1.0	0.8566*
S	-	-	-	-	-	-	-	1.0
	Cu	Pb	Zn	Co	Ni	Mn	Fe	S

Significance --- 0.553" @ 95%
0.684* @ 99%

levels (95% and 99%) have been calculated, and appear on the Tables.

The correlations obtained seem to indicate that, although the mixing of till material during emplacement naturally reduces the correlations, the mutual order of the coefficient remains unchanged (Wennervirta, 1968) (e.g. although the Zn and Pb contents of the source are low, and even though the actual concentrations have been further reduced by dilution, the correlation between them is still strong).

Other correlations of interest are:

1) Mn and Fe with Cu, Co, Pb and Zn - reflecting the scavenging propensity of limonite in the epigenetic till environment.

2) Ni correlates only weakly with Co in the Lower Red till thus reflecting its lack of association with the other elements analyzed and its absence in the source rocks. Nickel is, therefore, not a worthwhile tracer element in this study area.

A comparison of elemental correlations for the Upper Grey and Lower Red tills underscores the dominant mineralogy of the bedrock float source. Cu/Fe, Cu/S and Fe/S make up half the Lower Red till correlations and reflect the dominant chalcopyrite - pyrite mineralization in the vicinity. The Upper Grey till elemental correlations include all of those found in the Lower Red till (with the exception of the weak Co/Ni correlation) (Tables 15 and 16), however, these dominant ones are rendered obscure due to the occurrence of a welter of equally significant correlations of the less interesting elements.

TABLE 16

Correlation Matrix for Upper Grey till Data: S Included (52 samples)

Cu	1.0	-0.0204	0.3810*	0.7360*	0.1685	0.7257*	0.6439*	0.5154
Pb	-	1.0	0.4025*	0.0029	0.2098	0.0885	0.1021	-0.1480
Zn	-	-	1.0	0.3286"	0.2175	0.5037*	0.6382	-0.0112
Co	-	-	-	1.0	0.0212	0.8798*	0.6646*	0.6129*
Ni	-	-	-	-	1.0	0.0935	0.0867	0.0646
Mn	-	-	-	-	-	1.0	0.8036*	0.5138*
Fe	-	-	-	-	-	-	1.0	0.5447*
S	-	-	-	-	-	-	-	1.0
	Cu	Pb	Zn	Co	Ni	Mn	Fe	S

Significance --- 0.273" @ 95%

0.354* @ 99%

TABLE 17

Correlation Matrix for Upper Grey Till Data: S, Excluded (142 samples)

Cu	1.0	0.326	0.3295*	0.4682*	0.0430	0.4411*	0.4261*
Pb	-	1.0	0.3845*	0.1126	0.0600	0.1758"	0.4054*
Zn	-	-	1.0	0.3170*	0.1158	0.5335*	0.5499*
Co	-	-	-	1.0	-0.0207	0.5761*	0.4382*
Ni	-	-	-	-	1.0	0.0940	-0.0711
Mn	-	-	-	-	-	1.0	0.6264*
Fe	-	-	-	-	-	-	1.0
	Cu	Pb	Zn	Co	Ni	Mn	Fe

Significance --- 0.166" @ 95%

0.216* @ 99%

The ramifications of this observation coupled with the threshold contrast and profile sample data formerly presented (Figures 30-45 and 47) include 1) the importance of sampling the stratigraphically lowest unit in any geochemical study based on glacial till sampling, and 2) the importance of obtaining a glacial geological interpretation of the area to be studied prior to the geochemical survey.

TABLE 18 SUMMARY OF SIGNIFICANT CORRELATIONS

UNIT	CORRELATIONS
Upper Grey Till	Cu/Zn; Cu/Co; Cu/Mn; Cu/Fe; Cu/S; Fe/Zn; Fe/Co; Fe/Mn*; Fe/S; S/Mn; S/Co; Mn/Co*; Mn/Zn; Zn/Pb; Zn/Co**; Fe/Pb**
Lower Red Till	Cu/Fe; Fe/S; Zn/Pb*; Cu/S; Mn/Co; Co/Ni**

* Strongest significant correlations

** Weakest significant correlations

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

A reiteration of the three main aims of the Sheffield Lake - Indian Pond Project is in order here. They were to:

1) Interpret the Glacial History of the region

2) Delineate a source area for the sulphide float clasts which occur in the vicinity on the basis of combined Drift Prospecting techniques; and

3) Evaluate the applicability of each of these techniques to Newfoundland terrain and conditions.

A thorough search of relevant literature, an extensive air photo interpretation and field measurement of striae sets, grooves and crescentic marks all indicate a dominant ice flow toward the northeast. However, a more complex regional ice flow history was revealed during the analyses of till fabrics in the study area. An early, strong north easterly ice flow is preserved in the till fabrics of the Lower Red till and in the basal portion of the Upper Grey till in the area. However, higher in the Upper Grey till, the flow is indicated as moving toward the north and northwest.

The two till units, differentiated on the basis of various physico-chemical parameters, record two separate ice advances in the area, the earlier of which may antedate the Wisconsinan Period. This is the first conclusive evidence of multiple glaciation in north-central Newfoundland.

The primary float fan, which occurs in the Lower Red till, has been masked, smeared, and attenuated by the glacial re-advance which emplaced the Upper Grey till. Much of the past confusion in interpreting the source of the sulphide float in the Sheffield Lake - Indian Pond area has derived from the failure to recognize and correctly interpret the relationship of these two distinct till units as representing separate ice advances. This also accounts for the often "patchy" surficial occurrences of the float in the region.

Malmquist (1961) concluded his report on the Boliden-Brinex joint boulder tracing project in the Sheffield Lake - Indian Pond area with the observation that "without doubt, there must be ... copper mineralization somewhere" in the region, however, "whether the mother lode is an ore body of large or small size (or several such bodies) is a very difficult question to answer."

These conclusions, with a few important new considerations, are still basically applicable to the results of the present study. Unless the source of the hundreds of sulphide float clasts was completely eroded away during the pre-glacial and glacial periods since its formation, then copper mineralization must exist in the bedrock up-ice from the indicator train outlined during this study (Figure 27).

Because of the host rock of the float, (andesite) the ore body(s) must be within the area of suboutcropping andesite rock, north of the Andesite/Syenite and Granite/Andesite contacts.

The small angle of divergence of the primary indicator train in the Lower Red till indicates that the source area probably consists of one ore body of limited sub-outcropping extent (but quite possibly of tabular shape and steep inclination) enclosed within one of the alternating andesite "bands" revealed during the diamond drilling phase of the Boliden-Brinex project (Figure 51).

A short distance of transport is indicated by the angularity of the float clasts, the high chlorite content of the clays in the vicinity, the generally low resistance to comminition of sheared, chloritized and highly mineralized float clasts, the transport distances of associated indicator pebble lithology in the till, and the anomalous concentrations of tracer elements in the till matrix of the vicinity.

On the basis of the combined Drift Prospecting techniques utilized a probable source area on which to concentrate more intensive exploration (Figure 50) has been delineated. This target area encompasses a zone of small, lenticular rhyolite outcrops, so mineralization may be associated with the andesite-rhyolite contacts (H.R. Peters, Personal Communication, 1974).

The air photographic interpretation and bedrock preserved ice flow indicator measurements performed in the region gave a good indication of the dominant regional ice flow, however, little indication of the important, late, topographically controlled ice flow (revealed in the till fabrics) was indicated by these techniques.

The various sedimentological techniques utilized were particularly effective in differentiating the two till units in the study area on the basis of colour, texture, clay minerals, and pebble lithology. As well, these techniques were invaluable during the pre-treatment splitting, wet and dry sieving, and heavy mineral separation of the samples.

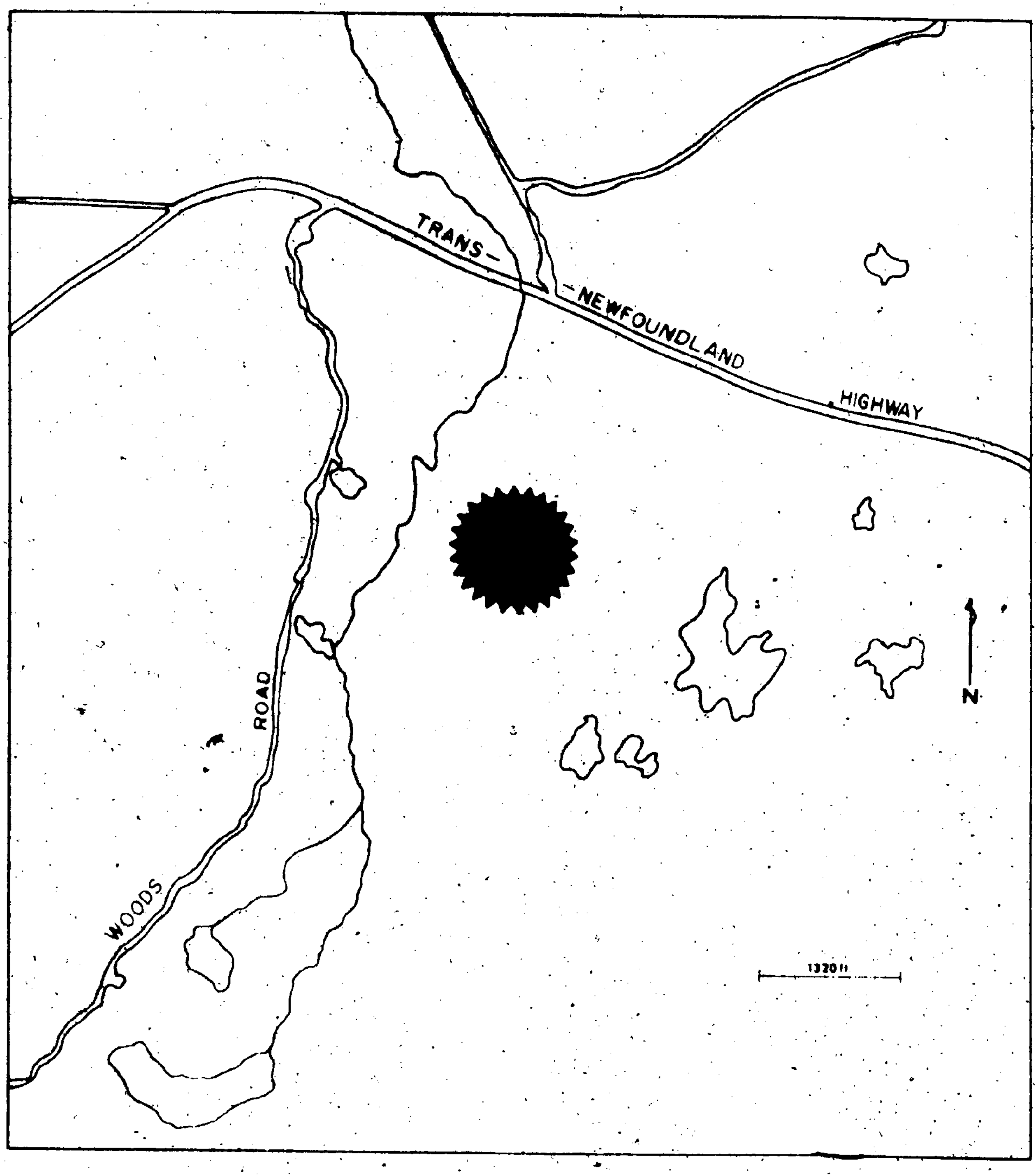


Figure 50 - Target area for Float Source

The Seismic refraction survey was useful in determining drift thickness, however, the contact between the two tills did not represent a significant velocity increase and so could not be mapped with this instrument. The survey was also limited due to the restricted penetration achieved using the hammer and plate mode instead of more efficient explosive boosters.

Stemming from the geochemical phase of the project are the observations that the -80, +230 mesh fraction of the till matrix is an exceptionally good size range on which to perform geochemical analyses, the hot HCl - HNO_3 digestion, and both the Atomic Absorption Spectrophotometer and the Leco Sulphur Analyser are well adapted to a study of this type, and the generation of Pearson Correlation Coefficients and correlation matrices were very useful to the final source determination, since important, obscure elemental affinities were enhanced. Cu, Fe and S were found to be the best tracer elements in the area, especially where they were mutually associated.

Recommendations

Malmquist (1961) recommended that any further work in the Sheffield Lake - Indian Pond area should concentrate near the Main Float Zone (his area "A"). The study area should "be extended further to the west and south (from Highway #2) as far as the boundary between andesite and syenite". He also recommended "a more extensive diamond drilling program complemented by bulldozer digging for ore boulders in order to follow the copper mineralization from the showings to the source". He further suggests that "it would also be of value to take samples for geochemical analyses in connection with digging in the till". All of Malmquist's (1961) recommendations, with the exception of costly diamond drilling, were incorporated in the present investigation.

As a result of the Sheffield Lake - Indian Pond study, it is recommended that:

I. Intensive exploration for the suboutcropping source of sulphide float be confined to the area shown in Figure 50.

II. Rotary overburden drilling on a grid pattern in the delineated source area be utilized for further intensive exploration. A unit of this type could quickly and efficiently collect basal till and bedrock chip samples for geochemical analyses and ultimately define a diamond drilling target.

III. The combined methods of Drift Prospecting, including glacial geologic, sedimentologic, geochemical and geophysical techniques, be used in the future for similar investigations in Newfoundland. Glacial geologic studies provide an understanding of glacial history, and most importantly of former ice flow and sediment transport directions. Sedimentologic investigations provide a means of differentiating drift units and estimating transport distance of drift. Geochemistry provides a further means of differentiating drift units, and more importantly, of tracing metallic float to its source. Geophysics provides an idea of the thickness of glacial drift and topography of buried bedrock.

IV. Of the various specific techniques and equipment employed in this investigation, the following were particularly well adapted to a study of this type:

a) Trenching with a backhoe (where possible) provides an investigator with a vertical section through drift for examining stratigraphy, measuring till fabric, and collecting samples at known depths for sedimentologic and geochemical analysis. For this latter aspect, trenching proved far more suitable than overburden drilling with a Pionjar drill, and extra information was obtained.

b) The Huntec seismic refraction unit utilized was suitable for determining drift thickness. However, it was not possible to differentiate drift units nor bedrock types.

c) Geochemical analyses of sediments should be confined to a specific size range (with a lower and upper size limit), such as the 0.180-0.062 mm. (-80, +230 mesh) fraction used in this investigation. By doing this it is possible to eliminate several sources of metals under investigation which ultimately simplifies interpretation. Spurious anomalies resulting from sediment textural variations are also eliminated.

d) Of the various elements investigated Cu, Fe and S are particularly good tracers, especially when the three are mutually associated. Mn, Zn, and Co were also found to be useful tracer elements. All six of these elements were anomalous but showed lower threshold contrast in the Upper Grey till of the main float zone, therefore, geochemical prospecting of surficial deposits is of some value in outlining areas of potential economic importance. However, geochemical analyses of stratigraphically lower parts of a till provide more useful imformation.

APPENDIX A
TABLE 19

DIAMOND DRILL HOLE LOGS: BRINEX-BOLIDEN JOINT PROJECT 1961-1962

(From Malmquist, 1961 and Peters, 1962)

Refer to Figure 51 for Drill Hole Locations

D.D.H. 61-1

Length 400'
Dip 45°
Azimuth 075

0 - Casing
30' - Andesite-minor pyrite
45' - Rhyolite Porphyry
60' - Andesite-pyrite
195' - Rhyolite Porphyry
210' - Andesite
225' - Rhyolite Porphyry
250' - Andesite
340' - Rhyolite Porphyry
360' - Andesite

D.D.H. 61-2

Length 405'
Dip 45°
Azimuth 155

0 - Casing
35' - Andesite-minor pyrite
55' - Rhyolite Porphyry
75' - Andesite-minor pyrite
225' - Rhyolite Porphyry
265' - Andesite
290' - Rhyolite Porphyry
310' - Andesite
390' - Rhyolite Porphyry
400' - Andesite

D.D.H. 62-3

Length	466'
Dip	45°
Azimuth	142
Core Recovery	93%

0 - Casing
35' - Andesite Porphyry - chloritic with epidotized sections
132' - Rhyolite Porphyry
140' - Andesite
253' - Quartz Feldspar porphyry
262' - Andesite
292' - Rhyolite porphyry
304' - Dacite
323' - Andesite
350' - Quartz Feldspar Porphyry
372' - Andesite
454' - Quartz Feldspar Porphyry

D.D.H. 62-4

Length	349'
Dip	50°
Azimuth	142
Core Recovery	84%

0 - Casing
41' - Brecciated Andesite porphyry-minor pyrite
78' - Quartz Feldspar Porphyry (considerable missing core).
177' - Andesite-minor pyrite
195' - Quartz Feldspar Porphyry
213' - Andesite-minor pyrite
274' - Quartz Feldspar Porphyry
290' - Brecciated Andesite

D.D.H. 62-5

Length 487'
Dip 50°
Azimuth 142
Core Recovery 98%

0 - Casing
26' - Porphyritic Andesite - epidote patches
37' - Quartz vein
39' - Andesite
78' - Silicified Andesite - minor chalcopyrite
90' - Porphyritic Andesite
132' - Quartz, Feldspar Porphyry
137' - Andesite
167' - Porphyritic Andesite - minor chalcopyrite
303' - Quartz, Feldspar Porphyry
313' - Lamporphyre Dike
315' - Quartz Feldspar Porphyry
355' - Andesite
379' - Massive fine grained Pyrite
381' - Andesite-minor pyrite
456' - Feldspar porphyry
462' - Andesite
463' - Dacite
470' - Andesite
481' - Quartz Feldspar Porphyry

D.D.H. 62-6

Length 400'
Dip 45°
Azimuth 112
Core Recovery 97%

0 - Casing
45' - Andesite, brecciated - minor pyrite
- massive pyrite 70'-71'
73' - Quartz Feldspar Porphyry
92' - Andesite-minor pyrite
141' - Diorite
147' - Andesite minor pyrite
162' - Quartz Feldspar Porphyry
176' - Andesite
189' - Quartz Feldspar Porphyry
201' - Andesite
207' - Quartz Feldspar Porphyry
242' - Andesite-minor pyrite
262' - Quartz Feldspar Porphyry
287' - Andesite-minor pyrite stringers
314' - Quartz Feldspar Porphyry-minor chalcopyrite
330' - Diabase Dike-minor chalcopyrite
349' - Andesite-minor pyrite
377' - Quartz Feldspar Porphyry/Rhyolite

D.D.H. 62-7

Length	325'
Dip	45°
Azimuth	135
Core Recovery	96%.

0 - Casing
30' - Porphyritic Dacite
50' - Porphyritic Rhyolite
59' - Andesite-minor hematite
67' - Porphyritic Rhyolite
113' - Andesite-minor pyrite
130' - Porphyritic Rhyolite
135' - Andesite - chloritic
152' - Porphyritic Rhyolite
157' - Andesite
207' - Porphyritic Rhyolite
228' - Andesite - ½" stringer of pyrite
254' - Porphyritic Rhyolite
267' - Andesite
276' - Dacite
286' - Andesite-minor chalcopyrite and pyrite
299' - Rhyolite Porphyry
320' - Andesite-minor pyrite

D.D.H. 62-8

Length	300'
Dip	45°
Azimuth	135
Core Recovery	95%

0 - Casing
26' - Fragmental Andesite - considerable pyrite throughout section
- some chalcopyrite especially 45' to 89'
- at 47', ½" stringer estimated 0.3% Cu
116' - Quartz Feldspar Porphyry
127' - Andesite - some hematite
129' - Granite - pink - coarse grained
140' - Chloritic Andesite - some pyrite
168' - Quartz Feldspar Porphyry
179' - Andesite
195' - Quartz Feldspar Porphyry
200' - Andesite - minor pyrite
223' - Quartz Feldspar Porphyry
249' - Andesite
256' - Quartz Feldspar Porphyry
278' - Andesite

D.D.H. 62-9

Length	300'
Dip	45°
Azimuth	135
Core Recovery	97%

0.	- Casing
25'	- Fragmental Andesite - 1" massive pyrite at 113' - minor <u>chalcopyrite</u>
174'	- Porphyritic Rhyolite
186'	- Andesite
188'	- Granite - inclusions of andesite
195'.	- Andesite - minor pyrite

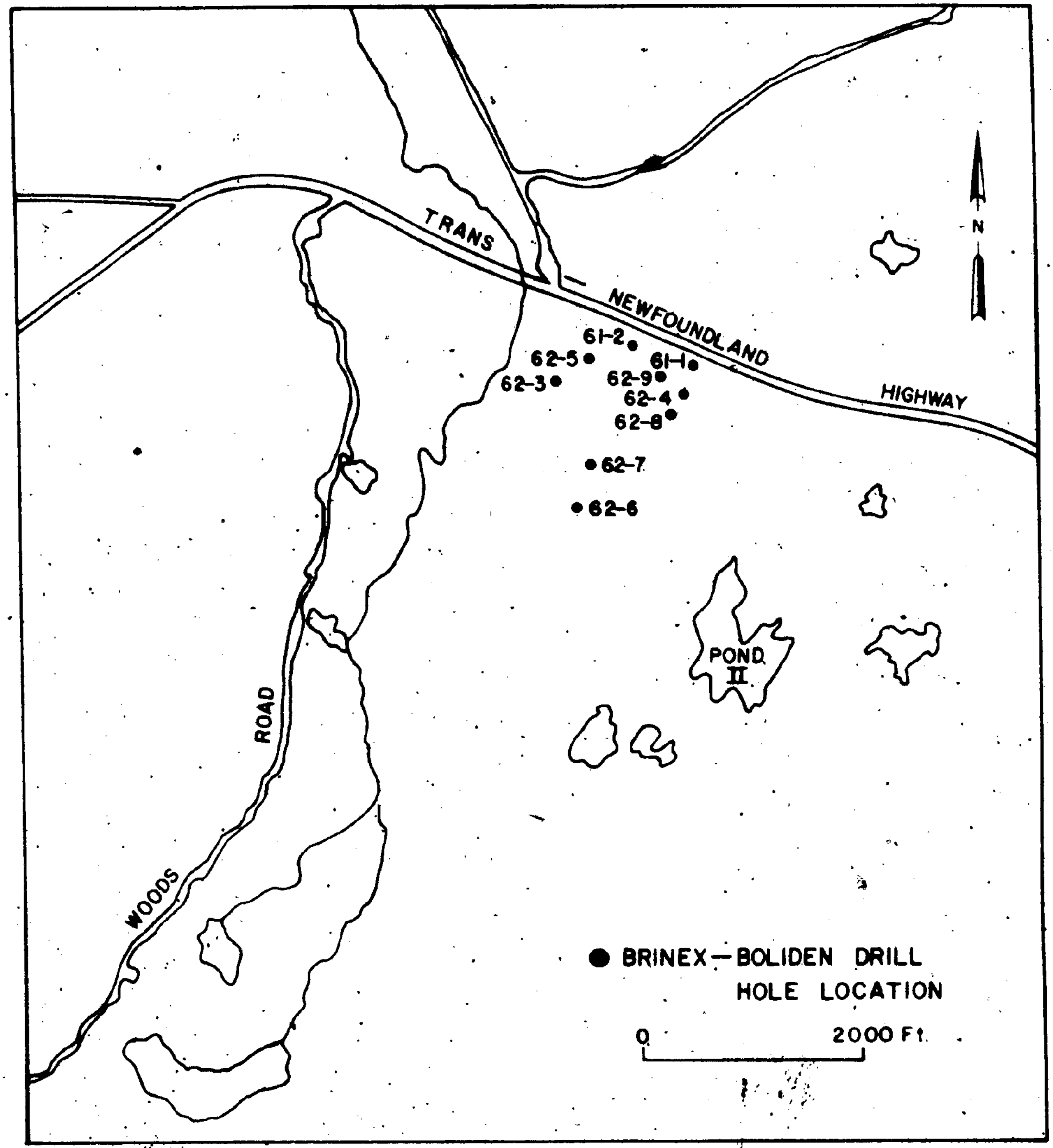


Figure 51 - Brinex-Boliden diamond drill hole locations

APPENDIX B

FIELD METHODS

Till Fabric Analyses:

As a means of determining regional ice flow directions in the Sheffield Lake - Indian Pond area, 108 pits were dug in the till to depths of between 5 and 12 feet. A depth of at least 3 feet was thought to be sufficient to restrict the affects of frost heaving and plant roots on pebble alignment. The pit sites chosen were always located on relatively flat ground to avoid, as much as possible, the affects of soil creep and solifluction. Usually, two till fabric analyses were performed at different depths in the deeper pits or where the Lower Red till unit was encountered, to determine ice flow variation with depth.

Fresh surfaces were cleared on the pit walls to avoid clasts disturbed by digging. The strike and plunge of at least 50 elongate pebbles with a visually determined A:B axial ration of 2:1 or more (Andrews and Smith, 1970), and a long axis of at least one centimeter (Young, 1969), were measured with a Brunton compass corrected for magnetic declination.

At least two workers were always employed in the measurements of clasts in any one pit, thereby, limiting personal bias.

If there was any doubt that the pebble had one dominant axis, it was discarded. Pebbles for measurement were selected, not from only one pit face, but rather a few were taken from each cleaned surface of the pit.

Results were plotted on Rose Diagrams and the dominant orientations obtained were plotted on Figures 13-15. One hundred and thirty one till fabric analyses were completed in this way, and an interpretation of regional glacial movement obtained.

APPENDIX C
FLOW CHARTS

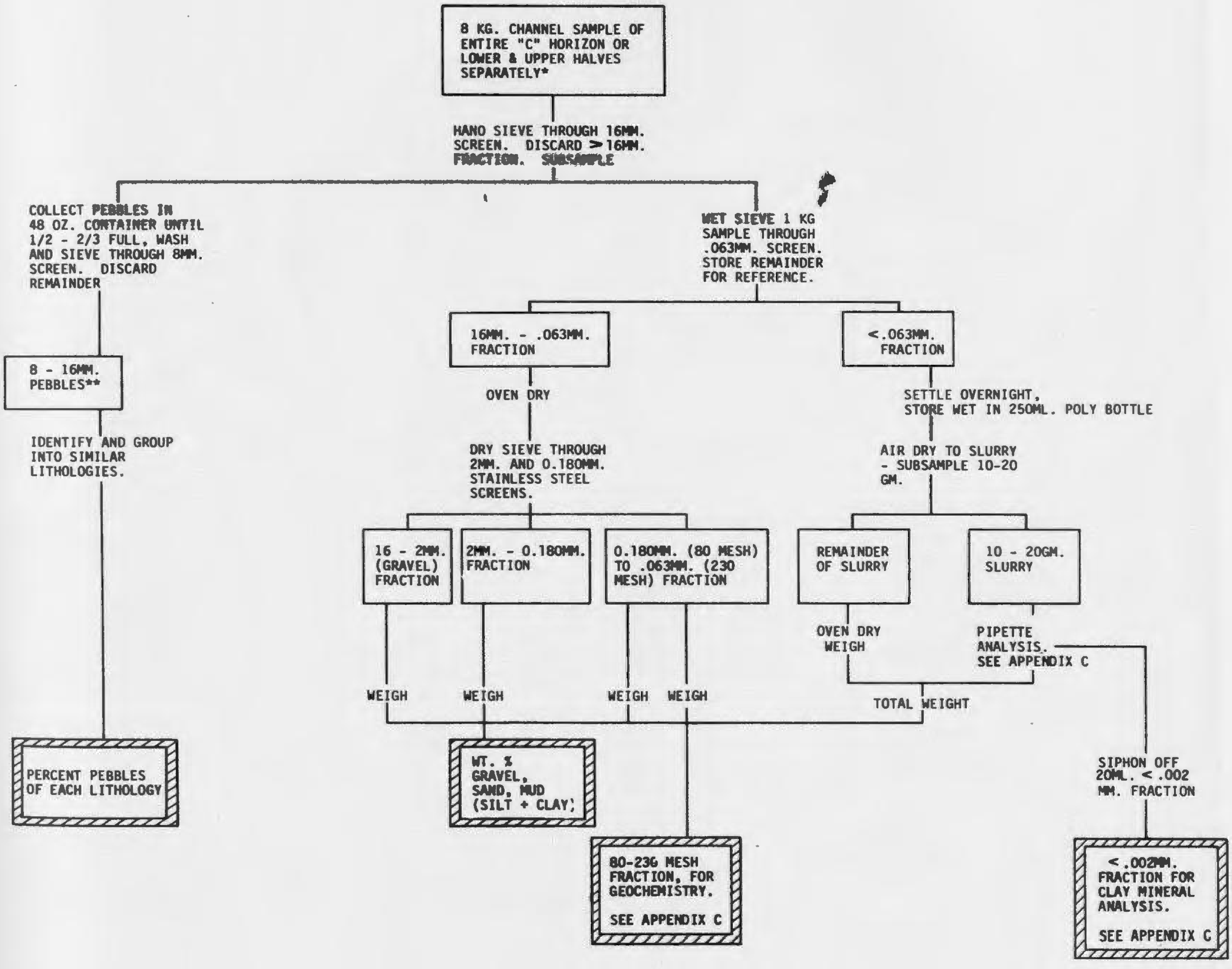


FIGURE 52 : PROCEDURES FOR SEDIMENT ANALYSES AND FOR OBTAINING SAMPLE FOR GEOCHEMICAL ANALYSIS

* - IN 6 OF THE 108 PITS DUG, PROFILE SAMPLES WERE COLLECTED AT 1 FT. INTERVALS, DENOTED A, B, C, ETC. FROM BASE OF PIT.

** - LEE, 1965

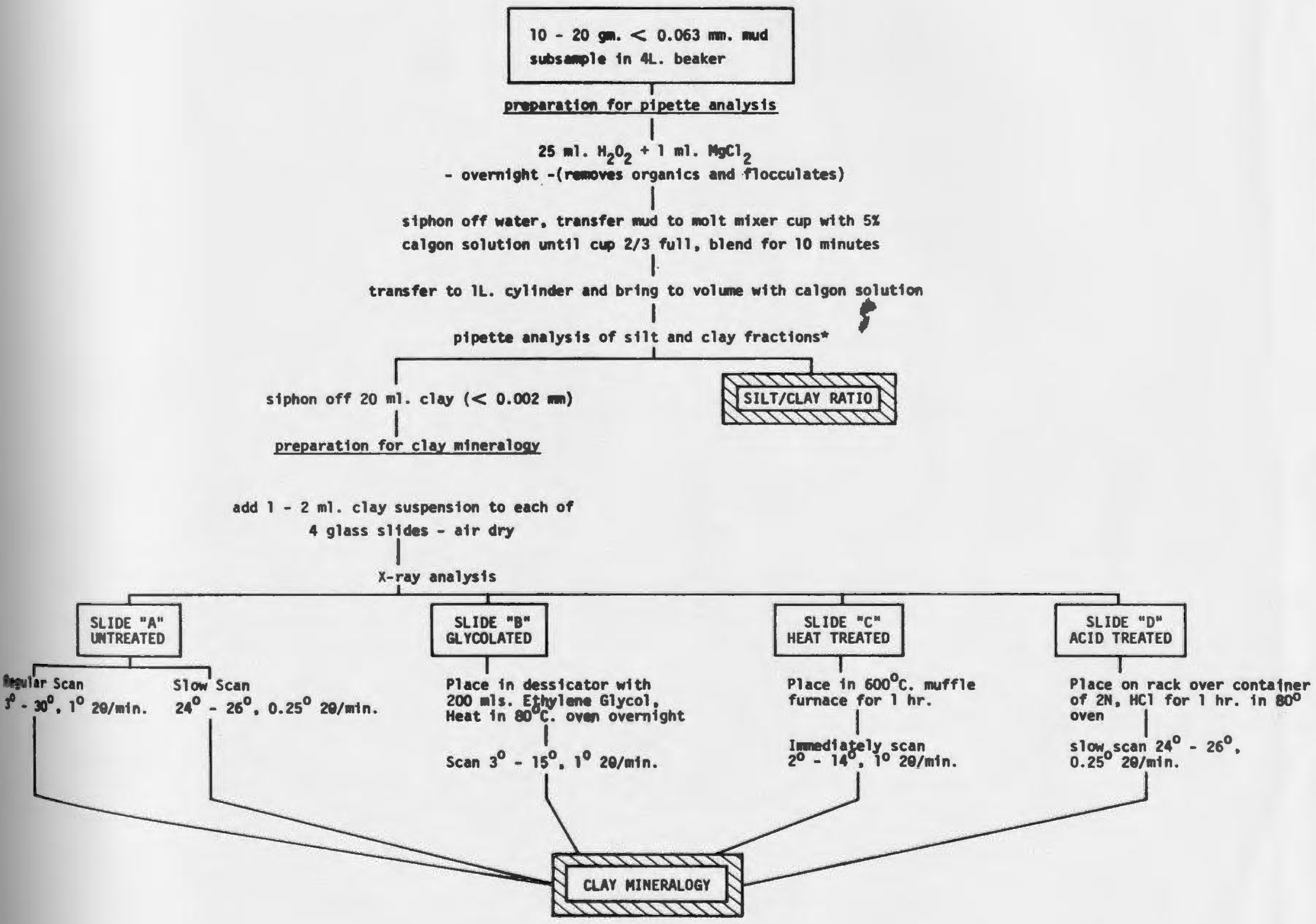


FIGURE 53 : PIPETTE ANALYSIS AND CLAY MINERALOGY

*Folk, 1968.

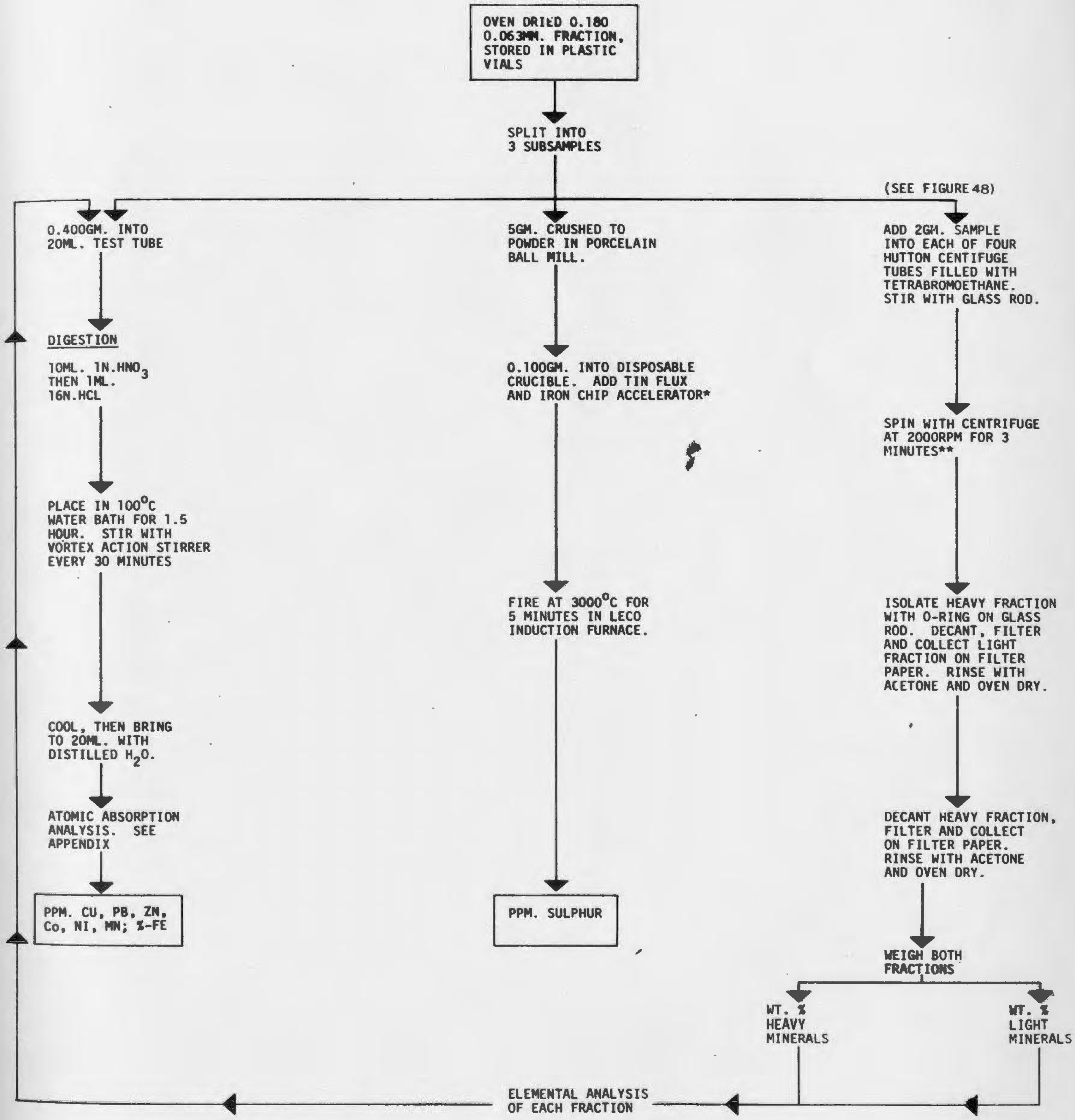


FIGURE 54 SAMPLE PRE-TREATMENT AND GEOCHEMICAL ANALYSIS

* FOSCOLOS AND BAREFOOT, 1970
** ALLMAN AND LAWRENCE, 1972

APPENDIX D
TABLE 20

Ice Flow Indicators

	Orientation			Location	
SET #	COARSE	FINE	TYPE	LATITUDE	LONGITUDE
1	030		Striae	49° 20' 00"	56° 39' 00"
2	025		"Nailhead" Striae	49° 20' 00"	56° 38' 35"
3	020		Striae	49° 20' 15"	56° 37' 40"
4	030		Striae	49° 20' 45"	56° 36' 00"
5	020		Groove	49° 20' 45"	56° 35' 00"
6	060		Striae	49° 20' 20"	56° 35' 00"
7	020		Striae	49° 20' 30"	56° 34' 30"
8	060		Striae	49° 21' 30"	56° 34' 00"
9	020	090	Crossing Striae	49° 21' 30"	56° 33' 45"
10	035		"Nailhead" Striae	49° 21' 45"	56° 32' 15"
11	020		Striae	49° 22' 30"	56° 32' 00"
12	025		"Nailhead" Striae	49° 22' 50"	56° 31' 50"
13	020	090	Crossing Striae	49° 20' 00"	56° 30' 45"
14	035		Striae	49° 22' 00"	56° 30' 45"
15	030		Striae	49° 21' 40"	56° 29' 30"
16	035		Striae	49° 24' 40"	56° 29' 30"
17	030		Striae and Gouges	49° 21' 35"	56° 29' 20"
18	020		Striae	49° 21' 45"	56° 29' 00"
19	025		Striae	49° 22' 05"	56° 29' 00"
20	045		Striae	49° 23' 00"	56° 28' 35"
21	040		Striae	49° 23' 50"	56° 28' 30"
22	025		Striae	49° 24' 40"	56° 28' 20"
23	020		Striae and Gouges	49° 25' 00"	56° 28" 15"
24	315		Striae	49° 25' 30"	56° 27' 50"
25	020		Striae	49° 25' 30"	56° 27' 15"
26	025		Striae	49° 25' 55"	56° 26' 50"
27	020		Striae	49° 26' 00"	56° 26' 15"
28	030		Striae	49° 26' 15"	56° 23' 50"
29	050		"Nailhead" Striae	49° 27' 00"	56° 23' 10"
30	060		Striae	49° 28' 00"	56° 23' 00"

APPENDIX E

Cost Sheet

Capital Expenditures (Seismograph-Lab Equipment-Field Equipment, etc)	$6,600.00
Transportation and Living Expenses	1,400.00
Salaries (3-man Field party)	8,200.00
Backhoe Rental (incl. operator)	510.00
Check Analyses (Atlantic Analytical Services)	120.00
Miscellaneous (Aircraft Rental - Air Photographs etc.)	3,040.00
Total	$19,870.00

APPENDIX F

TABLE 21

SEDIMENTOLOGICAL DATA

Sample Number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
T-1	4'	grey till	38.0	54.6	7.4
T-2	4'	grey till	54.3	33.0	12.7
T-3	4'	grey till	23.2	42.0	34.8
T-4	4.5'	grey till	35.3	43.8	21.0
T-5	4.5'	grey till	46.8	39.0	14.2
T-6	8'	grey till	49.3	47.0	3.7
T-7	4'	grey till	34.0	41.0	25.0
T-8	4'	grey till	17.6	56.6	25.8
T-9	4'	grey till	44.7	41.0	14.3
T-10	4'	grey till	27.8	63.6	8.6
T-11	4'	grey till	62.3	33.5	4.2
T-12	6'	grey till	49.6	22.6	27.8
T-13	5.5'	grey till	38.0	39.0	23.0
T-14	4.5'	grey till	36.2	34.8	29.0
T-15	6'	grey till	20.2	47.8	32.0
T-16	4'	grey till	47.2	47.0	5.8
T-17	5'	grey till	37.6	35.5	26.9
T-18	5'	grey till	50.0	33.9	16.1
T-19	4'	grey till	63.6	23.1	13.3
T-20	4'	grey till	53.9	26.0	20.0

See Figure12 for pit locations. T = dug by hand, TB = dug by backhoe.

SEDIMENTOLOGICAL DATA

Sample number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
T-21	5'	grey till	56.1	27.0	16.9
TB-22 high	4'	grey till	35.8	38.6	25.6
TB-22 low	7'	grey till	72.4	16.9	10.7
TB-23 high	3'	grey till	54.6	33.0	12.4
TB-23 low	5'	grey till	54.6	28.8	16.6
TB-24	7'	grey till	43.2	53.0	3.8
TB-25	7.5'	grey till	63.5	35.3	1.2
TB-26	7'	grey till	45.3	31.2	23.5
TB-27	7'	grey till	63.1	24.7	12.2
TB-28 high	3'	grey till	49.3	47.0	3.7
TB-28 low	6'	grey till	60.2	25.9	13.9
TB-29 high	4'	grey till	52.7	33.7	13.6
TB-29 low	8'	grey till	51.6	33.8	14.6
TB-30	7.5'	grey till	47.2	36.2	16.6
TB-31	7.5'	grey till	45.6	40.6	13.8
TB-32	7'	grey till	44.1	49.7	6.2
TB-33 high	4'	grey till	49.0	37.5	13.5
TB-33 low	8'	grey till	45.0	44.7	10.3
TB-34	7'	grey till	47.2	45.7	7.1

SEDIMENTOLOGICAL DATA

Sample number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
TB-35	6.5'	grey till	48.1	45.0	6.9
TB-36 high	4'	glacio-fluvial	58.4	36.4	5.2
TB-36 low	8'	glacio-fluvial	35.8	42.0	22.2
TB-37 high	4'	grey till	36.8	41.4	21.9
TB-37 low	8'	grey till	39.2	41.3	19.5
TB-38 high	4.5'	grey till	45.6	43.9	10.5
TB-38 low	8'	grey till	35.1	39.4	25.5
TB-39	7'	grey till	45.0	33.2	21.8
TB-40	7'	grey till	55.5	41.2	3.3
TB-41	8'	grey till	36.5	41.3	22.2
TB-42 high	3'	grey till	42.0	41.9	16.1
TB-42 low	7.5'	grey till	44.0	41.8	14.2
TB-43 high	4'	grey till	49.0	37.0	14.0
TB-43 low	7.5'	grey till	38.9	49.4	11.7
TB-44	7'	grey till	64.8	30.4	4.8
TB-45	7'	grey till	59.7	35.3	5.0
TB-46 Profiles A	10'	grey till	52.0	40.0	8.0
B	9'	grey till	53.4	35.4	11.2
C	8'	grey till	50.4	42.0	7.6
D	7'	grey till	55.3	37.5	7.2
E	6'	grey till	48.1	40.4	11.5
F	5'	grey till	44.3	41.8	13.9

SEDIMENTOLOGICAL DATA

Sample Number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt and clay)
G	4'	grey till	53.2	38.8	8.0
H	3'	grey till	48.7	39.6	11.7
TB-47	7.5'	grey till	27.5	37.3	35.2
TB-48	7'	grey till	60.3	28.5	11.2
TB-49	8'	grey till	65.9	25.0	9.1
TB-50	7'	grey till	51.1	36.7	12.2
TB-51	7.5'	grey till	60.3	28.7	11.0
TB-52	7.5'	grey till	50.3	44.0	5.7
TB-53	7.5'	grey till	44.3	39.9	15.8
TB-54	7'	grey till	67.8	22.0	10.2
TB-55	8'	grey till	46.7	48.5	4.8
TB-56	8'	grey till	45.8	38.8	15.4
TB-57	7.5'	grey till	46.8	36.4	16.8
TB-58	8'	grey till	23.6	51.5	24.9
TB-59 high	4'	grey till	48.1	34.7	17.2
TB-59 low	8'	grey till	48.9	37.7	13.4
TB-60 high	3'	grey till	39.5	35.0	25.5
TB-60 low	6'	grey till	45.4	37.6	17.0
TB-61	7'	grey till	18.4	45.0	36.6
TB-62	6'	grey till	24.8	44.0	31.2

SEDIMENTOLOGICAL DATA

Sample Number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
TB-63 high	4'	grey till	37.4	38.7	23.9
TB-63 low	7'	grey till	40.0	40.5	19.5
TB-64 Profiles A	8'	grey till	37.3	38.1	24.6
B	7'	grey till	33.3	36.1	30.5
C	6'	grey till	51.3	38.2	10.5
D	5'	grey till	40.0	36.3	23.7
E	4'	grey till	41.6	44.8	13.6
TB-65 low	7'	red till	53.5	31.0	25.5
TB-65 high	4'	grey till	25.2	40.3	34.5
TB-66 high	4'	grey till	38.8	50.6	10.6
TB-66 low	8'	grey till	26.0	45.5	28.5
TB-67	7.5'	grey till	38.7	33.2	28.1
TB-68	6'	G.F. (?)	30.4	50.1	19.5
TB-69	7'	grey till	59.2	33.3	7.5
TB-70 Profiles A	8'	red till	51.2	32.1	16.7
B	7'	red till	47.1	37.5	15.4
C	6'	grey till	44.5	40.1	15.4
D	5'	grey till	35.4	47.8	16.8
E	4'	grey till	18.6	42.3	39.1

SEDIMENTOLOGICAL DATA

Sample number		Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
TB-70B	Profiles A	7'	Red till	73.9	18.2	7.9
	B	6'	grey till	66.1	25.4	8.5
	C	5'	grey till	57.7	32.0	10.3
	D	4'	grey till	42.4	36.9	20.7
	E	3'	grey till	43.7	35.2	21.1
T-71		5'	grey till	39.6	47.7	12.7
T-72		5'	grey till	55.2	36.8	8.0
T-73		4'	grey till	55.0	32.4	12.6
T-74		4.5'	grey till	69.7	17.5	12.8
T-75		5'	grey till	50.3	44.2	5.5
T-76		4'	grey till	44.1	36.1	19.8
T-77		5'	grey till	69.8	22.1	8.1
T-78		4.5'	grey till	38.9	40.3	20.8
T-79		4'	grey till	34.7	38.8	26.5
T-80		4'	grey till	45.7	35.7	18.6
T-81		4'	grey till	38.0	45.1	16.9
T-82		4.5'	grey till	44.9	36.0	19.1
T-83		5'	grey till	31.8	42.5	25.7
T-84		5'	grey till	42.6	26.3	31.1
T-85		4'	grey till	61.7	24.7	13.6
T-86		5.5'	grey till	65.9	23.8	10.3

SEDIMENTOLOGICAL DATA

Sample number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
T-87	4.5'	red till	42.2	36.0	21.8
T-88	5'	grey till	60.6	27.8	11.6
TB-89 high	4'	grey till	14.6	53.5	31.9
TB-89 low	8'	grey till	12.8	53.5	33.7
TB-90 high	4'	grey till	28.5	44.1	27.4
TB-90 low	8'	red till	28.7	50.8	20.5
TB-91A low	8'	grey till	31.4	40.3	28.3
TB-91A high	4'	grey till	34.6	38.0	27.4
TB-91B low	8.5'	red till	49.4	33.3	17.3
TB-91B high	4'	grey till	16.8	41.2	42.0
TB-91B middle	6'	red & grey	50.4	27.9	21.7
TB-92 high	4'	grey till	38.2	39.0	22.8
TB-92 low	8'	red till	62.9	28.8	8.3
TB-92B Profiles A	7.5'	red till	58.4	31.0	10.6
B	6.5'	red till	63.7	25.0	11.3
C	5.5'	red & grey	64.0	18.7	17.3
D	4.5'	grey till	49.7	31.2	19.1
E	3.5'	Grey till	34.1	42.5	23.4
TB-93 high	4'	grey till	18.5	59.1	22.4
TB-93 low	8.5'	grey till	13.1	56.2	30.7

SEDIMENTOLOGICAL DATA

Sample number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
TB-94 high	4'	grey till	30.1	43.5	26.4
TB-94 low	7'	grey till	13.2	50.5	36.3
TB-95 High	8'	grey till	15.1	51.0	33.9
TB-95 low	4'	grey till	19.6	51.8	28.6
TB-96 high	5'	grey till	42.3	32.2	25.5
TB-96 low	9.5'	grey till	26.5	45.6	27.9
TB-97 high	4'	red till	46.6	42.4	11.0
TB-97 low	8'	red till	29.7	44.3	26.0
TB-98 high	5'	grey till	24.0	55.1	20.9
TB-98 low	9'	grey till	32.9	44.9	22.2
TB-99 high	4'	grey till	50.4	37.5	12.1
TB-99 low	8'	grey till	43.8	41.0	15.2
TB-100 high	3'	G.F. (?)	46.1	29.7	24.2
TB-100 low	6'	G.F. (?)	53.2	28.0	18.8
TB-101	6.5'	G.F. (?)	11.5	53.6	34.9
T B-102 Profiles A	8'	red till	44.7	39.2	16.1
B	7'	red till	51.9	31.8	16.3
C	6'	grey till	48.1	35.9	16.0
D	5'	grey till	47.9	34.4	17.7
E	4'	grey till	53.3	34.7	12.0
F	3'	grey till	42.0	44.0	14.0

SEDIMENTOLOGICAL DATA

Sample Number	Depth	Material	% 16mm-2mm (gravel)	% 2mm-0.063mm (sand)	% -0.063mm (silt & clay)
T-103	5'	grey till	52.2	33.4	14.4
T-104	4'	red till	47.0	37.6	15.4
T-105	5.5'	red till	51.8	31.6	16.6
T-106	4'	grey till	44.3	34.4	21.3

TABLE 21 SEDIMENTOLOGICAL DATA (Concluded)

APPENDIX G

TABLE 22

	PEBBLE COUNTS					TILL FABRIC			
Sample #	% Granite (18)	% Rhyolite (11A)	% Andesite (14)	% Others	Total Counted	Till Type (Grey or Red)	Depth (in feet)	Dominant Mode (Az.)	Secondary Mode (Az.)
T-1	59	8	33	-	203	G	4	030	345
T-2	91	7	2	-	330	G	4	015	090
T-3	30	61	-	9	252	G	4	315	020
T-4	15	50	35	-	236	G	4.5	325	045
T-5	24	22	47	7	315	G	4.5	300	-
T-6	40	39	-	21	345	G	8	335	060
T-7	36	64	-	-	252	G	4	320	035
T-8	46	40	-	14	353	G	4	045	100
T-9	63	19	18	-	357	G	4	000	065
T-10	40	25	35	-	587	G	4	345	-
T-11	46	18	36	-	463	G	4	015	130
T-12	NONE TAKEN DUE TO COMPACTED TILL								
T-13	56	32	-	12	224	G	5.5	060	015
T-14	35	30	-	35	316	G	4.5	015	-
T-15	37	23	40	-	362	G	6	335	020
T-16	17	17	66	-	302	G	4	000	035
T-17	3	-	97	-	410	G	5	045	-
T-18	14	4	82	-	415	G	5	060	350
T-19	2	-	98	-	284	G	4	040	075
T-20	-	-	100	-	324	G	4	355	-
T-21	5	95	-	-	360	G	5	340	-
TB-22 low	2	5	92	1	570	G	7	270	290
TB-22 High	7	14	75	4	387	G	4	335	030

See Figure 12 for sample locations.
Rock type numbers correspond to those of Neale and Nash, 1963.
G - denotes grey till; R-denotes red till; GF - denotes "Washed" grey till.
T - denotes pit dug by hand; TB - denotes pit dug by back hoe.

TABLE 22

	PEBBLE COUNTS					TILL FABRIC			
Sample #	% Granite (18)	% Rhyolite (11A)	% Andesite (14)	% Others	Total Counted	Till Type (Grey or Red)	Depth (in feet)	Dominant Mode (Az.)	Secondary Mode (Az.)
TB-23 low	26	18	49	7	366	G	5	335	-
TB-23 high	13	14	49	24	385	G	3	000	090
TB-24	26	13	59	2	335	G	7	340	040
TB-25	30	30	40	-	419	G	7.5	015	110
TB-26	20	-	80	-	490	G	7	090	015
TB-27	36	8	52	4	494	G	7	080	045
TB-28	-	-	100	-	316	G	6	015	095
TB-29 low	19	-	81	-	344	G	8	005	060
TB-29 high	20	-	80	-	239	G	4	015	-
TB-30	9	3	88	-	450	G	7.5	035	135
TB-31	52	6	42	-	316	G	7.5	285	-
TB-32	98	2	-	-	454	G	7	290	355
TB-33 low	58	8	34	-	442	G	8	310	350
TB-33 high	37	11	35	17	291	G	4	330	065
TB-34	88	8	4	-	513	G	7	340	065
TB-35	99	-	1	-	318	G	6.5	040	320
TB-36 low	32	-	68	-	352	GF (?)	8	RANDOM ORIENTATION	
TB-36 high	32	6	62	-	370	GF (?)	4	020	095
TB-37 low	49	13	38	-	471	G	8	070	000
TB-37 high	28	18	51	3	326	G	4	015	100
TB-38 low	19	11	59	11	535	G	8	050	100
TB-38 high	34	11	49	6	488	G	4	085	005
TB-39	34	13	43	10	296	G	7	345	-
TB-40	56	2	42	-	261	G	7	030	-
TB-41	77	11	9	3	504	G	8	350	270
TB-42 low	36	9	55	-	403	G	7.5	095	005
TB-42 high	21	10	65	4	691	G	4	010	315
TB-43 low	28	7	65	-	607	G	7.5	045	110
TB-43 high	31	7	62	-	485	G	4	030	350
TB-44	6	-	94	-	468	G	7	000	315
TB-45	9	4	87	-	739	G	7	030	-

TABLE 22

	PEBBLE COUNTS					TILL FABRIC			
Sample #	% Granite (18)	% Rhyolite (11A)	% Andesite (14)	% Others	Total Counted	Till Type (Grey or Red)	Depth (in feet)	Dominant Mode (Az.)	Secondary Mode (Az.)
TB-46 low	21	3	74	2	641	G	10	340	-
TB-46 high	11	9	72	8	260	G	4	290	005
TB-47	22	10	68	-	495	G	7.5	270	-
TB-48	3	-	97	-	544	G	7	005	075
TB-49	13	12	75	-	478	G	8	030	115
TB-50	20	7	66	7	544	G	7	030	-
TB-51	49	-	48	3	584	G	7.5	015	105
TB-52	26	6	68	-	319	G	7.5	045	105
TB-53	70	4	21	5	417	G	7.5	045	115
TB-54	31	26	43	-	477	G	7	010	130
TB-55	43	7	50	-	491	G	8	355	100
TB-56	22	13	60	5	414	G	8	020	130
TB-57	70	6	24	-	515	G	7.5	330	-
TB-58	21	15	64	-	469	G	8	345	-
TB-59 low	-	1	99	-	433	G	8	355	285
TB-59 high	15	2	83	-	385	G	4	335	305
TB-60 low	10	5	85	-	347	G	6	345	270
TB-60 high	14	4	82	-	382	G	3	330	260
TB-61	11	62	27	-	466	G	7	270	350
TB-62	15	5	80	-	271	G	6	315	10
TB-63 low	22	17	61	-	470	G	7	005	110
TB-63 high	42	7	51	-	292	G	3.5	345	085
TB-64 low	20	4	76	-	442	G	8	345	255
TB-64 high	18	8	74	-	274	G	4	280	355
TB-65 low	3	3	94	-	358	R	7	040	-
TB-65 high	42	11	47	-	349	G	4	015	045
TB-66 low	48	11	41	-	407	G	8	060	-
TB-66 high	49	11	40	-	400	G	4	030	330

TABLE 22

	PEBBLE COUNTS					TILL FABRIC			
Sample #	% Granite (18)	% Rhyolite (11A)	% Andesite (14)	% Others	Total Counted	Till Type (Grey or Red)	Depth (in feet)	Dominant Mode (Az.)	Secondary Mode (Az.)
TB-67	20	21	59	-	394	G	7.5	300	-
TB-68	29	45	26	-	402	GF (?)	6	000	050
TB-69	-	-	100	-	352	G	7	060	300
TB-70 low	2	87	11	-	386	R	8	355	330
TB-70 high	3	91	6	-	451	G	4	335	000
TB-70B low	-	99	-	1	366	R	6	000	085
TB-70B high	3	94	-	3	198	G	3	330	-
T-71	50	-	1	49	415	G	5	015	095
T-72	63	-	-	37	286	G	5	065	165
T-73	15	8	75	2	398	G	4	030	125
T-74	88	1	11	-	550	G	4.5	005	-
T-75	-	22	76	2	360	G	5	040	-
T-76	20	14	62	4	427	G	4	320	020
T-77	27	1	65	7	589	G	5	345	-
T-78	34	15	43	8	343	G	4.5	280	000
T-79	27	10	57	6	369	G	4	060	350
T-80	37	7	53	3	334	G	4	015	-
T-81	36	9	52	3	439	G	4	060	-
T-82	20	34	41	5	288	G	4.5	130	040
T-83	35	13	49	3	367	G	5	095	000
T-84	62	17	20	1	363	G	5	290	345
T-85	63	3	34	-	326	G	4	275	-
T-86	15	12	73	-	175	G	5.5	025	-
T-87	39	10	47	4	297	R	4.5	055	335
T-88	29	8	61	2	404	G	5	020	275
TB-89 low	22	27	50	1	472	G	8	350	-
TB-89 high	27	11	62	-	422	G	4	275	-
TB-90 low	31	18	49	2	348	G	8	015	250
TB-90 high	34	17	45	4	249	G	4	270	330

TABLE 22

	PEBBLE COUNTS					TILL FABRIC			
Sample #	% Granite (18)	% Rhyolite (11A)	% Andesite (14)	% Others	Total Counted	Till Type (Grey or Red)	Depth (in feet)	Dominant Mode (Az.)	Secondary Mode (Az.)
TB-91A low	20	7	72	1	358	R	8	015	-
TB-91A high	31	10	59	-	305	G	4	335	045
TB-91B low	5	3	92	-	331	R	8.5	040	-
TB-91B high	16	7	73	4	374	G	3	005	270
TB-91B middle	19	-	76	5	249	R	5.5	-	-
TB-92 low	-	12	88	-	150	R	8	030	335
TB-92 high	19	16	65	-	424	G	4	345	065
TB-92B low	-	43	57	-	145	R	7.5	045	330
TB-92B high	27	14	56	3	389	G	3.5	340	070
TB-93 low	43	19	37	1	339	G	8.5	020	065
TB-93 high	40	19	38	3	357	G	4	010	065
TB-94 low	21	13	63	3	297	G	7	000	-
TB-94 high	18	30	51	1	262	G	3.5	345	230
TB-95 low	40	13	46	1	351	G	8	015	090
TB-95 high	24	18	58	-	495	G	4	000	090
TB-96 low	8	13	75	4	333	G	9.5	355	-
TB-96 high	9	9	82	-	472	G	4.5	325	050
TB-97 low	-	1	99	-	389	R	8	045	345
TB-97 high	-	-	100	-	423	R	4	030	310
TB-98 low	29	18	50	3	400	G	9	350	-
TB-98 high	35	23	40	2	306	G	4.5	330	275
TB-99 low	11	-	89	-	425	G	8	085	015
TB-99 high	20	3	77	-	336	G	4	110	035
TB-100 low	24	8	68	-	458	GF (?)	6	285	010
TB-100 high	14	20	66	-	294	GF (?)	3	085	-
TB-101	36	8	54	2	365	GF (?)	6.5	030	125
TB-102 high	20	43	37	-	338	R	8	330	-

TABLE 22

PEBBLE COUNTS						TILL FABRIC			
Sample #	% Granite (18)	% Rhyolite (11A)	% Andesite (14)	% Others	Total Counted	Till Type (Grey or Red)	Depth (in feet)	Dominant Mode (Az.)	Secondary Mode (Az.)
T-103	1	2	97	-	376	G	5	330	055
T-104	-	-	100	-	423	R	4	065	325
T-105	-	-	100	-	376	R	5.5	065	330
T-106	22	-	-	78	246	G	4	015	105

TOTAL SAMPLES
141

TOTAL PEBBLES
54,581

Average of 385 pebbles/sample counted

PEBBLE COUNTS (COMPLETED)

APPENDIX H

TABLE 23

GEOCHEMICAL DATA

#	ppm Cu	ppm Pb	ppm Zn	ppm Co	ppm Ni	ppm Mn	% Fe	ppm S
1	8	4	21	5	20	153	0.6	34
1"H"	27	16	44	25	47	245	2.0	NA
1"L"	NA	NA	NA	NA	NA	NA	NA	NA
2	18	6	14	2	9	220	1.4	NA
3	8	8	25	1	26	185	0.6	30
4	8	9	50	2	6	268	1.0	NA
5	35	11	50	10	33	280	0.8	NA
6	23	9	60	8	26	320	1.6	"
7	10	5	24	2	26	173	1.0	"
8	10	65	20	7	99	118	0.3	"
9	13	15	20	2	13	155	0.9	"
10	45	95	63	2	45	260	0.9	Trace
11	20	65	34	3	26	280	0.8	NA
12	13	105	75	6	68	500	1.1	NA
13	5	7	18	2	44	135	0.6	Trace
14	3	5	14	4	15	135	0.5	NA
15	10	4	20	2	9	168	0.8	Trace
15"H"	25	20	46	8	30	255	1.9	NA
15"L"	NA	NA	NA	NA	NA	NA	NA	NA
16	28	5	35	2	6	315	1.5	"
17	13	7	18	2	10	265	1.3	"
18	16	2	26	2	13	200	0.9	"
19	30	9	45	5	18	390	2.1	"
20	18	5	48	3	20	335	2.0	"
21	46	4	34	2	16	350	1.1	"
22L	98	7	65	5	10	308	1.6	"
22L"H"	250	17	315	35	35	297	7.5	"
22L"L"	208	9	60	3	5	325	2.1	"
22H	24	6	25	2	8	178	0.7	"
23L	27	30	23	3	12	205	0.6	"
23H	33	60	21	1	26	240	0.7	"
24	18	11	21	3	13	163	0.7	"
25	WATER FILLED N.A.							
26	200	8	36	5	28	275	0.8	"
27	38	3	24	6	20	185	0.9	"
28L	73	5	25	2	12	218	1.7	"
28H	63	5	20	3	14	153	1.3	"
29L	53	9	21	6	20	180	0.6	"
29H	75	5	20	2	17	275	0.8	"
30	68	3	29	3	110	190	0.6	"
31	45	8	20	6	18	153	0.6	"
31(2)	50	7	20	6	20	153	0.4	"
32	15	3	26	7	19	238	0.7	"
33L	45	6	16	2	26	174	0.9	"
33H	43	60	21	6	25	143	0.8	"
34	53	3	16	3	20	198	0.7	"
35	18	6	20	6	20	155	0.7	20

GEOCHEMICAL DATA

#	ppm Cu	ppm Pb	ppm Zn	ppm Co	ppm Ni	ppm Mn	% Fe	ppm S
36L	15	7	20	2	13	160	0.6	NA
36H	15	7	20	2	6	220	0.6	"
37L	10	6	15	1	5	148	0.7	"
37H	28	65	20	6	63	143	0.5	"
38L	18	4	21	2	3	205	0.9	"
38H	30	3	28	7	16	230	0.8	"
39	22	3	35	8	22	215	0.8	NA
40	55	8	18	6	24	165	1.3	"
41	37	19	48	7	26	445	1.5	"
42L	13	8	18	2	4	165	0.8	"
42H	18	8	34	2	13	225	1.2	"
43L	13	6	28	2	3	185	0.8	"
43L(2)	15	5	28	2	20	195	0.9	"
43H	14	8	20	2	25	220	0.8	"
44	13	6	32	3	19	315	2.1	"
45	15	9	20	6	20	230	[illegible].0	"
46 A	16	6	25	2	10	253	0.9	NA
B	18	75	35	8	33	230	0.8	"
C	18	5	25	2	6	233	1.2	"
D	23	4	24	8	23	218	0.9	"
E	23	65	28	7	18	240	0.6	"
F	15	5	20	2	6	228	1.0	"
G	20	5	38	10	21	190	1.0	"
H	16	7	21	2	6	183	1.2	"
47	28	5	30	3	12	260	1.1	"
47(2)	20	8	31	2	10	253	1.1	"
48	8	8	90	9	20	260	2.3	"
49	6	60	34	6	28	500	2.1	"
50	18	6	21	9	13	225	1.0	"
51	23	3	30	9	6	266	0.9	"
52	13	6	28	3	19	240	0.8	5
53	15	3	25	11	18	215	1.0	Trace
53(2)	23	75	26	3	15	220	0.8	Trace
54	38	75	50	3	18	435	1.0	NA
55	23	15	42	6	5	238	1.9	"
56	28	9	26	2	10	230	1.1	"
57	23	9	38	1	9	200	1.0	8
58	15	30	26	8	10	240	1.3	NA
58(2)	16	4	28	8	13	235	0.8	NA
59L(1)	150	6	100	7	28	475	2.5	74
(2)	145	9	105	8	16	500	2.3	54
(3)	133	6	100	7	20	600	2.7	81
(4)	164	9	320	22	15	600	2.6	93
(5)	170	7	240	30	18	825	2.4	62
(6)	178	7	80	22	18	628	2.4	65
(7)	185	4	105	21	17	633	2.5	77
(8)	180	8	100	20	16	640	2.6	68
(9)	165	7	99	23	15	610	217	74
(10)	165	7	99	21	18	626	2.9	74

GEOCHEMICAL DATA

#	ppm Cu	ppm Pb	ppm Zn	ppm Co	ppm Ni	ppm Mn	% Fe	ppm S
59L"H"	218	8	113	60	32	612	4.0	NA
59L"L"	87	5	110	35	23	585	2.6	NA
59H	23	7	16	2	17	160	0.6	70
60L	45	5	36	5	6	390	1.5	68
60H	45	60	58	6	37	250	1.0	20
61	5	2	28	1	9	170	0.8	24
62	23	5	28	2	9	225	1.1	Trace
62(2)	23	5	26	3	5	225	1.3	NA
63L	23	2	28	2	6	212	0.9	NA
63H	25	10	29	2	25	245	1.0	"
64A	23	5	25	10	20	285	0.9	Trace
64A"H"	38	17	44	30	19	332	1.9	NA
64A"L"	NA	NA	NA	NA	NA	NA	NA	NA
B	28	10	30	10	25	300	1.0	29
C	28	3	31	12	15	243	1.0	20
C(2)	23	4	28	14	16	273	1.2	NA
D	23	3	18	5	18	110	0.6	97
E	23	7	35	8	32	293	1.1	20
E(2)	31	30	36	9	33	280	1.2	NA
65L	30	10	30	5	6	250	1.8	154
65L"H"	50	8	43	8	26	475	3.7	NA
65L"L"	15	3	14	5	20	138	1.5	NA
65H	18	6	17	5	6	140	0.8	5
66L	8	9	17	4	4	125	0.5	4
66H	8	5	25	4	13	158	0.5	19
66H"H"	15	19	49	12	7	192	1.4	Trace
67(1)	13	7	90	9	25	180	0.8	"
(2)	18	7	34	4	15	188	0.8	"
(3)	20	7	30	4	10	175	0.6	NA
(4)	15	9	32	1	8	190	0.9	NA
(5)	15	5	50	2	5	205	0.6	"
(6)	16	7	26	2	5	177	0.9	"
(7)	18	4	32	4	11	200	0.8	"
(8)	18	4	36	4	12	200	0.9	"
(9)	17	7	37	3	9	190	0.7	"
(10)	17	7	36	5	10	188	0.8	"
67"H"	31	22	72	14	34	332	1.9	"
67"L"	12	2	34	5	32	250	0.9	"
68	8	9	45	6	20	248	0.8	"
69	98	31	132	20	19	220	2.5	Trace
70A	151	175	202	30	67	575	5.6	284
70A(2)	153	175	200	9	78	550	5.8	NA
70A"H"	160	43	244	30	48	650	19.0	NA
70A"L"	115	175	252	28	28	588	5.7	NA
70B	63	63	187	27	19	540	3.8	120
C	15	19	63	9	13	300	1.0	Trace
D	8	13	60	8	25	245	1.1	Trace
E	1	12	50	8	6	140	0.9	30

GEOCHEMICAL DATA

#	ppm Cu	ppm Pb	ppm Zn	ppm Co	ppm Ni	ppm Mn	% Fe	ppm S
70B A	98	16	110	29	6	563	2.5	120
B	40	40	155	6	28	400	2.3	Trace
C	45	18	171	19	20	700	3.0	34
D	20	20	92	15	15	488	1.7	14
E	5	14	49	2	50	135	0.9	NA
71	15	60	43	11	115	220	1.1	"
72	41	7	23	7	12	325	1.5	"
73	30	7	19	2	14	225	1.0	"
74	55	16	33	3	13	226	1.5	"
75	8	25	32	5	10	217	4.6	"
76	23	5	18	2	6	220	0.8	"
77				2	20	214	1.1	"
78	15	5	19	1	8	203	0.6	"
79(1)	33	5	17	4	48	190	1.7	"
79(2)	10	6	23	4	8	255	1.6	"
80	18	5	38	1	8	145	0.7	NA
81	83	9	25	2	34	248	1.1	14
82	15	5	24	2	8	188	0.6	NA
83	13	5	19	1	13	140	0.6	"
84	18	5	14	1	14	170	0.7	"
85	45	9	14	3	14	235	1.0	"
86(1)	15	9	35	2	13	188	3.5	525
(2)	NA	NA	NA	NA	NA	NA	NA	544
(3)	"	"	"	"	"	"	"	527
(4)	"	"	"	"	"	"	"	544
(5)	"	"	"	"	"	"	"	489
(6)	"	"	"	"	"	"	"	484
(7)	"	"	"	"	"	"	"	467
(8)	"	"	"	"	"	"	"	484
(9)	"	"	"	"	"	"	"	466
(10)	"	"	"	"	"	"	"	432
86"H"	30	13	34	6	25	213	4.5	NA
86"L"	5	8	20	2	13	200	2.9	NA
87	30	3	19	19	10	500	0.6	30
88	18	9	14	1	8	205	0.7	10
89L	15	3	29	8	6	180	0.9	Trace
89L"H"	40	18	70	25	44	332	2.1	NA
89L"L"	NA	NA	NA	NA	NA	NA	NA	NA
89H	38	9	108	2	33	188	0.8	10
90L	18	7	18	2	14	190	0.6	Trace
90H	16	3	22	9	6	188	0.8	Trace
91AL	18	9	20	2	20	191	1.8	117
91AL"H"	28	10	46	13	40	175	2.1	NA
91AL"L"	17	7	36	8	24	265	0.9	NA
91AL"L"(2)	18	NA	NA	NA	NA	262	2.5	NA
91AH	18	7	18	2	17	155	0.9	Trace
91AH"H"	27	17	36	12	32	122	2.4	NA
91AH"L"	15	3	19	15	30	NA	0.8	NA

GEOCHEMICAL DATA

#	ppm Cu	ppm Pb	ppm Zn	ppm Co	ppm Ni	ppm Mn	% Fe	ppm S
91BL	23	7	29	7	26	310	3.0	394
91BM	38	13	40	12		275	1.7	29
91BH	48	8	27	6	15	240	1.3	85
92L	195	13	41	44	20	775	11.4	2515
92L(2)	173	13	30	37	28	563	12.2	2545
92L"H"	166	17	70	15	30	463	11.4	NA
92L"L"	160	12	24	34	65	620	10.1	NA
92H	41	4	31	17	15	450	1.5	153
92H"H"	95	17	54	21	40	385	3.5	NA
92H"L"	27	6	73	9	30	282	1.2	NA
92B A	300	19	50	11	15	550	10.0	1635
B	54	37	80	8	13	333	4.5	1481
C	53	24	32	8	15	275	3.4	292
D	38	7	24	13	10	260	1.1	45
E	40	7	25	3	16	135	1.1	22
93L	8	6	16	8	6	130	0.5	NA
93H	8	7	24	3	30	135	0.6	5
94L	24	16	25	8	20	240	0.9	7
94L"H"	110	17	59	17	23	332	2.4	NA
94L"L"	NA	NA	NA	NA	NA	NA	NA	NA
94H	18	4	32	8	21	158	0.9	5
94H(2)	15	9	32	8	20	185	0.7	NA
95L	8	8	85	5	10	120	0.5	19
95L"H"	18	15	44	21	30	332	1.9	NA
95L"L"	NA	NA	NA	NA	NA	NA	NA	NA
95H	15	7	26	8	13	145	0.8	Trace
96L	38	10	90	19	15	650	2.2	10
96L(2)	35	7	60	18	15	813	1.6	NA
96H	59	14	170	5	28	410	2.4	Trace
97L	83	13	62	79	30	1700	4.5	230
97H	33	6	63	12	15	450	3.4	198
98L	15	10	30	8	20	173	0.8	Trace
98H	18	6	31	12	20	325	1.0	Trace
99L	28	9	31	2	50	240	1.1	50
99H	30	5	24	2	14	285	1.0	Trace
100L	85	17	150	2	20	375	2.5	NA
100H	75	8	114	8	13	375	2.5	NA
101	20	5	10	2	8	90	0.5	NA
102 A	38	6	28	7	14	136	2.0	27
102 A"H"	40	11	37	19	25	87	3.4	NA
102 A"L"	NA	NA	NA	NA	NA	NA	NA	NA
102 B	35	8	20	2	12	125	1.5	138
C	28	7	16	2	6	115	1.5	118
D	25	9	16	2	10	110	1.3	35
E	28	3	26	5	19	125	1.7	35
F	30	10	23	8	20	140	1.4	65

GEOCHEMICAL DATA

#	ppm Cu	ppm Pb	ppm Zn	ppm Co	ppm Ni	ppm Mn	% Fe	ppm S
103	232	7	36	50	25	1000	2.8	245
103(2)	223	6	32	NA	19	705	2.4	NA
103"H"	255	7	24	50	32	577	3.4	NA
103"L"	NA	NA	NA	NA	NA	NA	NA	NA
104	60	6	40	8	15	480	3.6	157
104"H"	68	7	33	10	26	500	3.9	NA
104"L"	55	6	32	9	28	425	0.7	NA
105	126	18	110	8	14	475	5.4	366
106	28	7	22	2	8	135	0.8	Trace
R70								192
R92F	43(45)	5	30	20	55	580	3.9	1450
F1	218(195)	50	132	93	108	125	16.2	39100
F2	173(150)	32	52	143	130	750	15.7	28400
F3	238(210)	23	320	90	83	1250	15.3	23600
R60	15(8)	3	14	47	30	163	0.7	34
R92W	120(113)	6	22	29	55	680	4.8	4800

Table 23 Concluded

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