CHEMICAL STUDIES OF THE HOST ROCKS OF THE LAKE DUFAULT MINE, QUEBEC

by

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A thesis submitted to the faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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INTRODUCTION

This thesis is the outcome of a proposal made in the spring of 1962 by W. C. Martin to Falconbridge Nickel Mines Limited and Lake Dufault Mines Limited. Mr. Martin suggested the application of geochemical prospecting techniques to the problem of finding blind ore bodies on a property of Lake Dufault Mines Limited, the site of a new base metal discovery. The writer was employed to make preliminary studies for this purpose. He spent the first month of the summer of 1962 absorbing facts and ideas about the geology of the area. The remainder of the summer was spent collecting diamond drill core samples for chemical analysis. Chemical analyses were performed in the Department of Geological Sciences, McGill University.

It is the purpose of this thesis to report the results of this geochemical study and to interpret the chemical features of the host rocks of the Lake Dufault Mine on the basis of what is known of the geology of the Noranda area in general and of the Lake Dufault Mine in particular.

PREVIOUS WORK

Wilson (1910) and Cook, James and Mawdsley (1931) provided the first summary reports on the geology of the Noranda area. Wilson's (1941) memoir remains a standard reference. More recently, Robinson (1951), Dugas and Hogg (1962), Gilmore (1965) and Roscoe (1965) have contributed to the general knowledge of the Noranda area.

The first chemical data from the Noranda area were published by Wilson (1941) who noticed, among other things, that the volcanic rocks had a "...large proportion of soda in contrast with the small content of potash...", a relation first suggested by Schindler (1934) from petrographic data. Additional chemical data were presented by Riddell (1952) who established the chemical features of wallrock alteration in the district. Lickus (1965) gives many chemical analyses of rock on the property of Vauze Mines Limited. Roscoe (1965) published chemical analyses for major units of the Noranda volcanic rocks plus some chemical analyses of minerals.

Many studies of individual mines have been recorded, the most detailed of which include that of the Horne Mine by Price (1933, 1934, 1949) and that of the Vauze Mine by Lickus (1965).

Wilson (1941, p. 60) lists the following structural features associated with the massive sulphide ore deposits of the Noranda district: 1. faults, 2. pyroclastic and tectonic breccia in volcanic rock, 3. impermeable rock "barriers" above the deposits and, in some cases, 4. anticlinal folds. Wilson also reviews conflicting arguments which bear on the relationship of "late" diabase dikes to ore. Wilson favored a post-diabase age for the Noranda deposits and hence, like many of his contemporaries who studied the geology of the Noranda district, believed that the sulphide ore bodies were formed after their host rocks had been deformed and metamorphosed.

Since Wilson's memoir was published, additional information has become available and many geologists, perhaps influenced by the work of such men as Oftedahl (1958) and Stanton (1960), have come to realize that an alternate hypothesis is applicable to the problem of ore genesis in the Noranda district. They propose that the Noranda ore deposits and the volcanic rock in which they occur are contemporary products of Precambrian volcanic activity centered in the Noranda area. This idea was under serious consideration at the time of the C.I.M. Symposium on Massive Sulphide Deposits in 1959 (Gill, 1959). It has been advocated strongly during the past year by Gilmore (1965), Lickus (1965), and Goodwin (1965).

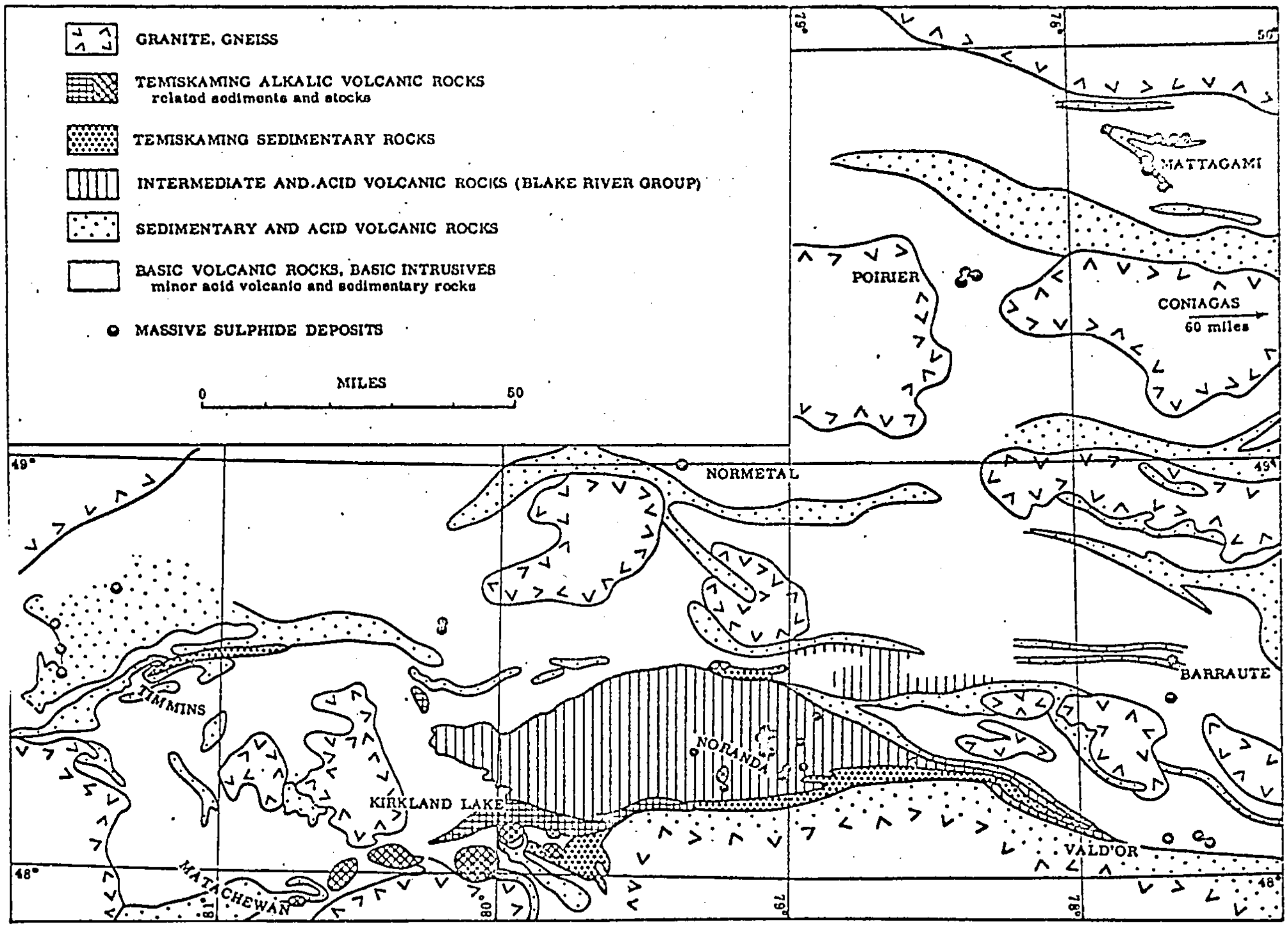

Fig. 1 Geological Setting of the Noranda Area. (from Roscoe,1965)

GEOLOGICAL SETTING

NORANDA AREA

INTRODUCTION

The Noranda ore deposits are all located in an elliptically shaped area (80 x 20 miles) of intermediate and siliceous volcanic rocks of Precambrian age. These rocks were called the "Blake River Group" by Gunning and Ambrose (1939) (fig. 1). To the south and parallel to the long axis of this area lies the east-trending Cadillac-Bouzan fault zone. South of this major "break" lie greywacke and conglomerate which give way still further south to metamorphosed sedimentary rocks mixed with granite and gneiss. All of these rocks are covered in places to the south and west by conglomerate and greywacke. The area to the north, east and west of the Noranda area consists mainly of mafic volcanic rocks and intrusives with minor bands of siliceous volcanic and sedimentary rocks.

EFFUSIVE ROCKS

Andesite

The rocks in the Noranda area that can be definitely recognized as flows range in chemical composition from basalts to dacites. Roscoe (1965) notes that the less mafic flows occur higher up in the sequence. Pillows and amygdales are common in these rocks, and minor flow breccia and chert have been reported. Microscopic examination of thin sections of andesite usually reveals clouded plagioclase feldspar with the alteration products, sericite, chlorite, actinolite, calcite and epidote, plus some quartz. Therefore the rocks of the Noranda area are properly placed in the greenschist facies of regional metamorphism. Schists are found only in fault zones.

Rhyolite

The only siliceous rocks in the area that might be classed as flows are small irregularly-shaped bodies of quartz-feldspar porphyry. One of these bodies has a flat base, a dome-like top and a long axis which trends N. 70° E. (staff, Lake Dufault Mines Ltd.). This "dome" is located 4,000 feet south of "the Lower A" ore body of the Amulet mine but is exposed only in a small area on the surface. It is suggested that these small siliceous bodies are the so called "endogenous domes" found so often in areas of siliceous volcanic activity (Rittman, 1962).

The remainder of the siliceous rocks have been called rhyolite, rhyolite flow breccia, rhyolite breccia and rhyolite tuff. In the opinion of the writer essentially all of this rock is pyroclastic. Most of the rhyolite units are thin relative to their areal extent and thus have a general form inconsistent with the shape of true siliceous lava flows. Often the most massive-appearing rhyolite can be seen, on closer examination, to consist entirely of fragments. The writer is convinced that detailed petrographic examination of the siliceous rocks of the Noranda area would, in most cases, reveal pyroclasts. A minor amount of bedded tuff occurs with much of the pyroclastic rock.

INTRUSIVE ROCKS

The intrusive rocks of the area include a myriad of dikes and sills of widely varying size, shape and composition. Some sills are closely related to the effusive rocks in the Noranda area (e.g., quartz porphyry, "metadiabase") and some dikes cut across all rock structures (e.g., "late" quartz-diabase). Many of the massive sulphide ore bodies are cut by dikes and probable sills (Lickus, 1965). Only the larger intrusive bodies for which some chemical data are available are described here.

Flavrian and Powell Granite

The Flavrian and Powell granite bodies are similar in many respects. Both intrusive masses contain abundant inclusions of rhyolite and other rocks, both are altered to a moderate degree with the development of chlorite, sericite, epidote and carbonate, and both cut andesite and rhyolite. On the basis of limited chemical work both have the same chemical composition (table 5, p.42). Both are also similar, chemically, to the rhyolite which they cut. This evidence suggests that the Flavrian and Powell granite and the rhyolite of the Noranda area all were crystallized from magmas of similar composition.

Lake Dufault Granodiorite

The Lake Dufault granodiorite is located to the east of the Flavrian mass, cutting andesite, rhyolite and diorite. The western half of the stock is relatively free of inclusions and is less altered than the Flavrian and Powell granite. The eastern half of the stock is a mixed rock (Webber, 1962) and contains a possible pendant of rhyolite in which the MacDonald ore body occurs. One analysis of a dacite flow at Vauze Mine corresponds to the few chemical analyses given for the granodiorite (Lickus, 1965) (table 5, p.42). The texture of granodiorite apophyses in country rock is as coarse as that of the main body (Wilson, 1941). It would seem therefore that the granodiorite intruded an already hot country rock.

Diorite Dike System

A map by J. Boldy (map I) shows a dike system around the Flavrian and Powell granite masses which, according to Wilson (1941), is composed of quartz diorite, diorite, gabbro, diorite porphyry and albite granite.[1] The variety of rock types plus the fact that internal chilled contacts have been observed in one of the larger dikes (Lickus, 1965), suggest that the rocks of the dike system have been intruded in a series of pulses. "Flat" or sill-like diorite is known to occur east of the Amulet mine, east of the Lake Dufault mine, at the Vauze ore body and near the Francoeur mine. Irregularly shaped areas of diorite are probably the "flat" or sill portions of the system. The dike portions of the system have steep dips so far as is known and actually lie along

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1. Some of Wilson's rock types may actually be unrelated to the diorite dike system. They may be massive portions of andesite flows or sills closely associated with the flows.

faults. These faults have a smaller apparent dip slip away from the Flavrian granite. The impression is gained that the diorite of the dike system encloses volcanic rock which was broken into huge blocks, possibly as a result of subsidence in the area of the Flavrian and Powell granite bodies.

STRUCTURE

Folding and Faulting

The structure of the Noranda area is relatively simple. The only strong deformation has occurred along the southern border of the area where the volcanic rocks became involved in the deformation along the Cadillac-Bouzon fault zone. Here, faults are numerous and the volcanic formations are folded. North of this deformed area the rocks are only gently folded (if at all) and the greatest deformational event seems to have been the faulting referred to in connection with the emplacement of the diorite dike system.

"Late" diabase dikes are offset by faults but are otherwise undeformed (map I), (Wilson, 1941, p. 47).

Lineaments and Domes

Many air photograph lineaments mark major faults, and post-ore faults have been noted at the Vauze (Lickus, 1965) and Lake Dufault mines (staff, Lake Dufault Mines Ltd.). Some lineaments have been shown to have great significance for it is at intervals along them that thickening of the rhyolite occurs. The Lake Dufault, Vauze and

Waite ore bodies are found at the top of locally thickened sections of rhyolite (Lickus, 1965; staff, Lake Dufault Mines Ltd.), a fact which suggests that rhyolite and ore may be genetically related.

MASSIVE SULPHIDE DEPOSITS

Gold-bearing quartz veins are found in most of the rock types present in the Noranda area, including the Flavrian and Powell granite. Minor, chalcopyrite bearing, quartz veinlets are present in the Powell granite on the Don Rouyn property and in extrusive rocks throughout the district.

All of the massive sulphide ore bodies in the Noranda area are found at the stratigraphic top of a siliceous pyroclastic rock unit except the upper ore bodies of the Old Waite mine and the Amulet "Upper A" ore bodies. The host rock for these ore bodies is andesite. The hanging wall rock for many ore bodies is bedded tuff or andesite. The ore bodies are tabular and their larger dimensions are essentially parallel to the nearest stratification or flow contact. In recent years many geologists have considered these features, which are common to many ore deposits, as suggestive of a close relationship between ore formation and an early volcanic environment (Thomson, 1960).

The massive sulphide ore bodies are easily grouped into combinations of (1) pyrite-sphalerite ore and (2) pyrite-chalcopyrite-pyrrhotite ore with or without sphalerite. Roscoe (1965) describes a large scale stratigraphic zoning in the Noranda district sulphide deposits. Sphalerite, often interlayered with pyrite and pyrrhotite (Lickus, 1965), is concentrated at the top of the massive sulphide ore and chalcopyrite is more common near the base and stratigraphically below massive ore in altered, mineralized rhyolite. This zoning holds true for the Horne deposits even though the strata are tilted to a vertical attitude. Roscoe suggests that such zoning in vertical strata must have been developed when the strata were in a sub-horizontal position. Interesting sulphide breccias have been noted at the Vauze mine (Lickus, 1965), at the West MacDonald deposit, and at one of the Horne ore bodies (Roscoe, 1965). Roscoe states that the breccias "contain displaced and corroded sulphide fragments and siliceous fragments that can be envisaged as bounced about during explosive fumarolic activity and recemented by sulphides and some siliceous material. These features suggest deposition at the surface, perhaps within loose tuffaceous materials." At the Vauze mine, Lickus describes sulphide fragments of contrasting mineral composition side by side in agglomerate. He suggests that fragmentation of sulphides must have been contemporaneous with the formation of the agglomerate. In summary, this evidence suggests that a genetic relationship exists between the Noranda area sulphide deposits and the volcanic rocks in which they are enclosed.

ALTERATION

The most striking feature of alteration in the Noranda area is the occurrence, with some of the ore bodies, of "Dalmatianite," a spotted rock containing biotite, cordierite and anthophyllite.

"Dalmatianite" is not found at the largest group of ore bodies in the district (the Horne mine) where only chlorite and sericite alteration is present. The significant facts of wallrock alteration in the Noranda area have been given by Riddell (1952). He shows that two styles of wallrock alteration corresponding to two types of massive sulphide ore deposits are present in the district. Sodium, magnesium and calcium have been leached, potassium has been fixed or added, and sericite has been formed in altered zones near massive sulphide bodies which contain pyrite and sphalerite but only minor copper. Where copper is present in the massive sulphides, magnesium has been added and chlorite has been formed. Sodium, calcium and, in some places, potassium have been removed from this last type of altered zone.

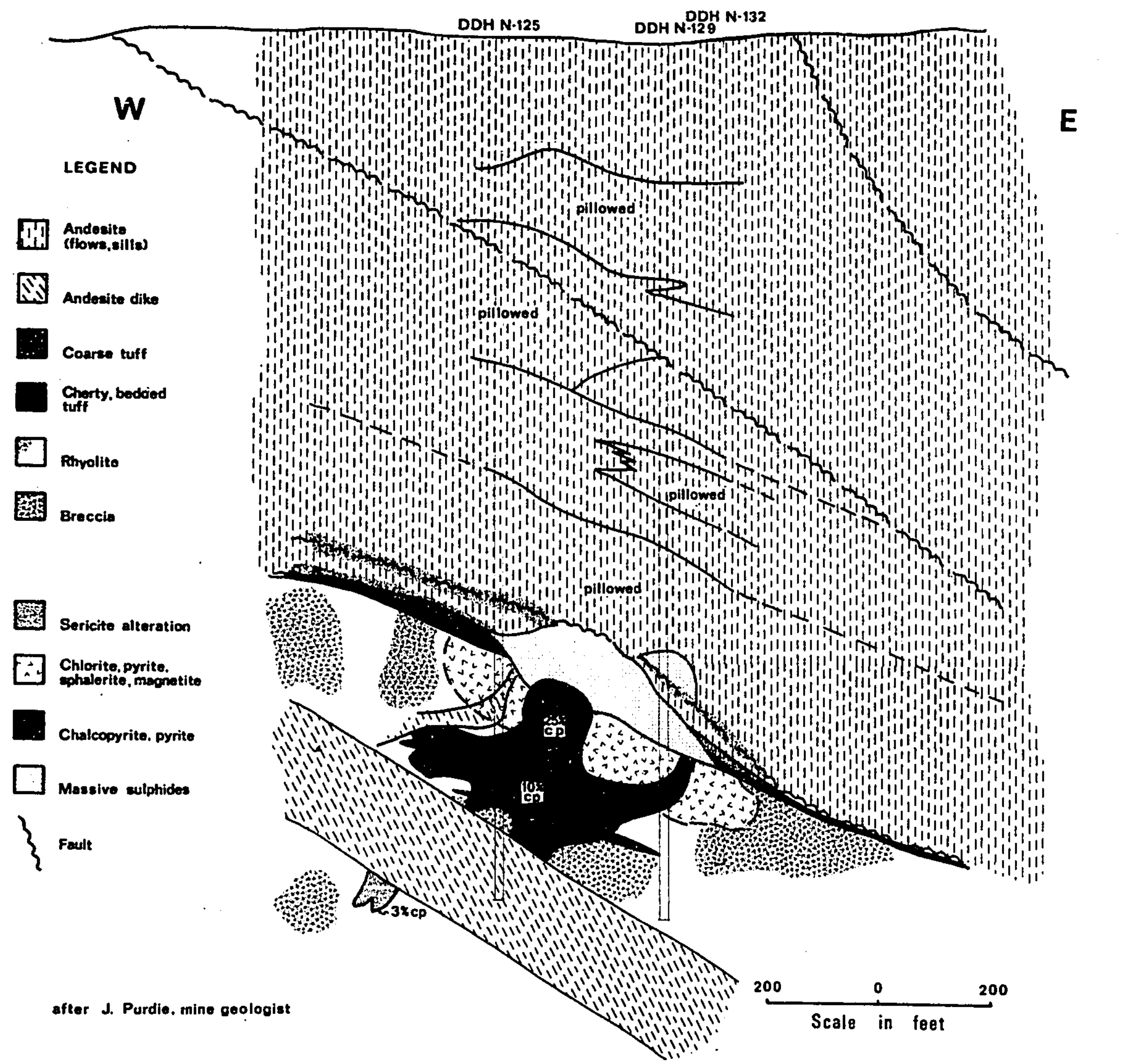
The chemical composition of "Dalmatianite" zones is similar to that of the chlorite-sericite zones (Riddell, 1952; Lickus, 1965).

At the Vauze mine an altered zone containing an unusually high amount of magnesium occurs stratigraphically below the massive sulphide ore body in fractured, mineralized rhyolite (Lickus, 1965). No magnesium seems to have been added to andesite which forms the hanging wall of massive ore. This is also a feature of the Lake Dufault deposit as described in a forthcoming section. It is the opinion of some geologists who have studied the Noranda district, and the writer concurs, that the andesite which now forms the hanging wall of massive sulphides in these deposits should contain some added magnesium if the flows were present at the time the sulphides were emplaced. A "Dalmatianite pipe" within andesite connects the "Lower A" and "Upper A" ore bodies in the Amulet mine area. Otherwise, magnesium metasomatism in andesite is rare.

"Dalmatianite" alteration zones have been reported only in areas near the Lake Dufault, Waite and Amulet ore bodies, all of which are close to the Lake Dufault granodiorite stock. It seems likely that biotite and "Dalmatianite" develop from the isochemical contact metamorphism of chlorite-sericite alteration. Riddell (1952) describes a concentric mineral and chemical zoning in "Dalmatianite" at the "Lower A" ore body, Amulet mine. The mineral zoning is, from the center outward, anthophyllite (gedrite)-biotite, cordierite-anthophyllite (gedrite)-biotite, cordierite-biotite and biotite and is, in the opinion of the writer, most probably caused by chemical zoning in a pre-existing chlorite-sericite alteration zone. Magnesium and iron are present in large amounts in the altered rock and increase as potassium decreases towards the center of the zone. Thermal metamorphism of a chlorite-sericite mass having this chemical zoning would result in the formation of biotite until potassium is used up, cordierite until aluminum is used up, and anthophyllite (gedrite) if there is enough magnesium, iron and silica left to satisfy its requirements. Lickus (1965) reports a similar type of chemical zoning in a chlorite-sericite "pipe" at the Vauze mine.

The existence of a contact metamorphic aureole near the Lake Dufault granodiorite stock is suggested by the work of Schindler (1934) on the old Waite-Ackerman-Montgomery property. He described pyroxene in andesite up to 200 feet away from granodiorite and biotite in andesite as far as 1,200 feet away from the granodiorite-andesite contact.

The anthophyllite-cordierite assemblage of the "Dalmatianite pipes" belongs to the hornblende-hornfels facies of contact metamorphism (Turner and Verhoogen, 1960, p. 511-520). These authors "tentatively correlate the hornblende-hornfels facies with temperatures of about 550^{o} to 700^{o}C. in the pressure range P_{H_2O} = 1,000 - 3,000 bars."



GENERALISED CROSS SECTION, LAKE DUFAULT MINES LTD.

LAKE DUFAULT MINE AREA

INTRODUCTION

The large Noranda properties of Lake Dufault Mines Limited are located mainly in Dufresnoy and Duprat townships approximately five miles directly north of Rouyn-Noranda (map I). The properties can be subdivided into two areas, one south and one north of the Lake Dufault granodiorite stock. The southern area is near the mined-out Amulet ore bodies. The northern area lies east of the mined-out Waite and Vauze ore bodies and is known as the Norbec area. The Norbec area consists of three faulted blocks of andesite and rhyolite separated by diorite of the dike system. These blocks are bounded at the north by a northeast trending fault and at the south by the Lake Dufault granodiorite stock. The Lake Dufault ore body is located in the central block. Geochemical samples were taken from the entire Norbec area.

ORE BODIES

The Lake Dufault ore body, actually two ore bodies, is a typical Noranda-style occurrence having a lens-shaped massive sulphide portion underlain by a fractured zone containing vein and disseminated sulphides (fig. 2). The massive body measures 150 feet by 400 feet by 550 feet. The longest dimensions lie in the plane of the contact between hanging-wall andesite and foot-wall rhyolite. Massive ore contains pyrite, pyrrhotite, sphalerite, chalcopyrite, magnetite and traces of galena and constitutes 1,644,400 tons of ore grading 9.3% zinc, 4.6% copper, 2.6oz.

silver and 0.04oz. gold. The low grade fracture zone is located stratigraphically below the massive body. The economically important mineral here is chalcopyrite, but pyrite, pyrrhotite, sphalerite and magnetite are common. That part of the fractured section which makes ore has a crude elliptical shape. To date, 545,000 tons of ore grading 1.6% copper, 0.1% zinc, 0.2oz. silver and 0.003oz. gold has been proved in this location. The long axis of the fractured and mineralized zone is parallel to the long axis of the massive sulphide body and is connected to massive ore by two pipe-like fracture zones. Layered sphalerite-pyrrhotite-pyrite ore is found at the top of the massive sulphide body. Sheared and structureless areas are common in massive ore. Coarse pyrite "nodules," similar to those reported by Kinkel (1963) in recrystallized ore, are present. A large scale zoning is present in massive ore as zinc increases and copper decreases toward the stratigraphic top away from the chalcopyrite-filled fractures below (staff, Lake Dufault Mines Ltd.).

HOST ROCKS

Amulet andesite[1] forms the hanging wall of the massive sulphide ore body. Waite rhyolite[1] forms the footwall of massive ore and is host to the ore of the fractured zone. Bedded, cherty tuff is found mainly between andesite and rhyolite. Dugas and Hogg (1962) and Lickus (1965) review the stratigraphy of the general area.

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1. These units were called Waite Hills andesite and Waite Lake siliceous rhyolite by Wilson (1941, p. 7). The terms "Amulet andesite" and "Waite rhyolite" are used by the staff of Lake Dufault Mines Ltd. and by Lickus (1965) for the same units in the Vauze mine area.

Amulet Andesite

The Amulet andesite is characteristically pillowed and amygdaloidal (Plate 7, fig. 1; Appendix H). Massive sections are common and some of these are almost certainly dikes and sills.

Alteration which is common throughout all of the andesite consists of three main types: (1) chlorite, actinolite, epidote and sericite which have developed from the breakdown of plagioclase feldspar and mafic minerals during regional metamorphism; (2) patches of epidote, quartz and calcite, and (3) white, sericitic patches. Small laths and phenocrysts of altered plagioclase feldspar are common.

Biotite has formed in the andesite in places close to diorite and granodiorite.

Chlorite, actinolite, sericite, quartz, calcite, pyrite, and pyrrhotite are often found in amygdales, small fractures and spots throughout the andesite. Away from the contact with massive sulphides only scattered bits of chalcopyrite with pyrrhotite and, very rarely, sphalerite have been reported. Chalcopyrite seems to have a much wider distribution in andesite than does sphalerite.

A major type of alteration of andesite is present mainly at its base (Plate 7, fig. 2; Appendix H). Here, the development of quartz-carbonate veinlets has accompanied the large scale development of sericite which changes the greenish andesite to a tan colored rock. Shearing always accompanies this alteration which is seen elsewhere, well away from the base of the andesite in other shear zones and, on a small scale, adjacent to some fractures. This alteration is commonly absent where andesite forms the foot-wall of massive ore.

Bedded, Cherty Tuff

Bedded, cherty tuff occurs mainly at the contact of andesite and rhyolite but it also has been seen well within the rhyolite. It is characterized by numerous, thin, alternating layers of light to dark gray chert and green chlorite (Plate 9, fig. 1; Appendix H). The bedded tuff is usually from two to twenty feet thick and seems to be thickest near ore. Pyrite and pyrrhotite are the most common sulphides present and are usually concentrated in thin layers. Chalcopyrite and sphalerite are often present. The contact between the bedded, cherty tuff and the underlying rhyolite is vague and unmarked in some places. Tuff at the main contact is sometimes sheared almost beyond recognition.

Waite Rhyolite

Microscopic and quantitative X-ray diffraction examination of the rhyolite has revealed the presence of sodic plagioclase feldspar both as phenocrysts and cryptocrystaline intergrowths with quartz in the matrix (A. R. Graham, personal communication). Flakes of chlorite and sericite, specks of magnetite and mosaics of quartz are common.

Far from being massive and uniform, the rhyolite exhibits a host of internal structures (Plates 1 to 5; Appendix H). The most common structure is a vague breccia, often barely discernible on a fresh surface, consisting of small (1" diameter) gray fragments in a slightly lighter matrix (Plates 8, 9; Appendix H). Other light colored, large, often angular fragments or blocks of highly vesicular rhyolite occur in a matrix which varies from a vague breccia through uniform and massive gray rhyolite to a relatively soft chloritic and sericitic rock (Plate 5; Appendix H). Another uncommon but interesting variety of breccia consists of small (about 1"), chloritic and sericitic, often deformed (stretched, flattened) fragments in a very dense, laminated, cream, lavender, pink or gray, cherty-appearing matrix (Plate 2; Plate 9, figs. 2a, 2b; Appendix H). Other less common breccias occur, as well as much rhyolite which appears massive or, at the most, vesicular or laminated. It is probable that almost all of the Waite rhyolite is a complex of very fine to coarse tuff, welded and nonwelded, which was deposited, at least for the most part, subaqueously. This latter condition is suggested by the presence of bedded, cherty tuff at the top and, in some places, within the rhyolite.

Like other rhyolite units in the Noranda area the Waite rhyolite is thin relative to its areal extent and like other deposits of the area the Lake Dufault ore body is located on a thickening of the rhyolite.

Sericite has formed along fractures, in spots, or over large areas throughout the rhyolite. Quartz, calcite, chlorite and epidote often occur in the rhyolite in spots and fractures. The borders of magnetite-ilmenite grains are altered to leucoxene.

The only large scale local alteration in the rhyolite is below the massive ore body in a fractured and mineralized zone (Plate 6; Appendix H). Here, the rhyolite has been completely reconstituted and recrystallized. A relatively narrow zone, present along the base of the massive ore, consists of pyrite, sphalerite, chlorite, sericite, garnet and magnetite in spots and fractures in the rhyolite. Below this zone and extending through it in places, is an extensive zone characterized by the presence of chalcopyrite, which is disseminated and in fractures. The amount of chalcopyrite in this zone increases upward as a function of the size and frequency of fractures. A major feature of this alteration zone is the development of a mosaic of clear, strain-free quartz grains. Sericite is present as flakes and chlorite appears as rosettes as well as scattered flakes. Cordierite, anthophyllite, biotite, chlorite and garnet have been found in this zone. It appears that the copper-rich zone is later than and cuts across the narrower pyrite-sphalerite-magnetite-chlorite zone beneath massive ore.

Apart from the fractured and altered zones beneath the ore no localized alteration zone was seen in the rhyolite. Pyrite and pyrrhotite are disseminated throughout the rhyolite in scattered specks and are very rarely present in veinlet form in spite of the fact that the rhyolite is well fractured in many places. Quartz-carbonate-chlorite veinlets and fractures containing essentially no sulphides often are found in rhyolite containing relatively large amounts of disseminated sulphides (Plate 9, fig. 1a; Appendix H). Sulphides occurring in distinctly fragmental rhyolite are almost entirely confined to the matrix. Three of four polished sections of pyroclastic rhyolite, examined with a reflecting microscope, revealed very fine disseminated sphalerite with coarser pyrite and pyrrhotite only in the matrix of the breccia. The fourth section revealed no sphalerite but a few grains of pyrite and pyrrhotite were noticed in the breccia matrix. Outside of the ore zone, sphalerite is more noticeable and chalcopyrite is less noticeable in the rhyolite than they were in the overlying andesite.

Magnetite is a conspicuous accessory mineral.

STRUCTURE

The most evident structural features in the Norbec area are faults, lineaments, thickened rhyolite and the Newbec breccia. Evidence of folding has not been mapped although Wilson (1941) placed fold axies to the west and northwest of the Norbec area. The contact between Amulet andesite and Waite rhyolite, often the locus of bedded, cherty tuff, is commonly referred to as the "main contact."

Faulting

The Norbec area is relatively undeformed. The main epigenetic structures are large northwest trending, steep faults now occupied by diorite dikes. Movement along these faults has formed three fault blocks and caused the raising of the volcanic rock in the eastern part of the Norbec area. The "main contact" and bedding in tuff in each of these fault blocks dip moderately (30^{o}) to the east. Northwest and northeast trending faults are found in the Norbec area. Some of the faults have shallow dips and one offsets part of the Lake Dufault massive sulphide ore body (fig. 2). Some movement may have occurred along the "main contact."

Lineaments and Domes

Northeast (N. 70^{o} E.) and northwest (N. 20^{o} W.) trending air photo lineaments, some of which are known to be expressions of fault zones, cut across the Norbec area. The Lake Dufault ore body occurs on a broadly thickened section of rhyolite near the intersection of two of these lineaments (staff, Lake Dufault Mines Ltd.).

Newbec Breccia

A circular exposure of breccia, the Newbec breccia is located in the southeast corner of the Norbec area. Wilson (1941) compares this breccia to breccia pipes in Leadville, Colorado, which are said to be of volcanic origin.

GEOCHEMISTRY OF THE HOST ROCKS

GENERAL APPROACH

The "main contact" in the Norbec area of the Lake Dufault Mines Ltd. property is a moderately dipping plane pierced by several vertical diamond drill holes. Usually four samples from andesite immediately above the contact and three to four samples from rhyolite immediately below the contact were taken from the core of each drill hole available for sampling. Each sample represents approximately twenty five feet of drill core. Cherty, well-bedded tuff was also sampled where it occurred in drill core at the main contact. All the samples were analysed for as many elements as time and opportunity permitted.

SAMPLING PROCEDURE

Rhyolite and Andesite

The object of sampling was to obtain a sample representing twenty five feet of rhyolite or andesite in a drill core. This was accomplished by a systematic sampling procedure which was suggested by Dr. A. R. Graham of Falconbridge Nickel Mines Limited. Two-inch long pieces of core were collected at twenty-inch intervals over twenty five feet of core, giving fifteen pieces in one sample bag. Each sample weighed approximately three pounds. Dikes were excluded from the sample and where necessary the length of the sampled core was adjusted slightly so that the sample would at least appear to be homogeneous.

Tuff

Because of the heterogeneity of the bedded, cherty tuff it was necessary to split in half the complete diamond drill core and to use one of the halves as a sample. Only the bedded variety of tuff was sampled, and, for each drill hole, one sample represents the total amount at the main contact (one exception, three samples in DDH #121).

SAMPLE REDUCTION

The entire content of one sample bag was crushed to one quarter inch size in a steel plated jaw crusher. This material was split down to a large handful using a Jones splitter. The sample was then brought to minus one hundred mesh using a Braun disk pulverizer with ceramic plates. The fine product was split down using a Jones splitter so that a portion would half fill a small vial. All of the crushed and pulverized sample was saved.[1]

SAMPLE PREPARATION (BEYOND REDUCTION)

The rest of the sample preparation involved weighing, mixing, fusing, crushing, grinding and filling of sample containers depending on which of the four analytical procedures was being followed.[2]

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1. Appendix G, figure G1.
2. Appendix G, figures G1, G2, G3, G4.

During the course of the three years of analytical work some of the techniques of mixing and crushing were changed and many different workers were involved in sample preparation.

ANALYTICAL PROCEDURES

Four analytical procedures were employed using a G.E. model XRD 3 X-ray emission spectrograph and a JACO 3.4 meter plane grating spectrograph.

The SiO_2, Al_2O_3, TiO_2, MnO, Total Fe as Fe_2O_3, K_2O and CaO contents of the samples were determined by an X-ray fluorescence method. The powdered rock sample was mixed with a flux (lithium tetraborate), fused, pulverized and packed by hand into a plastic sample holder.[1] Natural materials analysed by the National Bureau of Standards (N.B.S.) and the Geological Survey of Canada (G.S.C.) were used as standards.

Na_2O and MgO in the samples were determined with an optical spectrograph using material prepared for the X-ray method but mixed with graphite.[2] The lithium of the flux acted as an internal standard. The N.B.S. and G.S.C. materials were used as standards.

The Co, Cr, Cu, Ga, Ni, Sr, Y and Zr contents of the samples were determined by an optical spectrographic method.[3] The powdered rock sample was mixed with a flux (lithium carbonate), fused, pulverized, combined with graphite and packed in cupped graphite electrodes. Indium was added as an internal standard. Salts and oxides of the metals were added to an artificial base for standards.

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1. Appendix G, figure G1.
2. Appendix G, figures G1, G2, table G2.
3. Appendix G, figure G3, table G2.

The Ag, Bi, Cd, Ge, Pb, Sn, and Zn contents of the samples were determined by an optical spectrographic method.[1] The already powdered sample was ground to an extra fineness (about two hundred mesh), mixed with graphite and packed in cupped graphite electrodes. Antimony was added as an internal standard and the sample in the electrode was covered by a graphite electrode cap. Salts and oxides of the metals were added to an artificial base for standards.

All analyses using the optical spectrograph were done in duplicate.

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1. Appendix G, figure G4, table G2.

Table 1

Sample Preparation and Analytical Error

	Andesite #970			Rhyolite #965		
	N	$\bar{x} \pm C_A$	R	N	$\bar{x} \pm C_A$	R
SiO_2%	18	51.2 ± 8.6%	1.059	16	74.3 ± 5.0%	.9178
TiO_2%	18	1.26 ± 5.9%	.4471	16	0.26 ± 9.1%	.4755
Al_2O_3%	18	20.0 ± 7.7%	.7912	16	13.9 ± 14.2%	1.350
Fe_2O_3%	17	8.7 ± 3.0%	.1978	16	5.4 ± 2.3%	.0861
MnO%	18	0.11 ± 5.6%	.305	16	0.49 ± 3.0%	.0497
CaO%	18	7.3 ± 2.9%	.1938	16	3.4 ± 4.0%	.1326
K_2O%	18	0.47 ± 14.9%	.4562	16	1.40 ± 6.6%	.2008
MgO%	17	6.2 ± 11.1%	.5529	16	1.20 ± 9.4%	.1132
Na_2O%	17	3.5 ± 11.1%	.5528	16	1.35 ± 20.9%	.9002
Ag ppm	17	0.34 ± 53.7%	1.119	19	1.05 ± 24.8%	.4178
Co ppm	17	72 ± 13.9%	.4805	15	5.7 ± 20.9%	---
Cr ppm	18	227 ± 13.6%	.4619	8	51 ± 27.5%	1.34
Cu ppm	18	72 ± 30.5%	.3593	16	312 ± 20.4%	.2915
Ga ppm	18	26 ± 10.5%	.6322	16	30 ± 9.3%	.6026
Ni ppm	18	167 ± 30.3%	.7218	15	3.6 ± 78.7%	.8420
Pb ppm	16	1.4 ± 66.4%	.7554	19	15.6 ± 16.4%	.1683
Sn ppm	16	5.2 ± 63.3%	.9978	19	1.3 ± 27.8%	.3142
Sr ppm	16	260 ± 30.2%	.9265	16	414 ± 25.3%	.9843
Y ppm	18	20 ± 17.1%	.6528	16	62 ± 19.3%	.8961
Zn ppm	18	227 ± 19.5%	.4579	19	357 ± 10.3%	.1167
Zr ppm	18	176 ± 17.5%	.9994	16	416 ± 27.9%	.7564

$$C_A = \frac{\sigma}{\bar{x}} \times 100$$

$$R = \frac{C_A \text{ (analytical)}}{C \text{ (total)}}$$

C_A = relative deviation (analytical)

σ = sample standard deviation

$\bar{x}$ = mean of N replicate analyses

N = number of analyses

R = ratio of analytical deviation to total sample deviation

$C_{(total)}$ = sample deviation calculated from all samples except those near the ore body

REPLICATE ANALYSES : ESTIMATION OF ANALYTICAL AND SAMPLE PREPARATION ERROR

One sample of andesite (#970) and one sample of rhyolite (#965) were analysed repeatedly throughout the entire period of analytical work. Variations in the results are caused by errors in the analytical and sample preparation stages.

The sample relative deviation (C_A) due to analytical and sample preparation errors for each of the two replicate samples was calculated according to formula (1):

$$C_A = \frac{\sigma}{\bar{x}} \times 100 \qquad \sigma = \frac{1}{N}\sqrt{N\sum_{i=1}^{N} x_i^2 - \left(\sum_{i=1}^{N} x_i\right)^2} \qquad (1)$$

Where σ = sample standard deviation[1]
N = number of analyses per sample
x_i = an individual analysis
$\bar{x}$ = arithmetic mean of N analyses
C_A = relative deviation (analytical)

The results are given in Table 1.

Presentation of C_A (relative deviation attributable to analytical error) helps to point out that any one analysis represents a range of possible values. In this report, the value in question is actually the average of N analyses ($\bar{x}$), and the analytical error in the average[2] is $C_A/\sqrt{N}$. For example if there are four individual analyses in one drill

1. To convert sample standard deviation to best estimate of population standard deviation multiply by $N/(N - 1)$.

2. $C_A/\sqrt{N}$ might be called the "relative" error of the mean.

hole, sixty-eight percent of the time the real value of their average should be within the range represented by $x \pm C_A/\sqrt{4}$ or $x \pm C_A/2$. If there were no real variations in the concentration of an element in four samples from a drill hole the analytical error would result in a mean value having a 95% chance of being in the range $x \pm C_A$.[1] When C_A is large (that is, greater than 15 or 20%) this expression of confidence cannot be used. For discussion of this point see Ahrens and Taylor (1961, p.116-118).

C_A was calculated from the repeated analysis of one sample and cannot be strictly applied to all samples. For example, C_A may vary as a function of the level of measurements. Also the 95% limits are based on a normal distribution. It is therefore an approximate figure and as such is only a guide (the best one we have) to establish confidence in the analytical results.

The ratio, R, between the analytical relative deviation and the total relative deviation[2] indicates approximately how much of the total variation in the samples can be attributed to errors in sample preparation and analysis. Since C, the total relative deviation, is not accurate for all but normal, unimodal distributions, R is only an approximate figure for many elements. Nevertheless, only greatly anomalous values would seem significant for an element having R close to unity while analytical error would seem relatively insignificant when dealing with anomalous values for an element having R less than 0.2.

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1. e.g. if $x = 10.0\%$ and $C_A = 5\%$, $x + C_A = 10.0\% + \frac{5}{100} \times 10.0\% = 10.5\%$.

2. All samples close to the ore body have been removed from the calculations (i.e., those from diamond drill holes 135, 151, 163, 132, 133, 142, 149, 127, 128, 129, 125).

Table 2

Analysis of Errors of Manipulation

	CaO	TiO_2	Fe_2O_3	MnO	K_2O
c_a^2 Analytical	.00864[1]	.00264	.00291	.00649	.00676
c_p^2 Sample Preparation	.00559	.00042	.00099	.00483	.00170
c_r^2 Sample Reduction	.00067	.00114	.00008	.00154	.00035
c^2 Total	.0149	.00420	.00398	.01286	.00881

1. relative variance; formula (2)

ERROR IN SAMPLE REDUCTION

In order to estimate the error created by pulverizing and splitting and to compare this error with the error in sample preparation (beyond reduction)[1], a hierarchical model of replicate analysis was used.

The relative variance (c^2; formula 2) of a small number of replicate analyses was calculated at three levels: (1) analytical, (2) sample preparation, and (3) sample reduction (Shaw, 1961).

$$c^2 = \frac{N^2}{N-1} \left[\sum_{i=1}^{N} x_i^2 - \frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N} \right] \Bigg/ \left(\sum_{i=1}^{N} x_i\right)^2 \qquad (2)$$

c^2 = relative variance
x_i = individual analysis
N = number of analyses

Since the factor $\frac{N}{N-1}$ is included in formula (2) c^2 is an "unbiased estimate" of the population relative variance. The total relative variance is the sum of the relative variances caused by analytical error (c_a^2), sample preparation error (c_p^2) and sample reduction error (c_r^2).

$$c^2 = c_a^2 + c_p^2 + c_r^2$$

Table 2 gives the results of this analysis and shows how little of the total relative variance is attributable to errors in sample reduction.

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1. For definitions see p.23

METHOD OF PRESENTATION OF RESULTS

Data Charts

All the analytical data are summarized on charts (charts 1 to 42; Appendix B). By means of three graphs, a single chart shows for any one element and rock type: (1) the average value, $\bar{x}$, of the individual analyses for each drill hole, (2) the sample standard deviation of those values (σ)[1], and (3) the individual values themselves (x). Thus much pertinent information about the distribution of one element in rhyolite or andesite can be obtained by looking at one chart. The individual analyses are plotted from left to right in the order in which the samples were taken. Thus, for andesite, the last sample in a drill hole is closest to the main contact. For rhyolite, the first sample is closest to the main contact. Note that the numbers on the vertical scale of the graphs of average and individual values do not always start at zero. This fact should be kept in mind when comparing the values appearing on one graph with those on another graph.

The horizontal lines on these graphs are an attempt to designate background and anomalous values. The values which the horizontal lines represent were chosen after a study of the form of the frequency distribution of the element in question in andesite or rhyolite.

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1. The symbol σ is used to designate sample standard deviation in the ASTM Manual on Quality Control of Materials referred to in this report. A more commonly used symbol is "s."

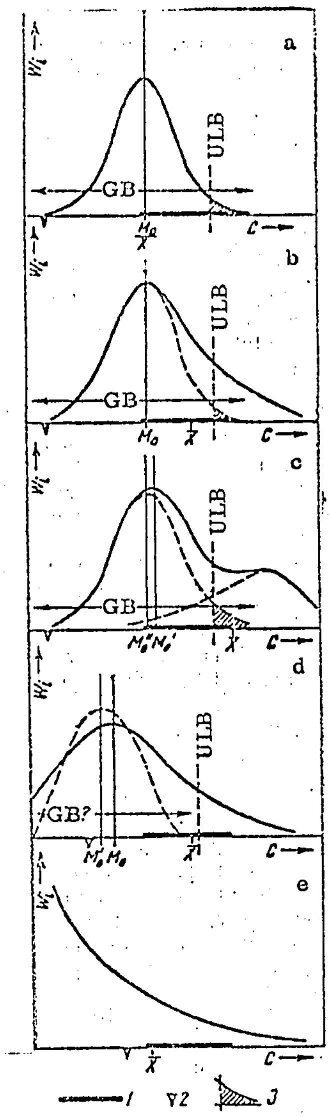

Fig. 1. Types of frequency distributions of concentrations of elements in geochemical systems.

C—concentration of element; W_i—frequency; $\overline{X}$-arithmetic mean of concentration; M_0—mode; ULB—upper limit of background concentration; GB—geochemical background; 1—concentration range which may contain average content of element; 2—sensitivity of analytical method; 3—region of large absolute deviations

Fig. 3 From Smirnov, 1963

Frequency Distribution Diagrams

All the analytical data are summarized on columnar frequency distribution diagrams (histograms) (Appendix A). These diagrams provide the easiest and clearest way to illustrate the behavior of an element in a group of samples or, as in this case, in rhyolite or andesite.

The anomalous values of an element were separated from background values on the basis of the form of its frequency distribution. The frequency distributions obtained can be placed in five groups: I - Unimodal (one peak) symmetrical curves[1] (fig. 3a); II - Unimodal asymmetrical curves with positive (or negative) skewness (fig. 3b); III - Bimodal or multimodal curves (fig. 3c); IV - Symmetrical or asymmetrical curves with some samples containing less than detectable amounts of an element (a frequency much greater than zero in the lowest valued class interval of the histogram) (fig. 3d); and V - the so-called J-shaped curves without a peak (fig. 3e) (Smirnov, 1963).

Elements which show a frequency distribution close to being unimodal and symmetrical (Type I) are referred to as being normally distributed.

Type I. Unimodal symmetrical curves (fig. 3a)

When values for an element in a system (rhyolite or andesite) are close to being normally distributed, anomalous values are chosen by a method outlined in the ASTM Manual on Quality Control of Materials, 1951, Part 3, Section 9b, p. 61.

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1. A curve is drawn by smoothing a histogram.

Formulae for Data Chart Lines (for Normal Distributions)[1]

	Central Line	Limiting Lines
for averages ($\bar{x}$)	$\bar{\bar{x}}$	$\bar{\bar{x}} \pm \frac{3\bar{\sigma}}{c_2 \sqrt{N}}$
for individuals (x)	$\bar{\bar{x}}$	$\bar{\bar{x}} \pm 3\bar{\sigma}$
for standard deviations (σ)	$\bar{\sigma}$	$\bar{\sigma} \pm \frac{3\bar{\sigma}}{c_2 \sqrt{2N}}$

Where: $\bar{\bar{x}}$ = the grand average of observed values of x for <u>all</u> samples[2]

$\bar{\sigma}$ = the weighted average drill hole standard deviation

N = number of samples per drill hole

$c_2 = 0.5642$ for $N = 2$

$c_2 = 0.7236$ for $N = 3$

$c_2 = 0.7979$ for $N = 4$

$c_2 = 0.8407$ for $N = 5$

c_2 is a factor that is a function of N and expresses the ratio between the expected value of $\bar{\sigma}$ for a large number of samples of N observed values each and the true standard deviation (σ') of the universe sampled.

Values of $c_2 = \frac{\bar{\sigma}}{\sigma'}$ approach a maximum of 1 as the number of observed values (N) increases. The expected value of $\bar{\sigma}$ is based on a <u>normal</u> distribution.

1. ASTM Manual on Quality Control of Materials, 1951, Part 3, Section 9, p. 61.
2. except those from drill holes close to the orebody

For normally distributed elements, the graphs for averages ($\bar{x}$) and individuals (x) are marked with a straight dashed line (central line) and two symmetrical solid lines (limits). The central line marks the grand average content of an element in the rock ($\bar{\bar{x}}$) and all values outside the limiting lines[1] are anomalous. Figure 4 gives the formulae which were used to calculate the limiting lines.[2]

The spread of the background limiting lines for averages and standard deviations should depend on the number of samples per diamond drill hole (N). The limiting lines for averages are approximately 3.8 standard deviations if N = 2, 2.4 standard deviations if N = 3 and 1.9 standard deviations if N = 4. The limiting line for σ does not vary significantly with the number of samples (N). The limiting line on the graph of individuals is at 3σ.

All the formulae for calculating limits are based on the choice of three σ's as a limit. This means that, assuming the background values have a normal distribution, 0.3% of the anomalous values are actually background.

<u>Type II - Unimodal asymmetrical curves with positive skewness (fig. 3b)</u>

Background and anomalous values forming distributions of Types II, III, IV, and V were separated using judgment only.

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1. ULB = upper limit of background; LLB = lower limit of background.

2. Values for samples close to the known ore body were not included in the calculations because of the good chance these values could belong to another distribution. If this proved to be the case these values would show up as anomalous on the graph. If not, it should be clear that no real harm was done by removing these samples. The samples removed are from drill holes 125, 127, 128, 129, 132, 133, 135, 142, 149, 151, and 163.

In this case, Type II, we can make an assumption to aid in our choice of a limit to background. The assumption is this: background values form a normal distribution, therefore the left branch of a positively skewed, unimodal, asymmetrical curve corresponds to the left branch of the symmetrical curve of the background values (Smirnov, 1963). It is then possible to sketch in the right branch of the symmetrical background curve. All values above the highest value falling on the normal curve would then be anomalous.

Because of the uncertainty involved in designating anomalous values in distributions of Types II, III, IV, and V the range of anomalous values was split up into two or three groups as shown on the histograms. Range a to b could be called possibly or probably anomalous while ranges greater than b might be called anomalous.

Type III - Bimodal or multimodal curves (fig. 3c)

Anomalous values were distinguished in multimodal distributions by assuming, as was done for Type II distributions, that the highest peak represented a symmetrical background distribution. Other lower peaks represent distributions of anomalous values.

Type IV - Asymmetrical curves with a frequency greater than zero in the lowest valued cell of the histogram (fig. 3d)

Type V - J-shaped distributions (fig. 3e)

Choosing anomalous values for these two classes of frequency distributions is strictly guess-work. One can only designate the most commonly occurring values as background and pick an upper limit to the background using good judgment.

As mentioned previously, the anomalous values have been classified further into two or three ranges marked a-b, b-c, >c on the histograms presented here.

Tables Summarizing the Vertical Distribution of Elements (Appendix E)

If the top half of the samples of rhyolite from a drill hole shows higher concentrations of an element than the bottom half, this drill hole was included in the first column of Tables E-1 and E-2; if not, a record was made in the second column. Groups of samples from drill holes were split into categories of "two samples only" and "three or more samples."

The same was done for the bottom of the andesite (Tables E-3, E-4).

METHOD OF PRESENTATION OF RESULTS FOR SAMPLES OF TUFF

The results for tuff were treated differently because of the small number of samples. In Tables C-1 through C-6 (Appendix C) the analyses of tuff samples are arranged in columns in order of increasing values. The middlemost value of each column is the <u>median</u>. Samples of tuff from holes near the known ore body are noted with an asterisk.[1] If the chemical compositions of these samples were not related to the presence of ore, the values would occur ideally in equal numbers on either side of the median. If, then, the ratio (r)[2] of the number of "near ore body" samples in the 0 - 50% range to the number of them in the

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1. Diamond drill holes cutting tuff near the ore body: 163, 135, 190, 139, 181, 159, 164, 144, 174.

2. $r = \frac{\#\text{ in } 0 - 50\%\text{ range}}{\#\text{ in } 50 - 100\%\text{ range}}$

50 - 100% range is 4/5 or 5/4 no significant variation in the tuff is demonstrated. Only the values for those elements which look interesting (r = 3/6 or better) are plotted on a plan of diamond drill holes (figs. 38, 39, 40).

Analytical Data for Standard Samples, G-1, W-1, CAAS Syenite, CAAS Sulphide

Element	G-1		W-1		CAAS syenite		CAAS sulphide	
	Fleischer[1]	Sakrison	Fleischer	Sakrison	Webber[2]	Sakrison	Webber	Sakrison
SiO_2	72.64%	78.3%	52.64%	61.3%	59.45%	64.3%	34.52%	44.7%
Al_2O_3	14.04	25.4	14.85	18.2	9.58	15.4	9.46	15.8
Fe_2O_3	0.87	--	1.41	--	2.27	--	--	--
FeO	0.98	1.78[3]	8.74	10.8[3]	5.44	7.8[3]	--	25.0[3]
Fe	--	--	--	--	--	--	22.87	--
MgO	0.41	0.38	6.62	7.8	4.07	4.5	3.93	4.41
CaO	1.39	1.36	10.96	10.7	10.32	9.1	3.96	3.9
Na_2O	3.32	3.52	2.07	2.30	3.24	3.8	1.03	2.65
K_2O	5.45	5.32	0.64	0.65	2.75	2.41	0.63	0.72
TiO_2	0.26	0.28	1.07	1.06	0.49	0.45	0.81	0.86
MnO	0.03	0.03	0.16	0.17	0.40	0.38	0.11	0.14
Ag	0.04ppm	<0.3ppm	0.06ppm	0.26ppm	1.6ppm	0.5ppm	3.9ppm	0.5ppm
Co	2.3	1.0	52	61	19	29	546	510
Cr	22	30	120	242	58	125	368	--
Cu	13	15	110	119	25	37	8291	--
Ga	18	30	16	22	18	31	13	--
Ni	1-2	2	78	78	42	68	13103	--
Pb	49	44	8	17	516	485	248	265
Sn	4	--	3	11	12	8	11	4
Sr	250	534	180	252	320	--	110	168
Y	13	12	25	20	447	670	21	15
Zn	45	200	82	192	200	192	298	1640
Zr	210	427	100	143	3048	--	108	253

Table 3

1. Fleischer (1965)
2. Webber (1965)
3. Fe (total) as Fe_2O_3

ACCURACY OF RESULTS

Each of the standard samples, G-1, W-1, CAAS syenite and CAAS sulphide, was analysed once. Table 3 presents the results of these analyses along with the "preferred values" for the elements from many analyses of the standard samples as given by Fleicher (1965) and Webber (1965).

Large, systematically high discrepancies are noted for SiO_2, Al_2O_3, Cr, Ga, Sr, Zn and Zr. Conclusions which must be tempered by consideration of these discrepancies are noted in the forthcoming sections.

Analyses for some of the above-mentioned elements have relatively low precisions (Table 1), a fact which may account for a part of the inaccuracies. The background value given for each element in andesite and rhyolite in this work is the most common value (statistical mode) of more than two hundred analyses and thus is free from error caused by low precision.

Many of the above-mentioned elements are present in the standard samples in amounts near the lower detection limits of the analytical procedures used in this work. This is true of chromium in G-1 and CAAS syenite, strontium in W-1 and CAAS sulphide and zinc in G-1 and W-1. This may account for some of the inaccuracies noted for these elements.

Table 4

MAJOR ELEMENT CONTENT OF THE HOST ROCKS

	AMULET ANDESITE		WAITE RHYOLITE		TUFF	
	mode (%)	mean (%)	mode (%)	mean (%)	median (%)	range (%)
SiO_2	52.5	52.4	77.0	75.5	61.0	15.4
Al_2O_3	16.4	18.3	13.6	14.2	15.8	8.4
Fe as Fe_2O_3	9.4	9.3	4.5	4.9	13.2	15.8
MgO	5.2	4.9	0.5	1.1	1.5	2.6
CaO	10.3	8.9	2.5	2.6	5.5	8.0
Na_2O	2.9	2.8	2.7	3.1	2.8	2.6
K_2O	0.5	1.1	1.3	1.5	1.7	2.0
TiO_2	1.11	1.20	0.23	0.32	0.68	0.68
MnO	0.16	0.19	0.10	0.16	0.15	0.14

Table 5

PUBLISHED ANALYSES OF NORANDA AREA ROCKS

	N	SiO_2	Al_2O_3	FeO	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	Rittman's[1] σ (1962)
1	1[2]	48.52[3]	12.90	11.31	3.53	6.25	10.11	1.94	0.40	1.42	0.27	1.0
2	3	49.1	15.3	13.7		6.7	11.2	2.0	0.2	1.5	0.23	.8
3	1	49.42	14.64	9.12	2.11	6.80	10.17	2.32	0.30	0.94	0.22	1.07
4	4	50.1	14.1	13.6		7.6	9.1	3.5	0.1	1.8	0.27	1.8
5	1	51.75	17.47	9.16	2.96	9.40	9.16	5.20	1.37	1.15	Tr	.17
6	1	53.86	14.56	9.16	1.36	7.44	2.49	1.38	1.01	1.04	0.10	.5
7	1	53.91	14.72	7.12	2.53	5.00	6.50	3.40	0.26	1.48	0.16	1.2
8	1	54.02	15.67	8.46	2.38	4.12	7.14	4.84	0.64	1.63	0.01	2.7
9	3	54.4	17.1	9.9		4.0	9.1	3.5	0.3	1.6	0.17	1.3
10	1	55.35	15.0	7.42	1.55	5.03	5.72	3.82	0.85	1.18	0.16	1.8
11	6	56.5	15.6	9.7		6.3	5.6	4.4	0.3	1.3	0.20	1.6
12	1	57.87	14.53	6.16	2.04	4.62	6.12	3.23	0.69	1.11	0.16	1.0
13	8	58.2	17.0	7.4		3.8	7.8	4.0	0.6	1.3	0.17	1.4
14	1	58.3	16.63	5.86	1.42	4.18	8.31	3.08	0.62	1.12	0.16	1.0
15	1	59.56	14.18	5.06	1.85	4.27	4.77	3.11	1.66	0.93	0.17	1.4
16	1	60.28	15.08	7.42	1.60	2.79	3.77	5.52	0.21	1.60	0.12	1.9
17	1	62.66	13.80	6.90	1.73	2.31	2.48	3.84	1.29	0.85	0.14	1.3
18	4	66.0	16.7	4.0		2.4	4.8	4.2	1.4	0.5	0.07	1.4
19	1	68.72	14.33	2.32	0.99	0.83	2.84	6.80	0.55	0.70	0.08	2.1
20	1	72.72	11.00	2.71	1.22	0.30	2.46	2.10	2.52	0.24	0.09	.7

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1. $\sigma = \dfrac{(Na_2O + K_2O)^2}{SiO_2 - 43}$; a σ of less than 1.8 demonstrates a strong to extreme calc-alkaline affinity.

2. N = number of analyses.

3. Except for Roscoe (1965), the analyses originally were presented along with analyses for water and other minor constituents.

PUBLISHED ANALYSES OF NORANDA AREA ROCKS

	N	SiO_2	Al_2O_3	FeO	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	Rittman's[1] σ (1962)
21	1	72.90	10.90	2.86	2.51	1.02	1.64	3.83	1.09	0.25	0.04	.8
22	1	73.79	11.83	4.18	0.72	0.62	2.21	3.94	0.85	0.39	0.07	.75
23	1	74.76	11.50	2.05	1.77	0.77	0.81	4.89	1.18	0.20	0.03	1.2
24	1	74.60	11.43	1.54	1.84	0.66	1.42	3.87	1.72	0.25	0.03	1.0
25	1	74.89	13.27	3.65	0.36	0.40	1.15	4.25	0.37	0.22	Tr	.67
26	3	75.3	12.5	2.5		1.3	1.6	5.4	1.0	0.2	0.12	1.3
27	1	76.00	11.27	1.73	0.67	0.73	1.36	4.71	0.50	0.52	0.06	.9
28	1	76.42	11.08	1.54	1.22	0.60	1.61	4.37	1.15	0.19	0.04	.9
29	4	78.7	11.5	2.2		0.5	1.7	3.4	1.6	0.2	0.07	.7
30	1	76.78	11.21	2.77	1.04	1.33	0.21	3.13	0.80	0.28	Tr	.43
31	1	85.11	7.97	0.98	0.36	0.05	0.77	2.68	0.89	0.25	Tr	.30
32	6	60.5	17.4	4.5		2.1	2.9	5.1	6.8	0.6	0.06	2.5

1. $\sigma = \frac{(Na_2O + K_2O)^2}{SiO_2 - 43}$; a σ of less than 1.8 demonstrates a strong to extreme calc-alkaline affinity.

Table 5 (cont'd)

Table 5 (cont'd)

PUBLISHED ANALYSES OF NORANDA AREA ROCKS

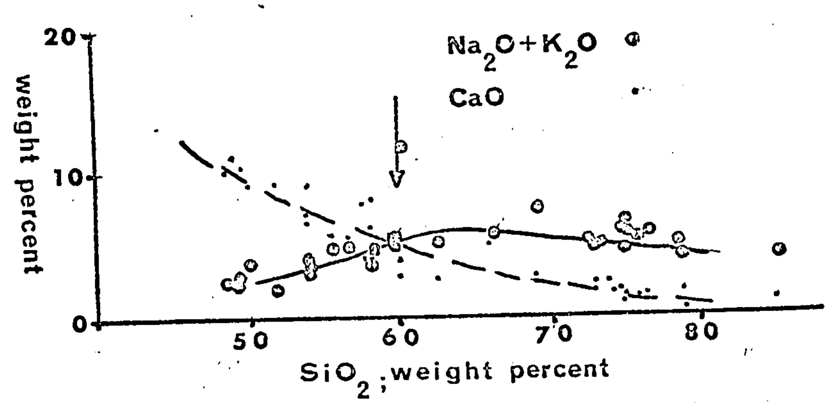
1. "Flat" diorite, Waite Lake Area, Duprat Twp., Lickus (1965).
2. Gabbro in Waite and Amulet Andesites, Roscoe (1965).
3. "Steep" diorite, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
4. Basalts, pre-Blake River Group, Kirkland Lake and Noranda Areas, Roscoe (1965).
5. Pyroxene gabbro, Dufresnoy Twp., Wilson (1941).
6. Waite andesite, Waite Lake Area, Duprat Twp., Lickus (1965).
7. "Metadiabase," Waite Lake Area, Dufresnoy Twp., Lickus (1965).
8. Massive andesite, Dufresnoy Twp., Wilson (1941).
9. Diorite in Waite and Amulet andesite, Roscoe (1965).
10. Waite andesite, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
11. Waite andesite, Blake River Group, Vauze Drill hole, Roscoe (1965).
12. Amulet andesite, Waite Lake Area, Duprat Twp., Lickus (1965).
13. Amulet andesite, Vauze drill hole, Roscoe (1965).
14. Amulet andesite, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
15. "Metadiabase," Waite Lake Area, Dufresnoy Twp., Lickus (1965).
16. Unaltered andesite, Amulet Mine, Riddell (1952).
17. "Transitional" dacite, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
18. Lake Dufault granodiorite, Roscoe (1965).
19. Rhyolite (trachyte), Amulet Mine, Riddell (1952).
20. Waite rhyolite, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
21. Waite rhyolite, Vauze Mine breccia member, Dufresnoy Twp., Lickus (1965).
22. Flavrian granite, Duprat Twp., Wilson (1941).
23. Waite Rhyolite, lower member, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
24. Waite rhyolite, upper member, Waite Lake Area, Dufresnoy Twp., Lickus (1965).

Table 5 (cont'd)

PUBLISHED ANALYSES OF NORANDA AREA ROCKS

25. Powell granite, Rouyn Twp., Wilson (1941).
26. Flavrian Lake sodic granite, Roscoe (1965).
27. Unaltered rhyolite, Amulet Mine, Riddell (1952).
28. Waite rhyolite, Waite Lake Area, Dufresnoy Twp., Lickus (1965).
29. Waite rhyolite, Roscoe (1965).
30. Rhyolite, Duprat Twp., Wilson (1941).
31. Spherulitic, micropegmatitic rhyolite, Duprat Twp., Wilson (1941).
32. Syenites, Matachewan (Ontario), Duparquet, Dasserat, Noranda, Roscoe (1965).

figure 5. Peacock's alkali : lime index for rocks from the Noranda area.



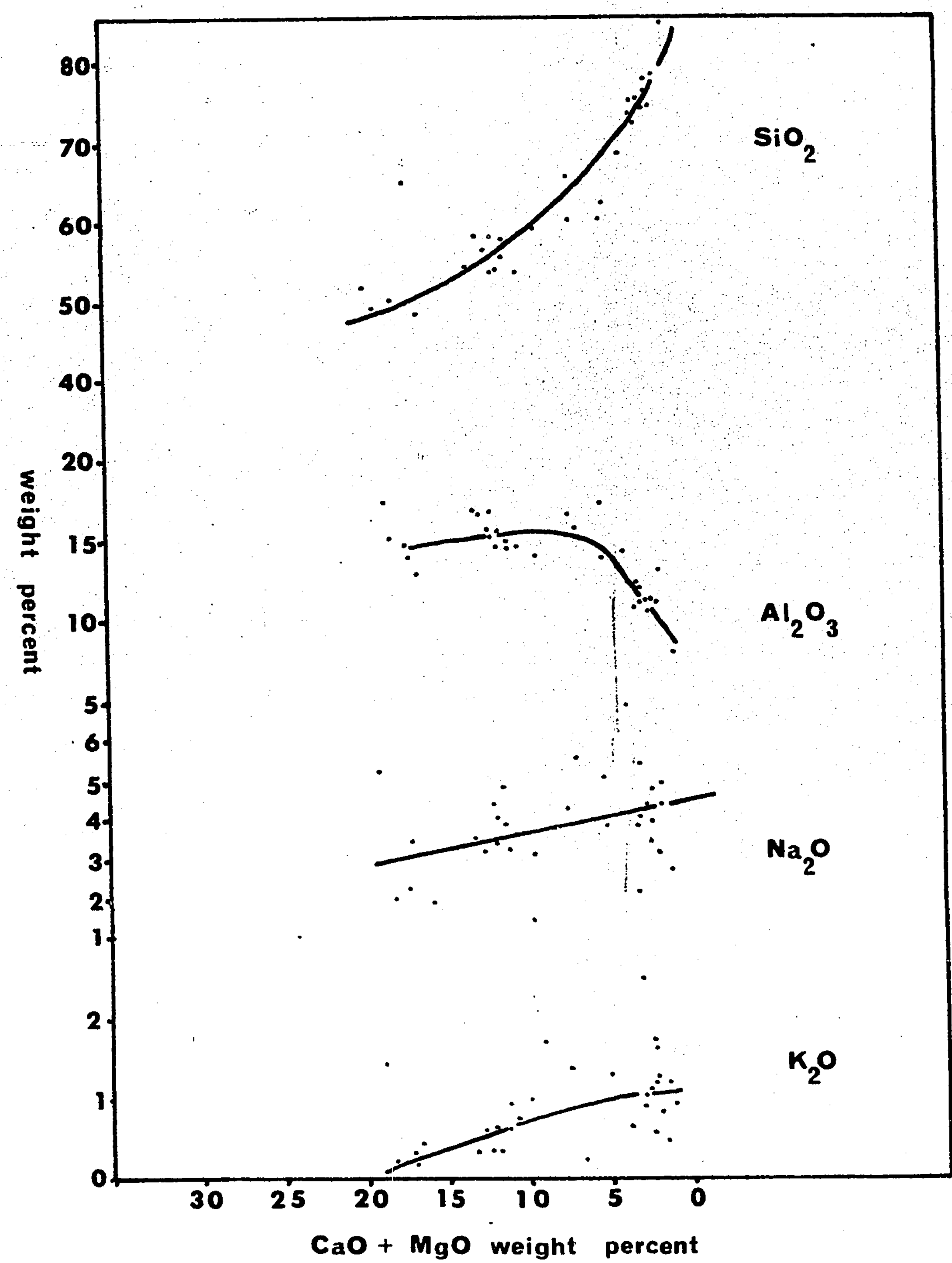


Fig. 6. Variation Diagrams for Rocks of the Noranda Area.

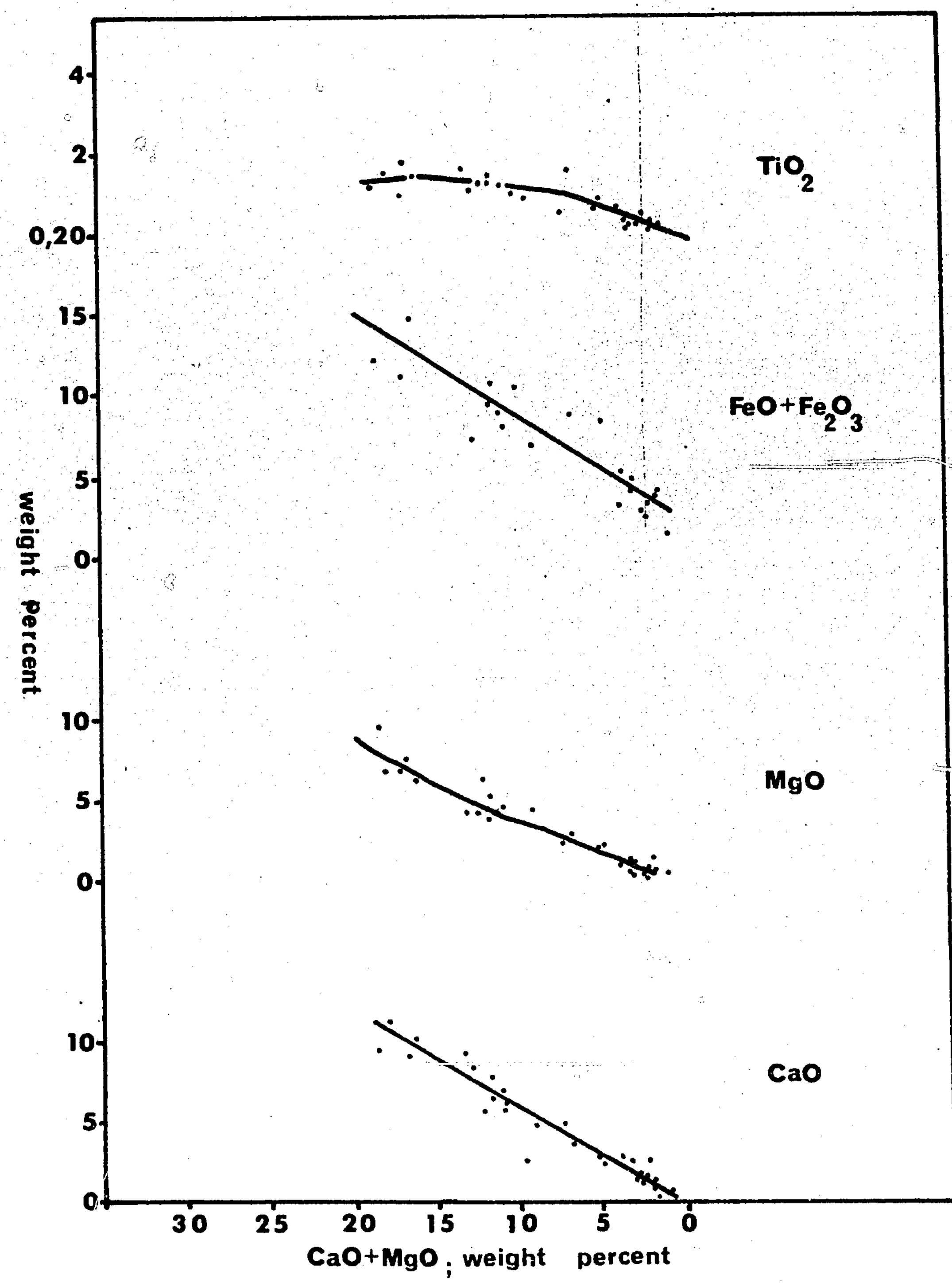


Fig. 6 cont'd. Variation Diagrams for Rocks of the Noranda Area.

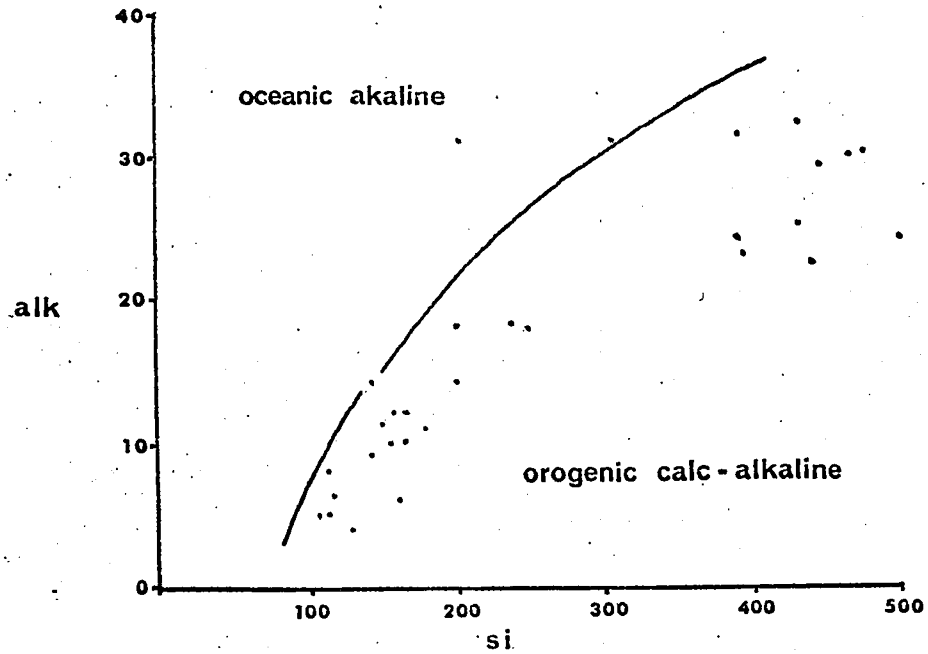


Fig. 7 Plot of Niggli alk-si values for Rocks of the Noranda Area.

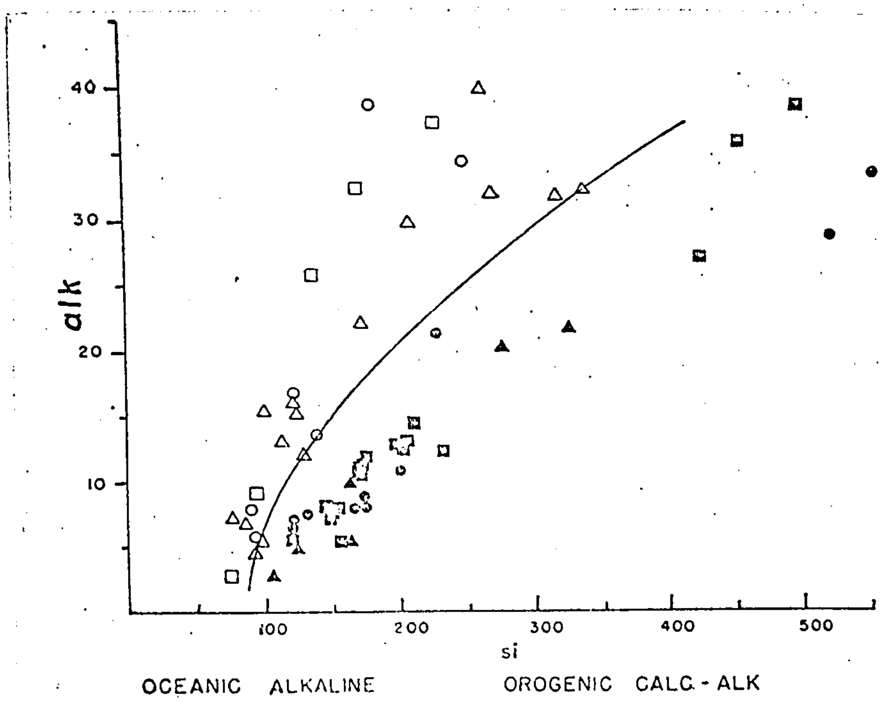


FIG. 5. Plot of Niggli alk-si values for control groups of lavas. Oceanic alkaline: △ Truk, □ Tahiti, ○ Kerguelen; orogenic calc-alk: ▲ Fuji, ◘ Izu, O Mariana.

Fig. 8 Figure 5 from Wilson, H. D. B., 1965.

BACKGROUND VALUES FOR ELEMENTS IN THE HOST ROCKS AND THEIR SIGNIFICANCE

MAJOR ELEMENTS

Background values (statistical modes) for major elements in Amulet andesite, Waite rhyolite and tuff obtained in this work are presented in table 4.[1] Analyses of Noranda area rocks were collected from the literature and are presented in table 5.

Variation diagrams for the Noranda rocks are presented in fig. 6. The Niggli values for "alk," plotted against "si," are presented in fig. 7. The resulting graph can be compared with a similar plot of oceanic alkaline and orogenic calc-alkaline rocks (fig. 8) (Wilson, H.D.B., 1965). Peacock's alkali-lime index is given in fig. 5 and Rittman's (1962, p. 110) sigma values are presented in table 5. These parameters show that rocks from the Noranda area have no alkaline affinity and that, with the exception of minor syenite, all the rocks belong to a single, highly differentiated, calc-alkaline volcanic suite. The distinction between the Noranda volcanic suite and the spilite suite is less clear. The average spilite is a basalt with high contents of soda (Na_2O - 4.9%) and titania (TiO_2 - 3.2%) (Turner and Verhoogen, 1960, p. 271). Roscoe's average basalt, from the Kirkland Lake and Noranda areas, contains much less of these constituents (Roscoe, 1965). On the basis of 261 analyses, H.D.B.

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1. Chemical analyses obtained for Waite rhyolite and Amulet andesite in this work have come from samples within one hundred feet of the "main contact" and therefore do not represent the whole of the units.

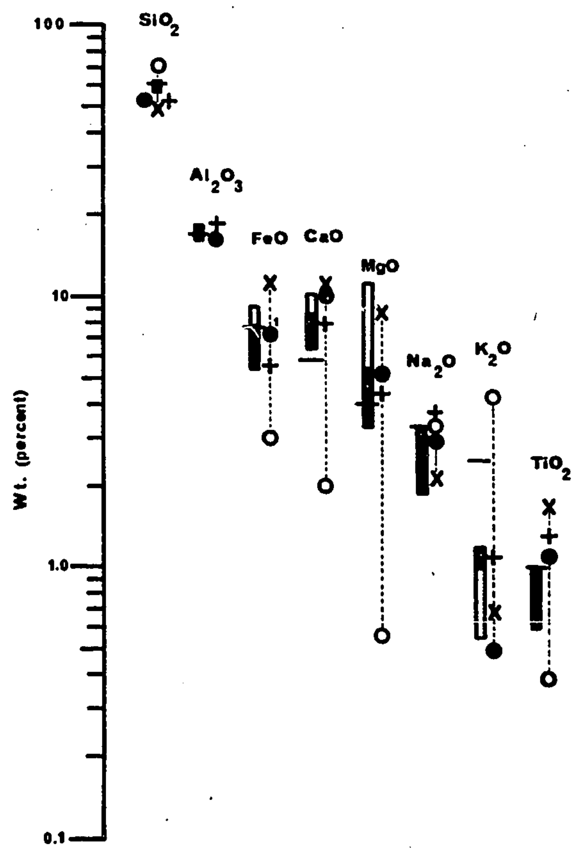

figure 9. COMPARISON OF THE MAJOR ELEMENT COMPOSITION OF ANDESITES, BASALT, GRANITE AND CONTINENTAL CRUST. Filled rectangles, andesite from Japan and New Zealand; unfilled rectangles, mafic andesite from Japan and New Zealand; ●, Amulet andesite; +, Nockolds (1954) average andesite; O, granite; X, basalt; -, continental crust (after Taylor and White, 1965)

Analyses of New Zealand and Japanese andesite are by Taylor and White (1965).

The data for granite and basalt were compiled by Taylor and White from Daly (1933), Kolbe (1965),[2] and Turekian and Wedepohl (1961).

The data for continental crust are based on a 1:1 ratio of mafic and siliceous rocks and were compiled by Taylor and White from Poldervaart (1955) and Taylor (1964).

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1. Average of 11 wet chemical analyses by H. Soutar, McGill University.

2. Kolbe, P., Ph.D. thesis, Australian National University, 1965.

Wilson concluded that the Archean volcanic rocks (mostly from Ontario) belong not to the alkaline or spilite suites but to the basalt-andesite-rhyolite association typical of continental and island arc areas (Wilson, H.D.B., 1965). In fact, it is not so much a high soda content but a distinctly low potash content which characterizes the Noranda volcanic suite. This deficiency in potash is discernible in the Amulet andesite (fig. 9) but is particularly noticeable in the Waite rhyolite[1] which contains 1.3 per cent K_2O compared to 5.35 per cent K_2O in Nockolds' (1954) average calc-alkalic rhyolite. The Flavrian and Powell granites are chemically very similar to the Waite rhyolite and it is probable that both rocks were formed from the same magma. If this is correct, the original alkali content of the Waite rhyolite must not have been altered by a process such as alkali transfer during devitrification. Twelve of forty eight samples of Archean rhyolite analyzed by Wilson are chemically similar to the Noranda rhyolite (Wilson, H.D.B., et al, 1965). Except for increased amounts of iron and possibly potassium, the median contents of major elements in tuff are intermediate when compared with the compositions of Amulet andesite and Waite rhyolite.

Recent work suggests that potash deficient rhyolite is one of the end products of an extreme differentiation of a relatively uncontaminated, oceanic, tholeiitic magma (Engel, 1965). This idea is supported by the fact that practically all reported analyses of relatively young, potash-poor rhyolites come from volcanic island areas

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1. Although "rhyo-dacite" is a more appropriate term for this unit, the term "rhyolite" is retained because of its common usage. Nockolds' (1954) average rhyo-dacite contains 3.01 per cent K_2O.

SOME ANALYSES OF LOW POTASH, HIGH SILICA (> 70%), VOLCANIC ROCKS

LOCATION	NO. OF ANALYSES	Na_2O PER CENT	K_2O PER CENT	REFERENCE
SAIPAN AND GUAM	4	3.5	1.7	Schmidt, 1952
JAPAN				
Northeast	6	3.8	1.6	Yagi, 1962
Izu-Hakone Area	4	3.7	1.3	Isshiki, 1964
Kamitaga Dacite Dome	1	3.9	1.8	Kuno, 1950
Shikotsu District	1	3.6	2.0	Ishikawa et al, 1957
Aira District	1	4.0	2.9	Ishikawa et al, 1957
Usu Volcano	2	4.2	1.1	Minikami et al, 1950
Hakone Volcano	1	4.1	1.4	Kuno, 1962
Asama Volcano	4	4.3	2.2	Kuno, 1962
Agagi Volcano	1	2.9	2.2	Kuno, 1962
Narugo Volcano	2	3.3	1.6	Kuno, 1962
Akita-Yake-Yama Volcano	1	3.4	2.1	Kuno, 1962
Kōzu-sima	4	4.4	2.3	Kuno, 1962
Nii-Zima Volcano	1	4.3	2.9	Kuno, 1962
Atosanupuri Volcano	1	4.0	1.6	Kuno, 1962
NEW ZEALAND	8	4.6	3.0	Ewart, 1963
SUMATRA				
Krakatau Group	4	4.6	2.6	Westerveld, 1952
SAKHALIN ISLAND	1	2.0	1.0	Verokhov, 1952
EASTER ISLAND GROUP	5	5.3	3.3	Bandy, 1937

Table 6

SOME ANALYSES OF LOW POTASH, HIGH SILICA (>70%), VOLCANIC ROCKS

LOCATION	NO. OF ANALYSES	Na_2O PER CENT	K_2O PER CENT	REFERENCE
KAMCHATKA	11	3.7	3.1	Tomkeiff, 1949
EAST KAMCHATKA Uzon	1	4.4	2.4	Vlodavetz and Piip, 1959
ALASKAN-ALEUTIAN ARC	3	4.2	2.7	Tomkeiff, 1949
WASHINGTON	1	3.2	1.0	Coombs, 1952
ALASKA Katmai	2	4.2	2.8	Fenner, 1926
YELLOWSTONE	1	4.6	2.5	Coombs and Howard, 1960
CHILE	2	2.9	1.3	Casertano, 1963
SOUTH SANDWICH ISLANDS	1	4.7	0.7	Gass, 1963
ICELAND	4	4.7	3.2	Carmichael, 1962

Table 6 (cont'd)

judged to be at the edge of the sial of the continents (table 6). Potash deficient Cenozoic volcanic rocks of the western United States occur in a narrow zone parallel to the Pacific Coast. Increasing potash content in volcanic rocks eastward from the coast was correlated with a thickening of the sial as demonstrated by the decreasing Bouger gravity (Moore, 1965). Relatively young volcanic rocks become progressively more potash rich toward the Asian continent across the Japanese and Indonesian Islands (Ishikawa and Katsui, 1959), (Kuno, 1960), (Rittman, 1962, p. 159).

Vast areas of relatively young, siliceous volcanic rocks occur closer to the center of continents but these rocks almost always contain abundant potash and correspond to Nockolds' (1954) averages for rhyolites. Engel's (1965) states that "...tholeiitic lavas, contaminated with Si, K and the chemically coherent trace elements and radiogenic isotopes from the sial, also have been the predominant or only magma generated in the mantle under the continents."

If Engel's' suggestion is correct we are presented with two major mechanisms for the generation of siliceous rocks. One involves the assimilation by a tholeiitic magma of sial under the continents and, presumably, differentiation which produces rhyolite containing potash and soda in roughly equal, and substantial, amounts. The other mechanism involves the extreme differentiation of a tholeiitic magma, with a minimum of assimilation of sial, probably in a wet environment (Osborn, 1959), at the edges of continents or in island arc areas and produces a potash deficient, siliceous rock referred to most often in the literature as soda - rhyolite. Accumulation of volatile substances during such a differentiation process would result in much explosive volcanic and hydrothermal activity.

The major element analyses of the Noranda area rocks support two ideas. First, the Noranda rocks belong to a single highly differentiated volcanic rock suite which is similar to younger extremely differentiated rock suites found at the edges of continents, especially along island arc systems. Second, the close association of both the Noranda ores and much recent solfataric activity to the pyroclastic varieties of this suite of rocks suggests that the Noranda ores and the recent sulphur and sulphide deposits of the volcanic islands[1] may share a similar origin.

The Canadian shield, locale of many of the Noranda-type of ore bodies is also, on the basis of a few analyses, the site of some potash-poor rocks (Engels, 1965; Wilson, H.D.B., 1965; Maxwell et al, 1965). Other examples of this association are the Mattagami area, Quebec (Sharp, 1964), the North Coldstream Mine, Port Arthur, Ontario (Giblin, 1964) and the East Buchans Mine, Newfoundland (Relly, 1960). Outside Canada, examples are the Jerome area, Arizona (Anderson and Creasy, 1958) and the Shasta district, California (Kinkel et al, 1957). Other areas in the world where soda-rich (and therefore possibly potash-poor) rocks have been reported associated with massive pyritic deposits include the Philippines, Alaska, Scandinavia, Central Europe, Cyprus, Turkey and the Ural Mountains in Russia (Kinkel, 1962).

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1. For an excellent review of young sulphur and sulphide deposits in Japan see Mukaiyama (1959).

Table 7

TRACE ELEMENT CONTENT OF THE HOST ROCKS

	WAITE RHYOLITE		AMULET ANDESITE		TUFF	
	mode (ppm)	mean (ppm)	mode (ppm)	mean (ppm)	median (ppm)	range (ppm)
Ag	.17	.38	.18	.24	1.25	4.36
Co	mostly < 1		43	53.8	85	71.3
Cr	mostly < 40		155	197	150	176
Cu	20	104	70	119	700	2213
Ga	27	30	24.5	24.5	25	19
Ni	1	7.8	50	104	60	77.9
Pb	0.7	2.4	0.3	1.0	4.6	24.8
Sn	0.5	1	2.5	1.4	4	21.1
Sr	370	418	150	197	340	285
Y	50	70	20	24	32	23
Zn	180	394	160	240	800	3925
Zr	260	405	180	180	260	223

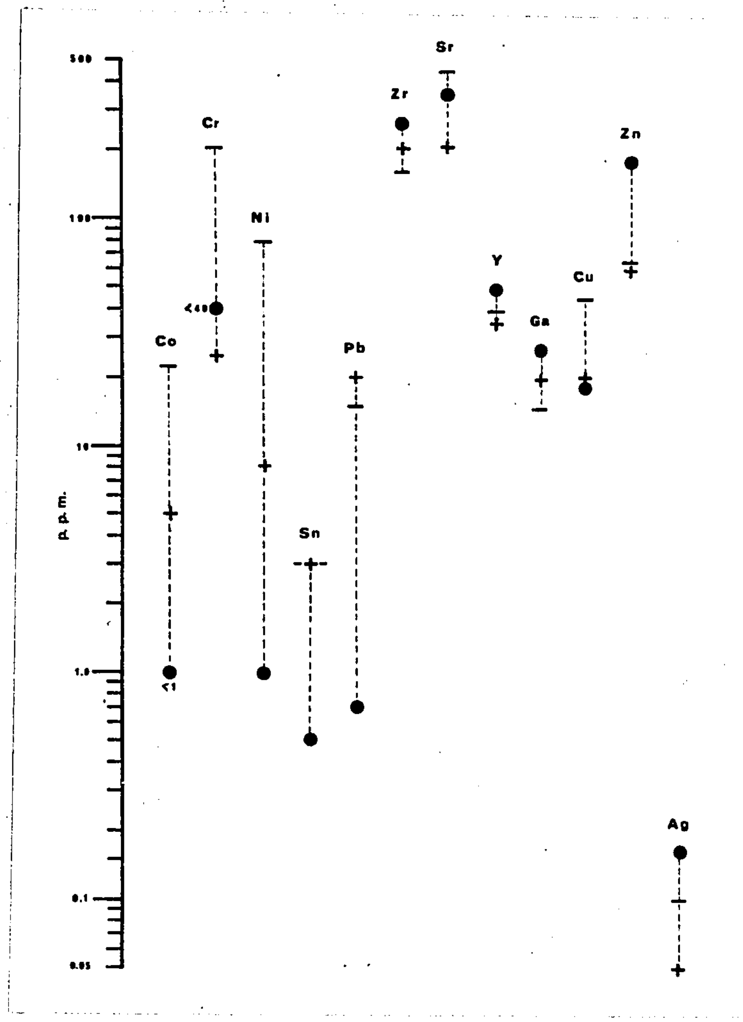

figure 10. COMPARISON OF THE WAITE RHYOLITE WITH THE CONTINENTAL CRUST AND THE AVERAGE FELSIC ROCK. ●, Waite rhyolite; +, average felsic rock; –, continental crust.

The data for the average felsic rock are from Vinogradov (1962).

The data for continental crust are based on a 1:1 ratio of mafic and siliceous rock and are from Mason (1960) (cf. figs. 9 and 11).

TRACE ELEMENTS

The background values (statistical modes) of many trace elements in the host rock of the Lake Dufault ore body are assumed to represent the original contents of these elements in the rock. Other trace elements have been added or removed to such an extent that rock containing original amounts of these elements may have been sampled only in a few places. Background values of the trace elements are presented in table 7.

Waite Rhyolite

The background values of trace elements in Waite rhyolite are plotted in fig. 10 along with abundance data for the earth's crust and felsic rocks. The earth's crust is assumed to be composed of equal portions of siliceous and mafic rock (Mason, 1960).

Cobalt, nickel and chromium

The Waite rhyolite, when compared with the average felsic rock, contains very small amounts of Co, Ni, and Cr. Wager and Mitchell (1951) in their study of the contents of trace elements in the rocks of the Skaergaard intrusion, showed that Cr, Ni and to some extent Co, are concentrated in early rocks so that later rocks contain little or none of these elements. These elements are concentrated in early-formed minerals in a crystallizing magma and, therefore, become depleted in residual melts produced by fractional crystallization.

Lead and tin

The small amount of lead in the Waite rhyolite may be related to its low potassium content. As reported in an earlier section, Engel (1965) suggests that magma generated in the mantle under the continents becomes contaminated with radiogenic isotopes as well as potassium from the sial. Unlike the Amulet andesite (fig. 12), the Waite rhyolite has a low tin content.

Zirconium, strontium and yttrium

The background zirconium[1] content of the Waite rhyolite is less than that of granophyres associated with differentiated basic bodies like the Skaergaard intrusion (300-500ppm or more) but greater than that of the majority of rhyolites or quartz-monzonites and granites of the orogenic belts (200ppm or less) (Chao and Fleischer, 1960). The zirconium content of the Waite rhyolite is similar to that of soda-rhyolites and quartz latites reported by Chao and Fleischer from the Aleutian Islands. Alkalic volcanic rocks contain much greater amounts of zirconium than volcanic rocks of the calc-alkalic or tholeiitic series.

The Waite rhyolite has a high strontium to calcium ratio. High ratios of strontium to calcium in many rhyolites and pegmatites have been reported by Turekian and Kulp (1956) who suggest that these ratios may be a consequence of magmatic differentiation by fractional crystallization.

Wager and Mitchell (1951) showed that yttrium tended to substitute for calcium in "late" pyroxene in rocks of the Skaergaard intrusion. The Waite rhyolite contains slightly more yttrium than the average felsic rock (fig. 10).

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1. Analyses of standard samples (table 3) show that the background values of zirconium and strontium given in this work may be erroneously high.

Gallium

The gallium[1] content of the Waite rhyolite is slightly higher than that reported in felsic rocks (fig. 10) and in siliceous volcanic rocks from Kamchatka (Borisenok, 1959). Gallium shows no tendency to become concentrated in rest magmas and becomes separated from aluminum only during supergene alteration.

Silver, copper and zinc

The background contents of Ag and Zn[1] in the Waite rhyolite are higher than their contents in the average felsic rock. The background content of copper in the Waite rhyolite is similar to the average copper content of felsic rocks (Vinogradov, 1962; Wedepohl, 1953, 1962).[2] Variations of these elements in the Waite rhyolite clearly show that large amounts have been added during the ore-forming process.

Amulet Andesite

The background trace element composition of the Amulet andesite is plotted with analyses of andesite from New Zealand and Japan, estimates of the trace element content of the average granite, basalt and continental crust (Taylor and White, 1965), and abundance data for andesite and other intermediate rocks given by Vinogradov (1962) (fig. 11).

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1. Analyses of standard samples (table 3) show that the background values of gallium and zinc given in this work may be erroneously high.

2. The value for copper is higher than Wedepohl's average for felsic rocks.

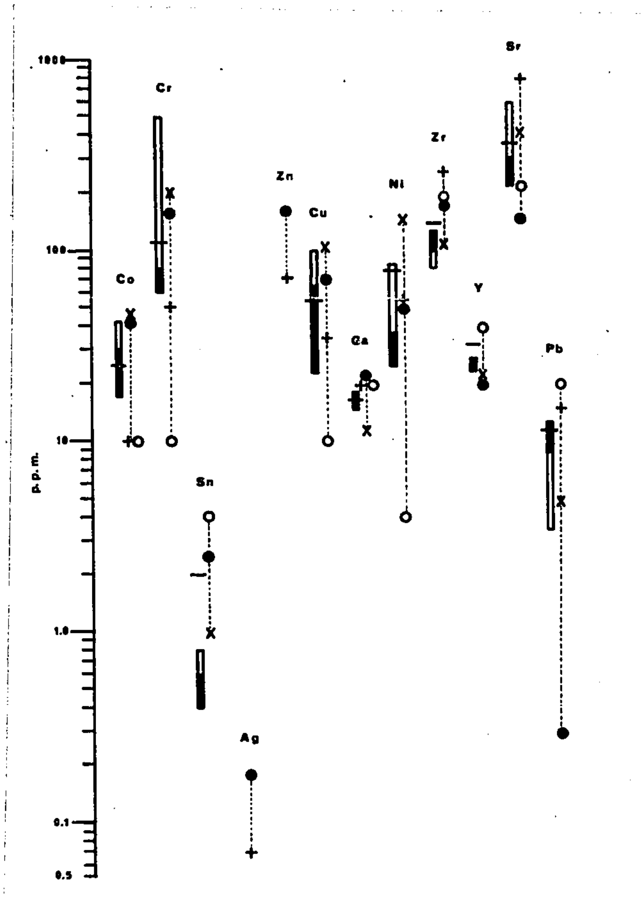

figure 11. COMPARISON OF THE TRACE ELEMENT COMPOSITION OF ANDESITES, BASALT, GRANITE AND CONTINENTAL CRUST. Filled rectangles, andesite from Japan and New Zealand; unfilled rectangles, mafic andesite from Japan and New Zealand; ●, Amulet andesite; +, Vinogradov's (1962) average andesite and intermediate rock; O, granite; X, basalt; –, continental crust (after Taylor and White, 1965).

Analyses of New Zealand and Japanese andesite are by Taylor and White (1965).

The data for granite and basalt were compiled by Taylor and White from Daly (1933), Kolbe (1965)[1] and Turekian and Wedepohl (1961).

The data for continental crust are based on a 1:1 ratio of mafic and siliceous rocks and were compiled by Taylor and White from Poldervaart (1955), Taylor (1964).

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1. Kolbe, P., Ph.D. thesis, Australian National University, 1965.

Cobalt, chromium, nickel and tin

The background values for Co and Cr[1] in Amulet andesite are higher than their usual contents in andesites whereas that for nickel is normal. The same is true of andesites from Japan and New Zealand. Analyses of pyrite from the Noranda area given by Roscoe (1965) showed unusually high amounts of tin and cobalt. The background tin content of the Amulet andesite is significantly higher than the tin content of andesite from Japan and New Zealand (fig. 11).

Lead

The background content of lead in the Amulet andesite is lower than the lead content of the average andesite. New Zealand and Japanese andesites show the same feature (fig. 11). This deficiency in lead parallels the potassium deficiency in these rocks.

Zirconium

The background content of zirconium[2] in the Amulet andesite is lower than Vinogradov's (1962) average and higher than the zirconium content of andesites from Japan and New Zealand (fig. 11) and the Aleutian Islands (65ppm, 13 analyses) (Chao and Fleischer, 1960). The zirconium content of the Amulet andesite corresponds to that of the andesite from the Cascade Mountains in California and Oregon. What is perhaps more significant is the fact that the content of zirconium in the Amulet andesite (180ppm) differs relatively little from that in the Waite rhyolite (260ppm). This minimal variation is typical of the

1. Analyses of standard samples (table 3) show that the background values of chromium given in this report may be erroneously high.

2. Analyses of standard samples (table 3) show that the background values of zirconium given in this work may be erroneously high.

basalt-andesite-dacite-rhyolite series of the Circum-Pacific region (Chao and Fleischer, 1960). These authors show that the alkalic rock series is higher in zirconium and shows a more pronounced increase of zirconium from mafic to siliceous composition. The calc-alkalic rocks of the Southern California batholith and the Caledonian rocks of Scotland have irregularly varying zirconium contents.

Strontium

The Amulet andesite has a much lower background content of strontium than is usual in andesites. It is quite possible that this was caused by the leaching of some of the original strontium, especially at the base of the andesite (fig. 42).

Yttrium and gallium

The yttrium and gallium[1] contents of the Amulet andesite are essentially the same as that reported in other andesite.

Silver, copper and zinc

The background contents of Ag and Zn[1] in the Amulet andesite are very similar to those in the Waite rhyolite and are higher than the Ag and Zn contents of the average intermediate rock. The background copper content of the Amulet andesite is higher than that of the Waite rhyolite and higher than the average copper contents of intermediate rocks (Vinogradov, 1962). It will be shown in forthcoming sections that certain amounts of these elements have been added to the Amulet andesite.

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1. Analyses of standard samples (table 3) show that the background values of gallium and zinc given in this thesis may be erroneously high.

Conclusions

It has been suggested in a previous section that the rocks of the Noranda area belong to a single volcanic rock suite which is similar to suites of younger, extremely differentiated volcanic rock found at the edges of continents, especially along island arc systems. A comparison of the contents of trace elements in the Waite rhyolite and Amulet andesite with the small amount of data available for volcanic rocks from volcanic islands lends some support to this idea. Of special significance in this regard may be the unusually low lead content of the Waite rhyolite and Amulet andesite. Engel (1965) suggests that magma generated under the continents would become contaminated with radiogenic elements as well as with potassium.

The contents of other elements in the host rocks suggest a similarity between these rocks and rocks from volcanic island areas. These elements are Zr in the Waite rhyolite and Co, Cr, and Zr in the Amulet andesite.

The unusually low contents of Co, Cr and Ni in the Waite rhyolite compared with the average felsic rock may be explained by the tendency of these elements to become depleted in residual melts produced by fractional crystallization.

The Waite rhyolite and the Amulet andesite contain unusually high background amounts of Ag and Zn and the Amulet andesite has a high background copper content. As shown in forthcoming sections, these elements have been added to the host rocks during the ore-forming process.

Bedded, Cherty Tuff

The median values in tuff of elements found concentrated in ore (Ag, Co, Cu, Ni, Pb, Sn, Zn) are higher than the background values of these elements in either Waite rhyolite or Amulet andesite. The range of values for each of these elements in tuff is also greater than that of any of the other elements (Cr, Ga, Sr, Y, Zr). This feature of the tuff implies a relationship between it and ore.

DISTRIBUTION OF ELEMENTS IN THE HOST ROCKS

LATERAL DISTRIBUTION OF ANOMALOUS VALUES OF ELEMENTS IN RHYOLITE AND ANDESITE

Perusal of the data charts (Appendix B) shows that the average value ($\bar{x}$) for an element in the rock sampled from one drill hole is in many cases beyond the limits of background. The significance of these "anomalous" values is established by plotting them on diamond drill hole plans (figs. 12 to 33). One plan is given for each element with more than just a few anomalous values in rhyolite or andesite. Those drill hole locations marked with open circles denote rhyolite or andesite which contains background amounts of an element.

Rhyolite

Rhyolite which contains SiO_2, Fe (total as Fe_2O_3), Mno, MgO, Na_2O, Ag, Co (?),[1] Cu, Ni, Pb, Sn and Zn in anomalous amounts was

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1. Because most samples contain less than detectable amounts of Co, results for this element are not plotted on a plan of diamond drill holes.

sampled from several diamond drill holes. Rhyolite directly below the massive sulphide ore body, mainly in an altered and mineralized zone, is deficient in SiO_2 and Na_2O (figs. 12 and 13). Rhyolite containing abnormally high amounts of nickel was cut by several drill holes scattered throughout the property (fig. 14). The "ore-major" and "ore-trace" elements, Fe (total as Fe_2O_3), MnO, MgO, Ag, Co (?), Cu, Pb, Sn and Zn occur in abnormally high amounts close to the sides of the massive sulphide ore body and in the altered and mineralized zone beneath it (figs. 15 to 22).

Andesite

Andesite containing abnormally high amounts of Al_2O_3, CaO, K_2O, Ag, Co, Cr, Cu, Ni, Pb, Sn and Zn was cut by several diamond drill holes in the Norbec area. Anomalous values for Al_2O_3, CaO, K_2O, Co, Cr, Ni, and Sn are scattered throughout the area (figs. 23 to 29). The "ore-trace" elements in andesite (Ag, Cu, Pb, Zn) occur in amounts greater than background over the massive sulphide ore body (figs. 30 to 33).

Summary of Anomalous Values

On tables in Appendix D the average value for each element from each drill hole is designated as background (equal to "0"), probably anomalous (equal to "1")[1] and anomalous (equal to "2").[2] For normally distributed elements, values outside background limits

---

1. Values between "a" and "b" on the histograms (Appendix A).
2. Values outside of "b" on the histograms (Appendix A).

(ULB, LLB) are weighted as anomalous (equal to "2" or "-2" respectively). Results for the "ore-elements" are summed and the sum is plotted on diamond drill hole plans (figs. 34 to 36). These figures confirm the contention that the "ore-trace" and "ore-major" elements are present in anomalous amounts in the host rock over, under and close to the sides of the massive sulphide ore body. The northwest Norbec section is the only other sampled part of the property which may have been similarly effected. The results are further summarized on tables 8 and 9, p.99, 100.

LATERAL DISTRIBUTION OF ELEMENTS IN BEDDED, CHERTY TUFF

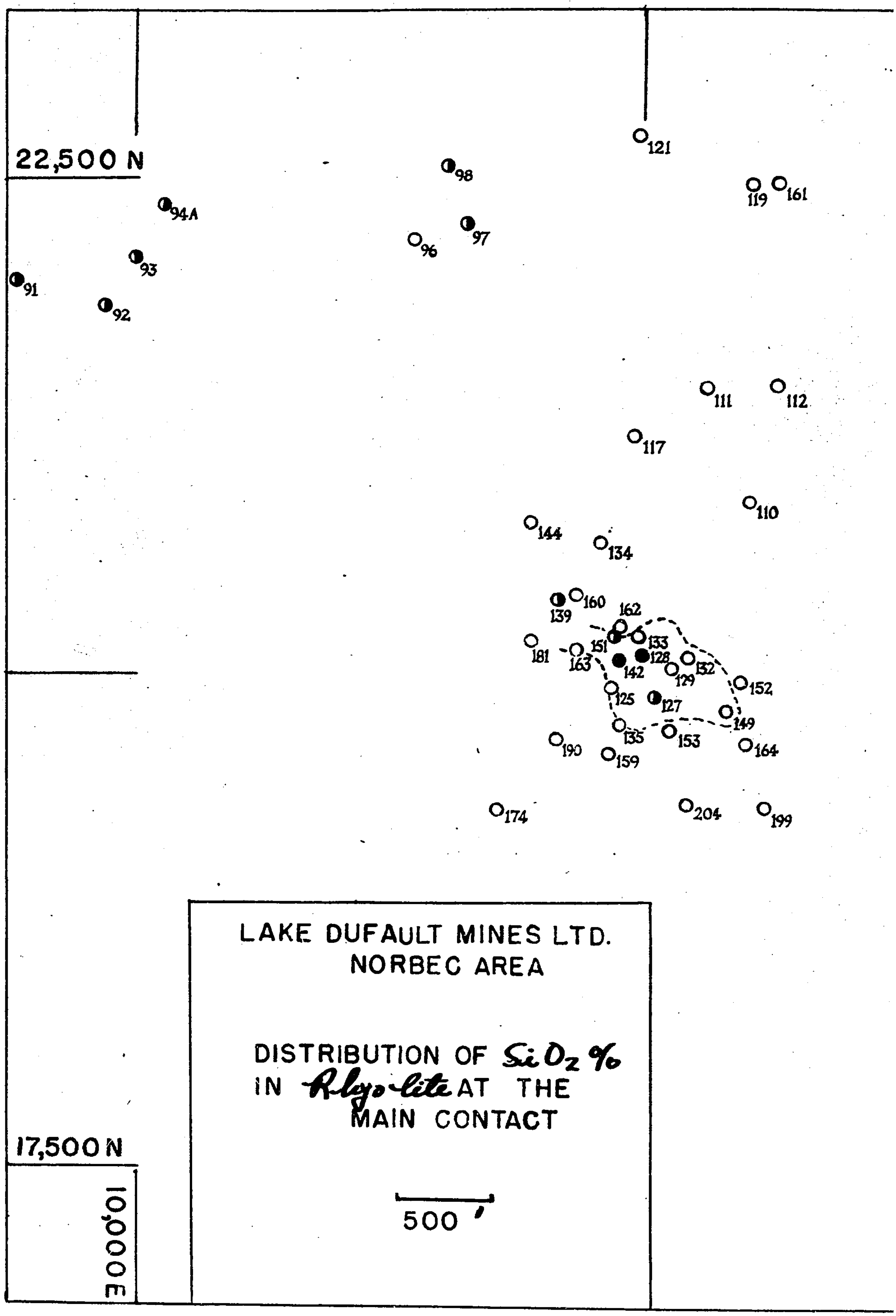
Analyses of tuff samples are treated as described previously (p.37). The only elements which seem to have a lateral distribution related to the massive sulphide ore body are Pb, Cd, and Zn (figs. 37, 38 and 39).

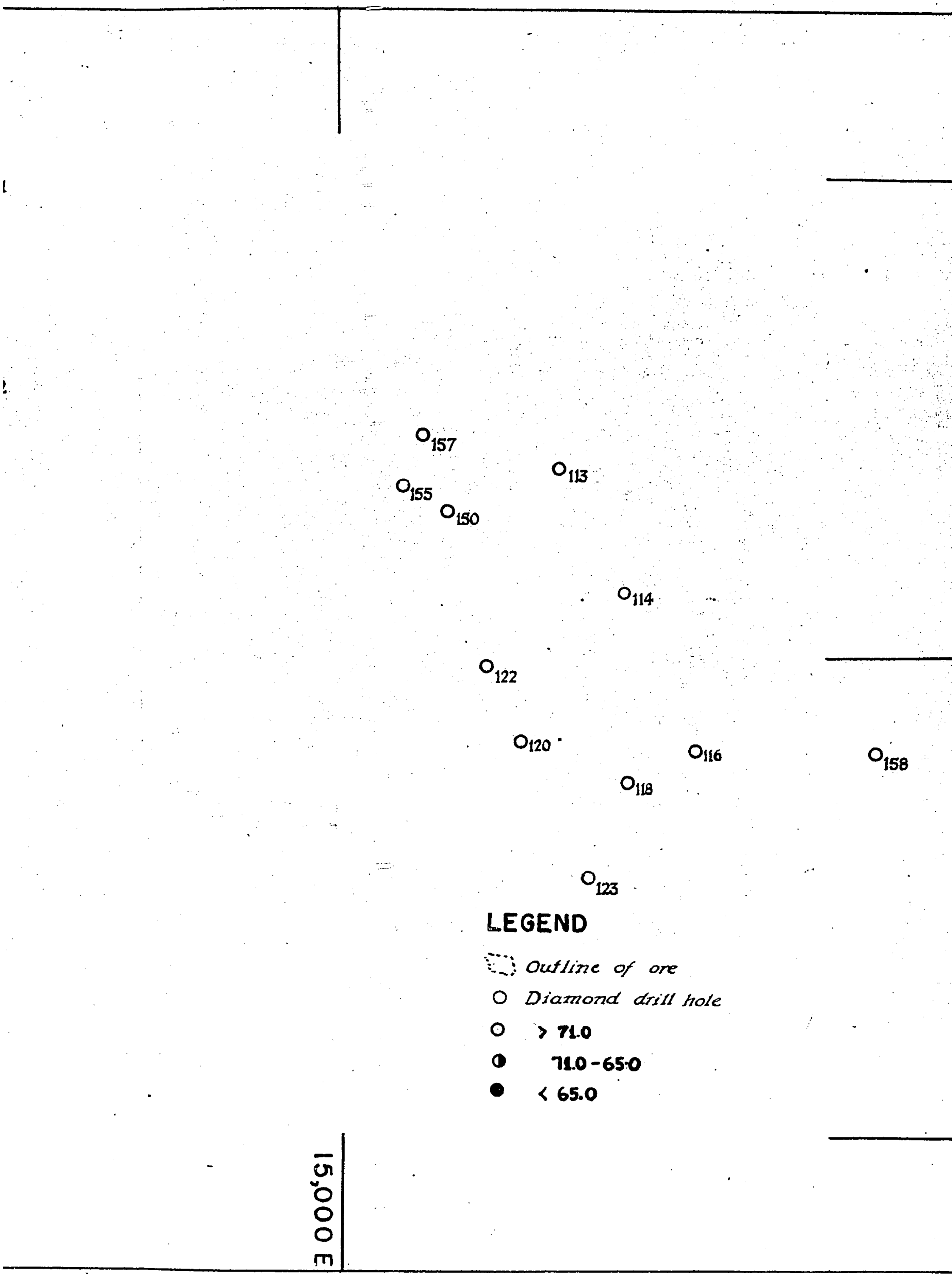
VERTICAL DISTRIBUTION OF ELEMENTS IN RHYOLITE AND ANDESITE

Very simple graphs constructed from the data of tables E1, E2, E3 and E4 (Appendix E) show which elements tend to be present in greater or lesser amounts near the main contact (figs. 40, 41). For rhyolite, the ordinate of the graphs is the number of holes in which the top half of the sampled section contains a higher concentration of the element than does the bottom half. The abcissa is the number of holes in which the top half of the sampled section is deficient in an element. The base of the andesite is tested in the same way. If, for a given element, there is no variation at all in many drill holes, the plot of that element would fall close to the origin. If a given element has a random

SiO_2 rhyolite

Figure 12

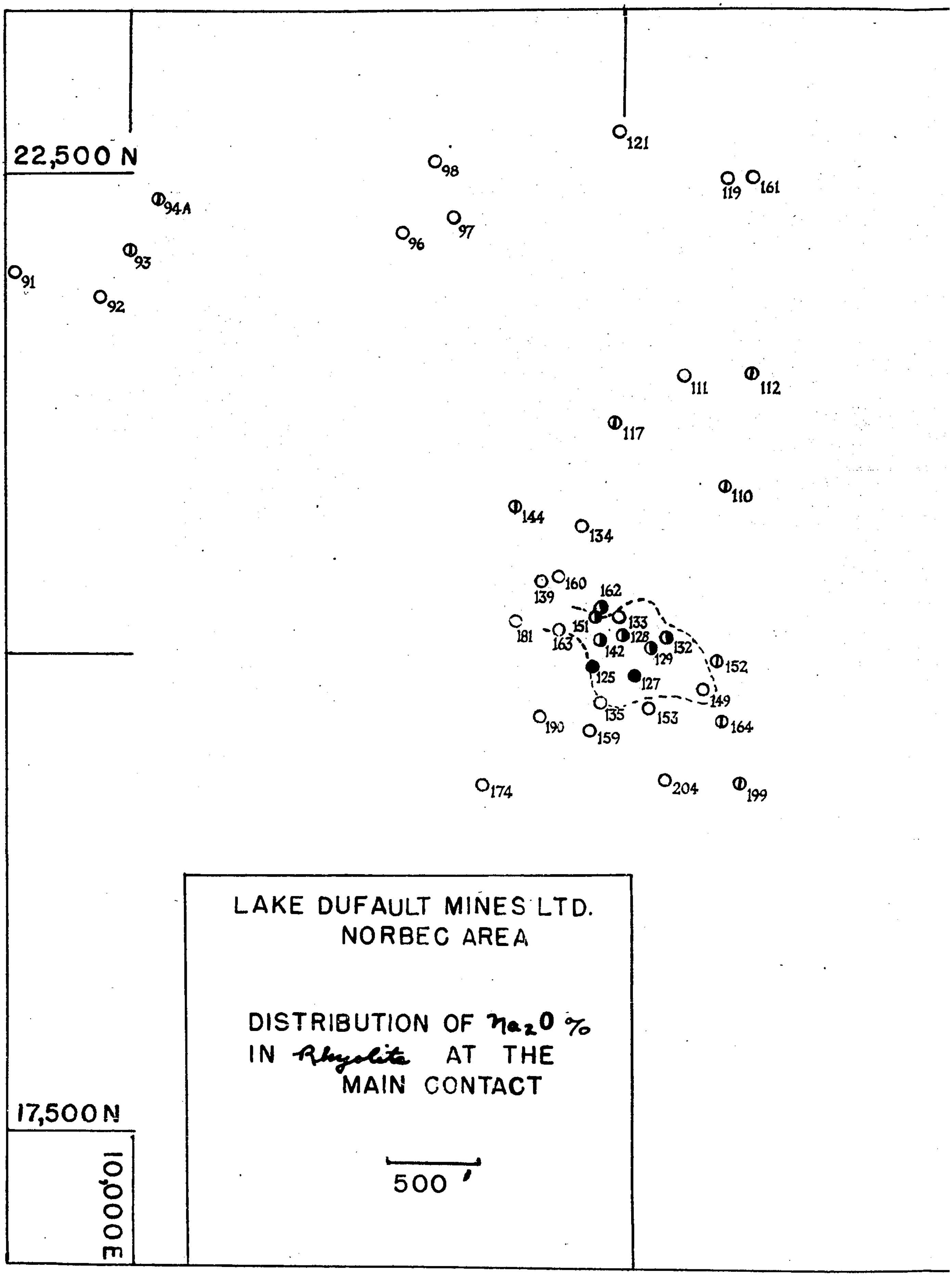

22,500 N
17,500 N
10,000E
121
98
119
161
94A
97
96
93
91
92
111
112
117
110
144
134
139
160
162
133
181
151
128
163
142
132
129
152
125
127
149
135
153
190
159
164
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF SiO2 %
IN Rhyolite AT THE
MAIN CONTACT
500 '



157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
> 71.0
71.0 - 65.0
< 65.0
15,000 E

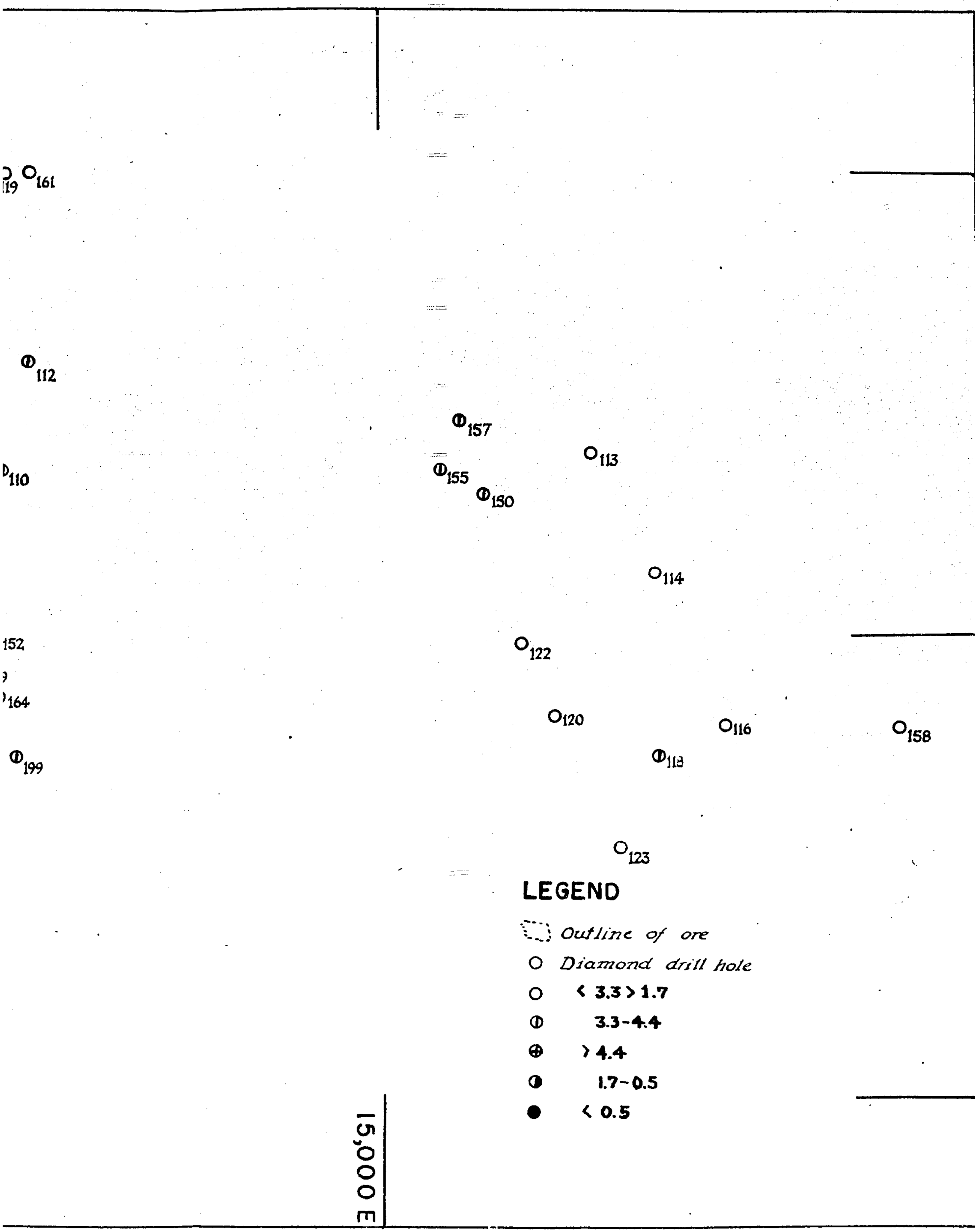
Na_2O rhyolite

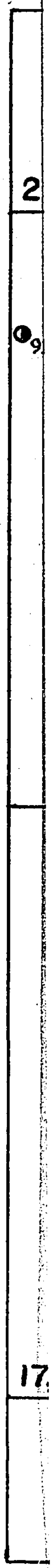
Figure 13



LAKE DUFAULT MINES LTD.
NORBEC AREA

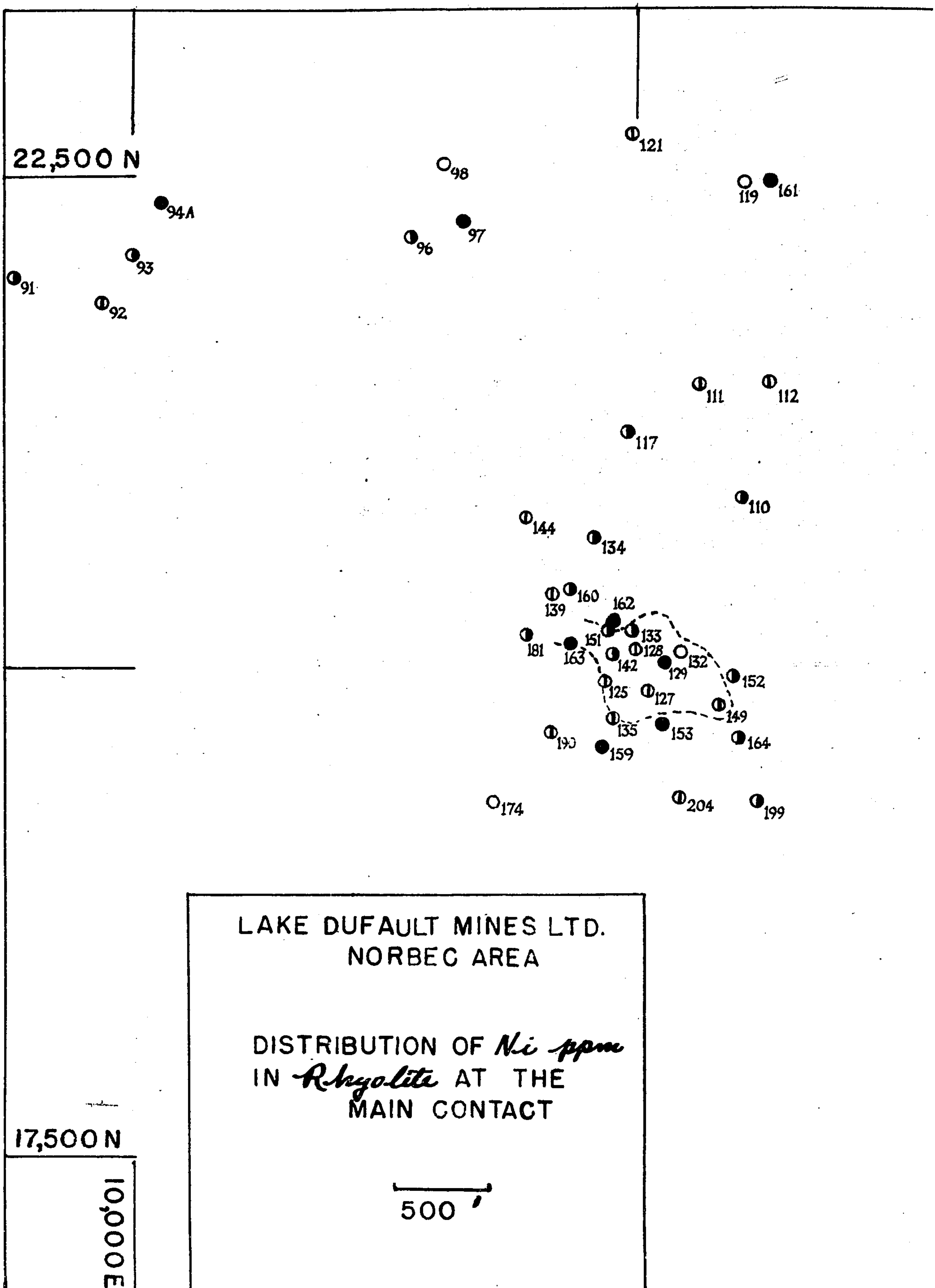
DISTRIBUTION OF Na_2O %
IN Rhyolite AT THE
MAIN CONTACT

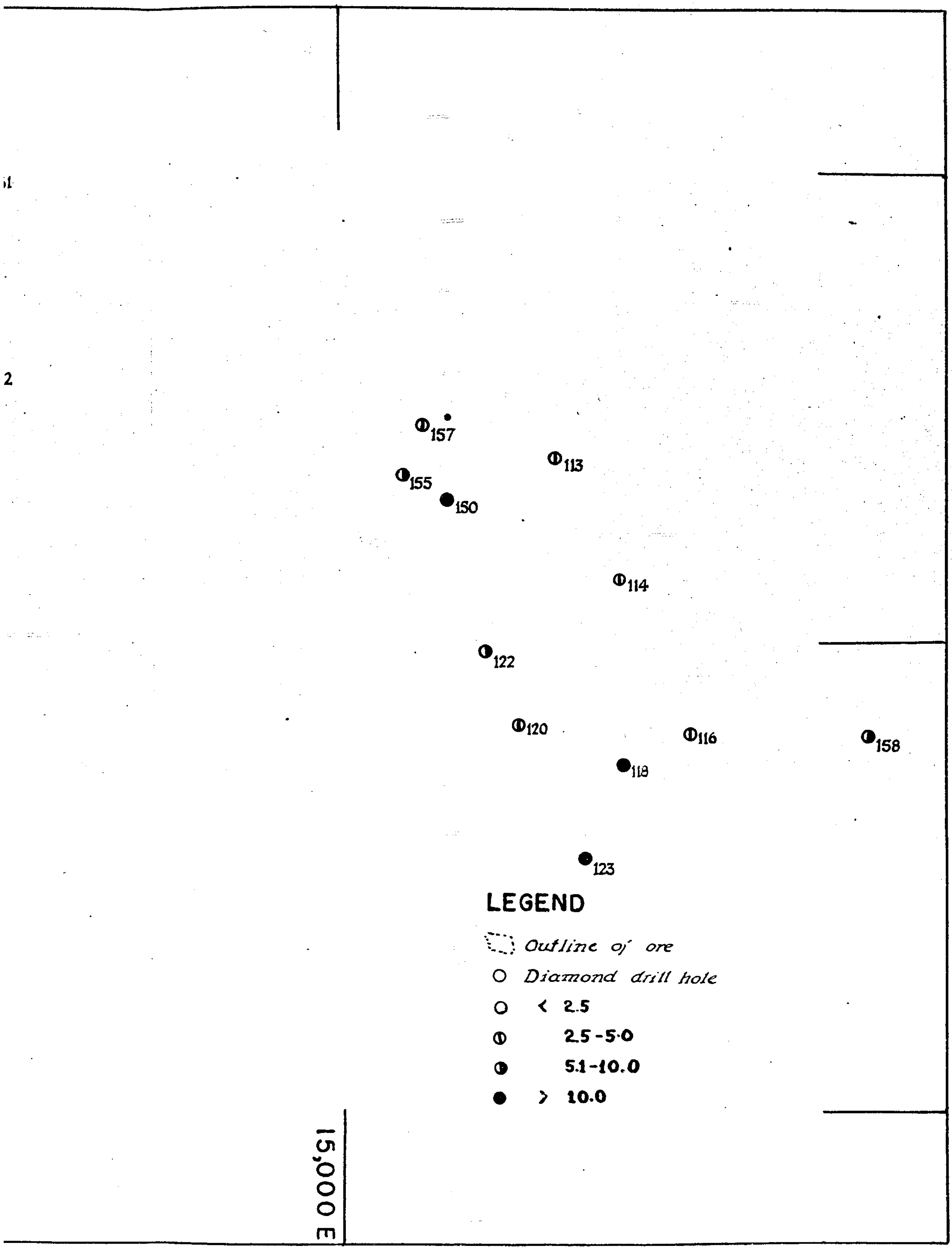

119
161
112
157
113
110
155
150
114
152
122
164
120
116
158
199
118
123
LEGEND
Outline of ore
Diamond drill hole
< 3.3 > 1.7
3.3-4.4
> 4.4
1.7-0.5
< 0.5
15,000 E



Ni rhyolite

Figure 14

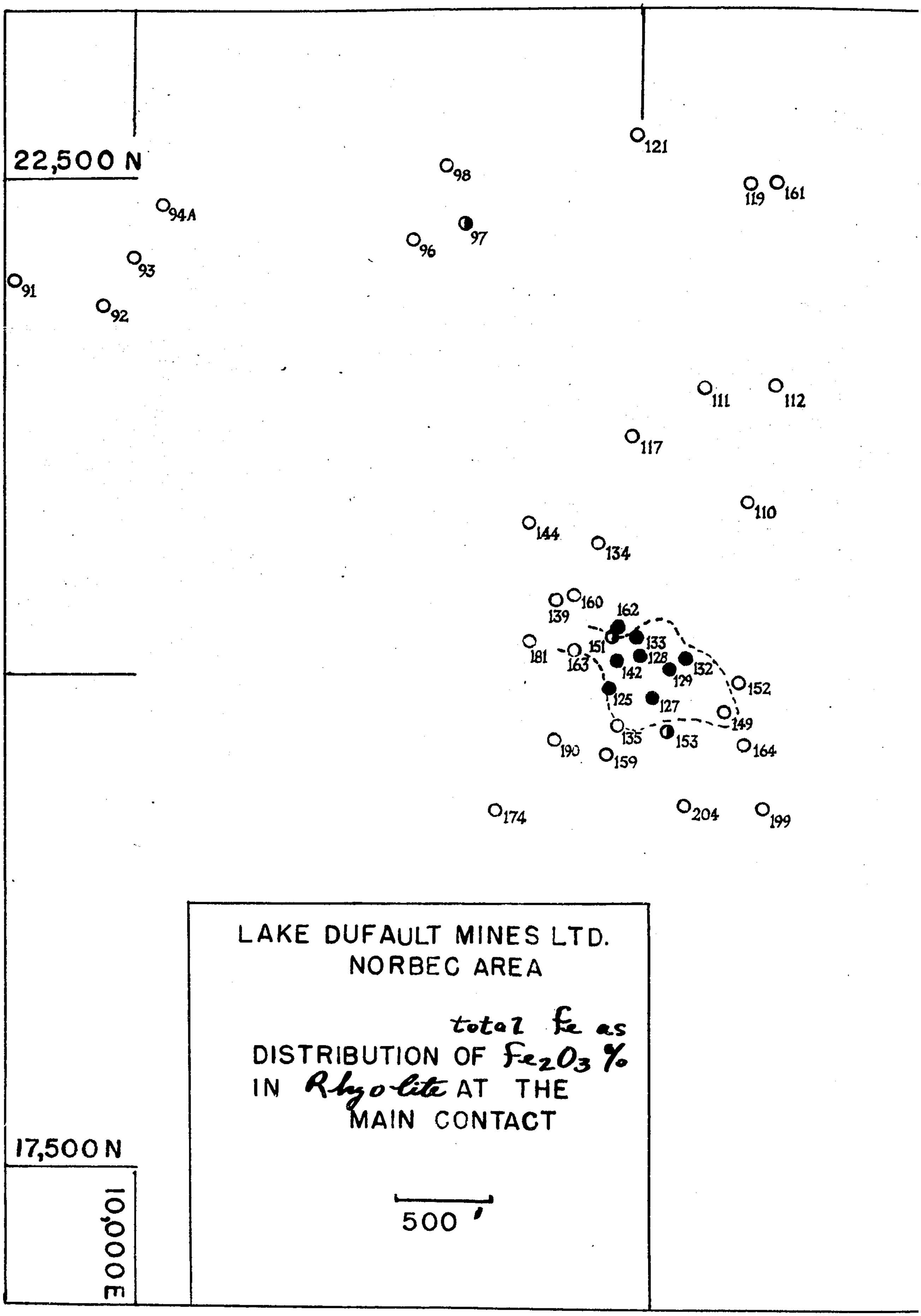

22,500 N
17,500 N
10,000 E
94A
91
92
93
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
163
151
133
142
128
132
129
152
125
127
149
135
153
190
159
164
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Ni ppm
IN Rhyolite AT THE
MAIN CONTACT
500 '

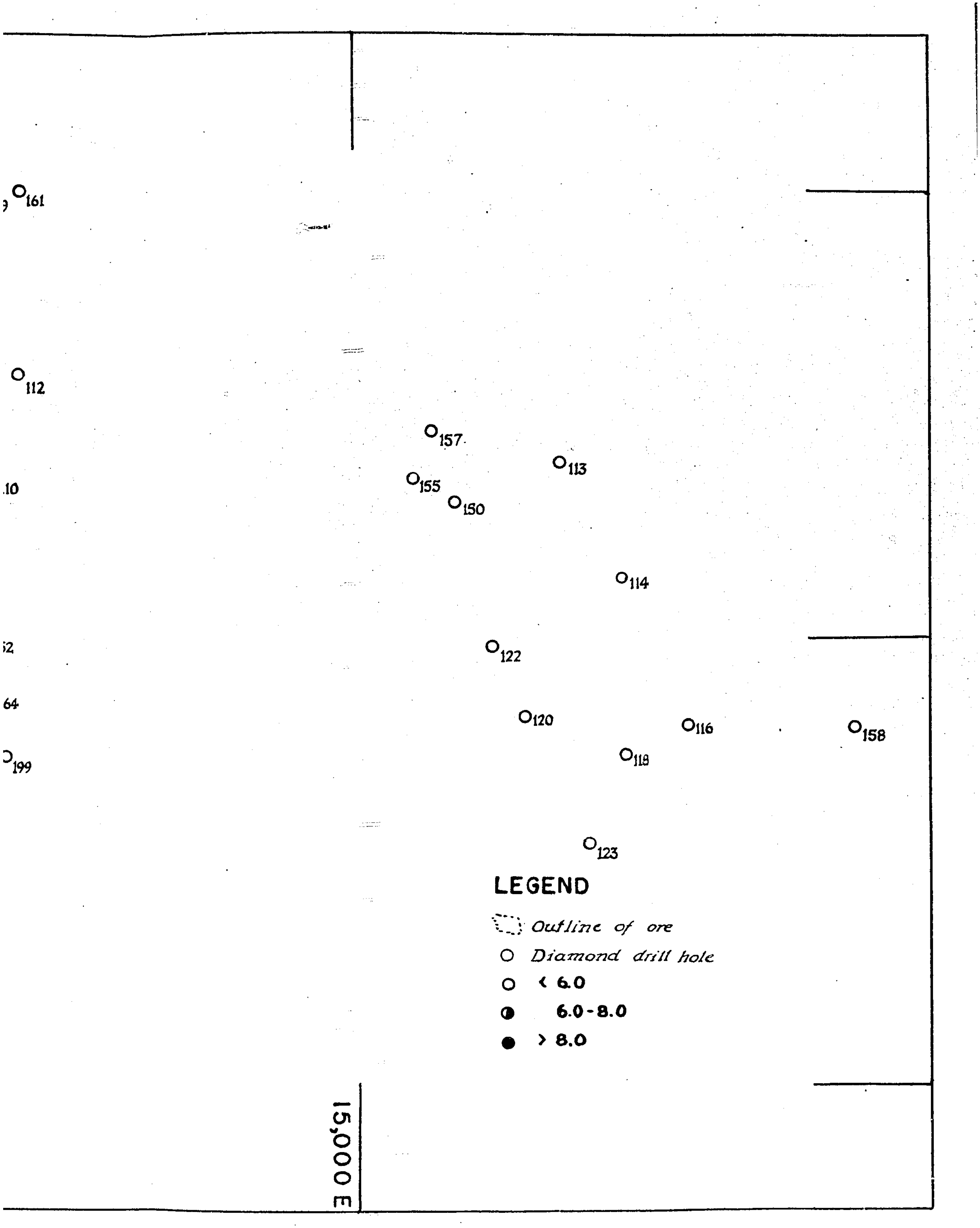


1
2
157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 2.5
2.5 - 5.0
5.1 - 10.0
> 10.0
15,000 E

Fe rhyolite

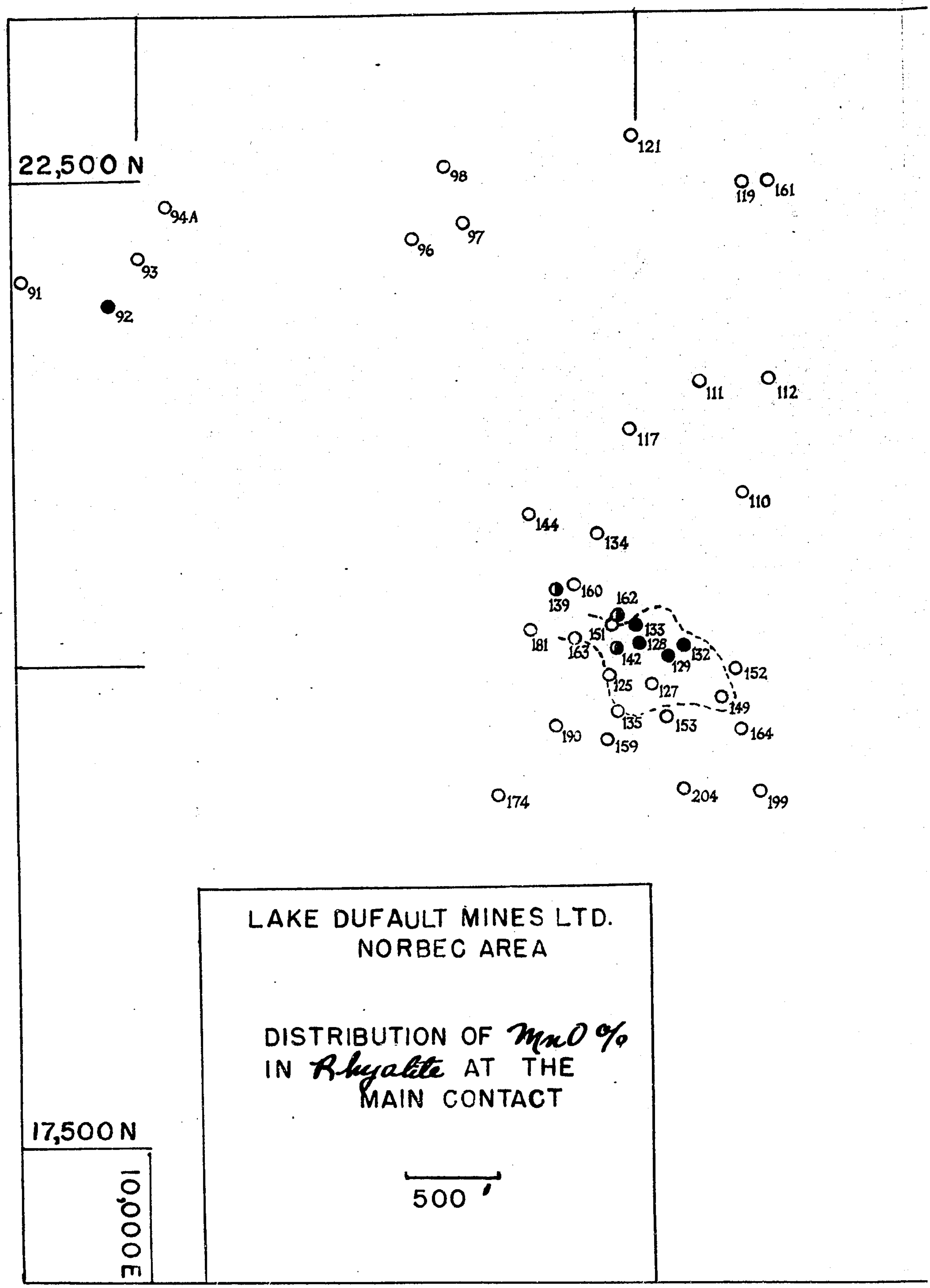
Figure 15

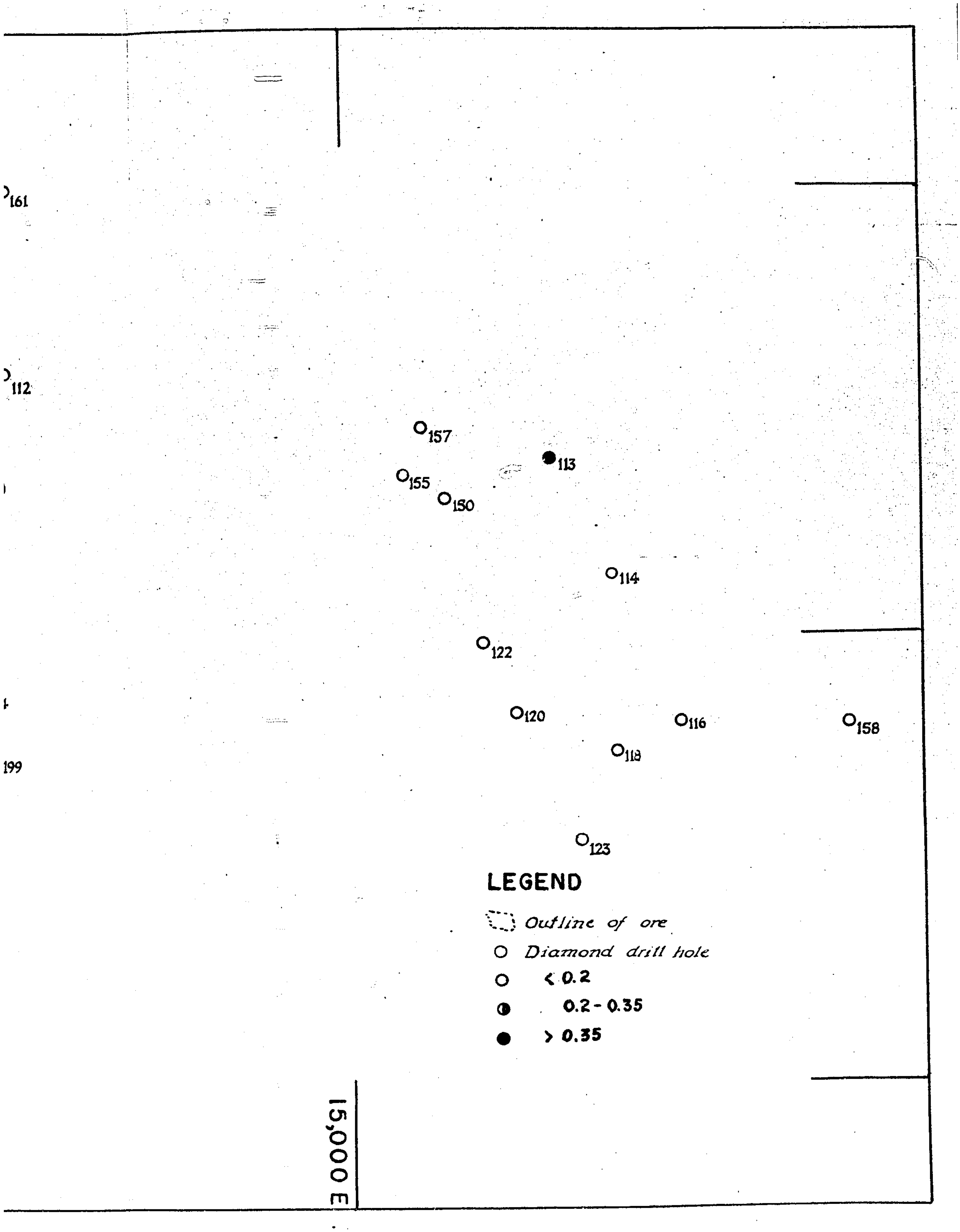

22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
151
133
181
163
128
132
142
129
152
125
127
149
135
153
190
159
164
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
total Fe as
DISTRIBUTION OF Fe2O3 %
IN Rhyolite AT THE
MAIN CONTACT
500'


161
112
157
113
.10
155
150
114
i2
122
64
120
116
158
199
118
123
LEGEND
Outline of ore
Diamond drill hole
‹ 6.0
6.0 - 8.0
› 8.0
15,000 E

MnO rhyolite

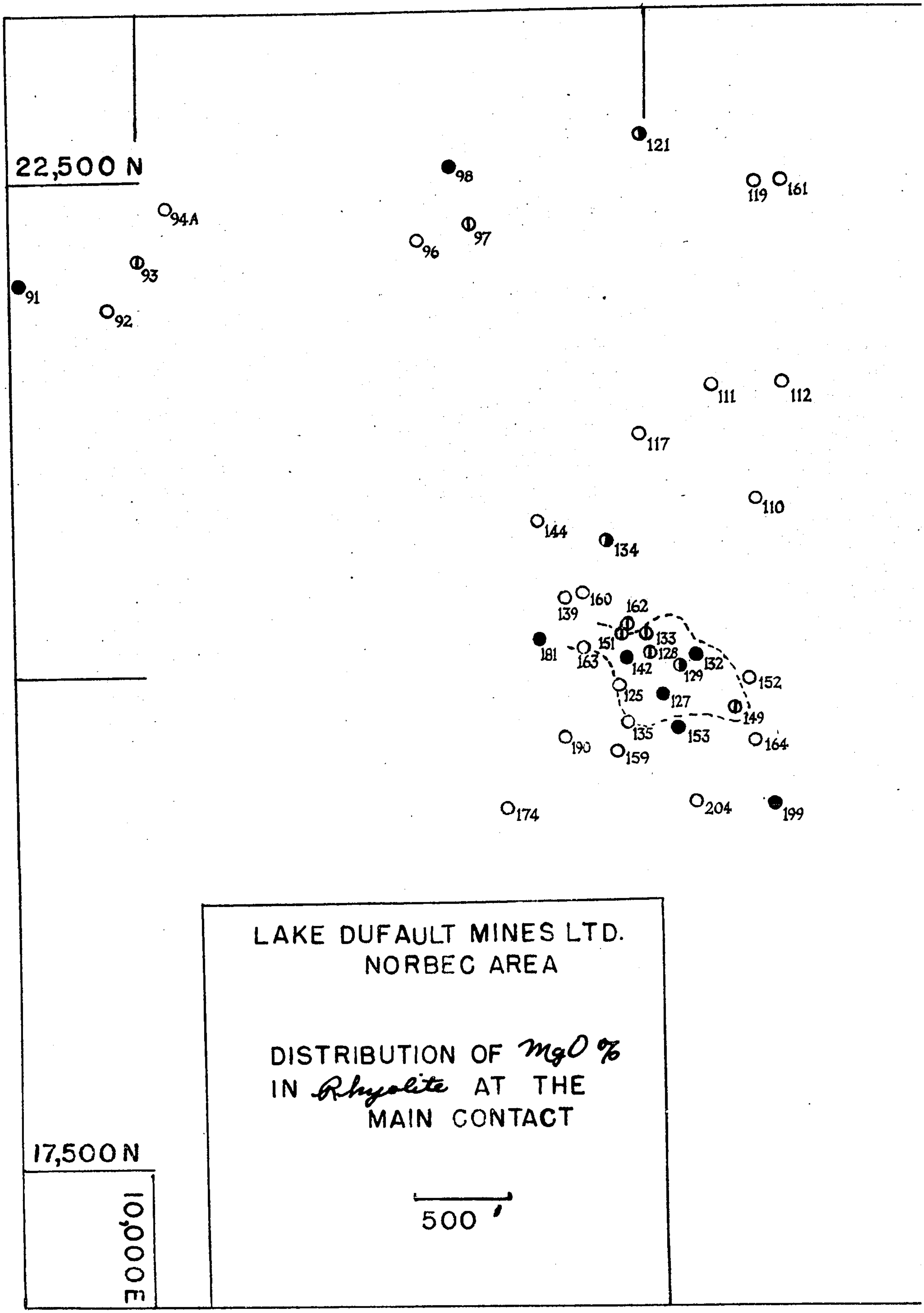
Figure 16

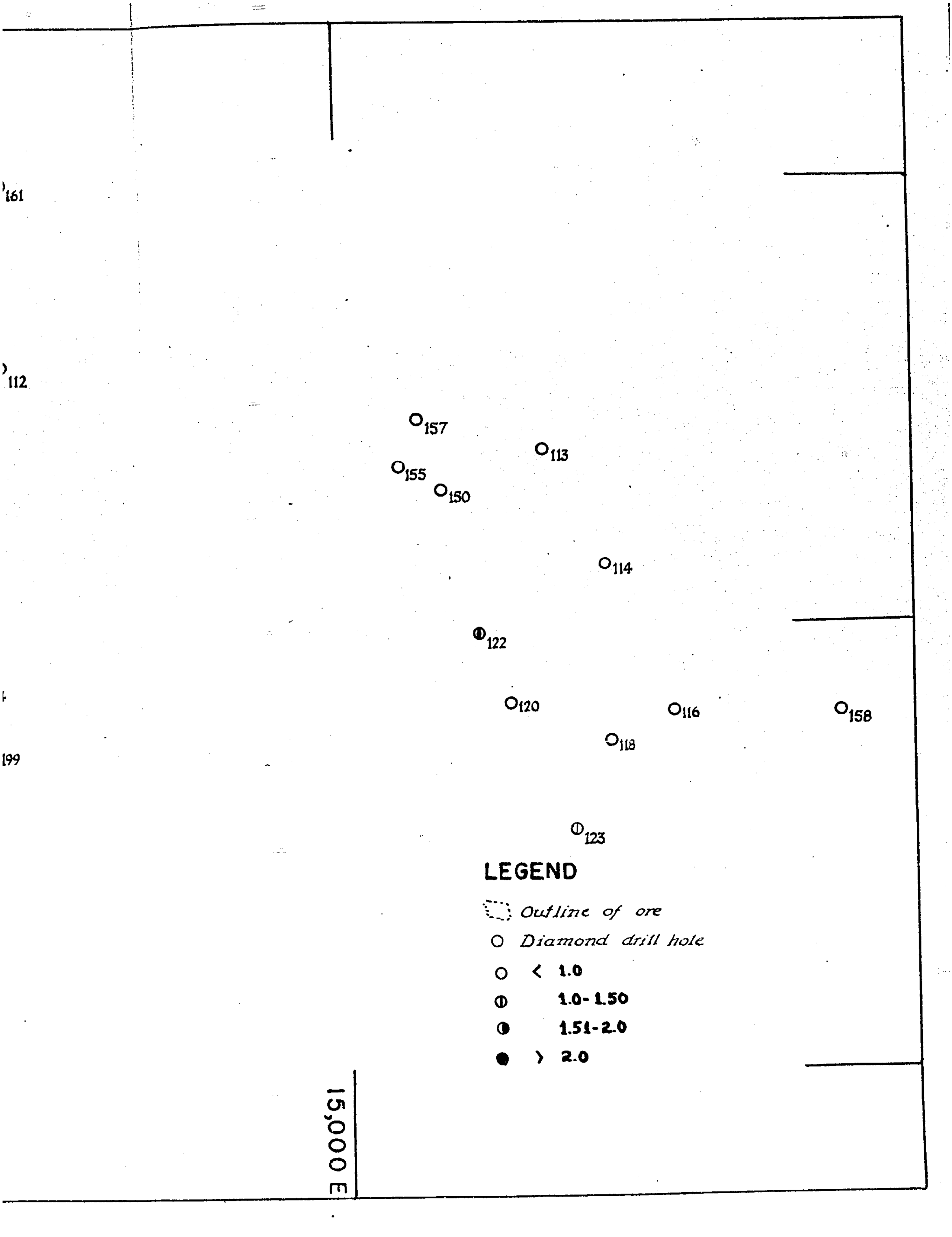

LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF MnO %
IN Rhyolite AT THE
MAIN CONTACT
500'
22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
151
133
181
163
142
128
132
129
152
125
127
149
135
153
164
190
159
174
204
199


161
112
157
113
155
150
114
122
120
116
158
118
199
123
LEGEND
Outline of ore
Diamond drill hole
< 0.2
0.2 - 0.35
> 0.35
15,000 E

MgO rhyolite

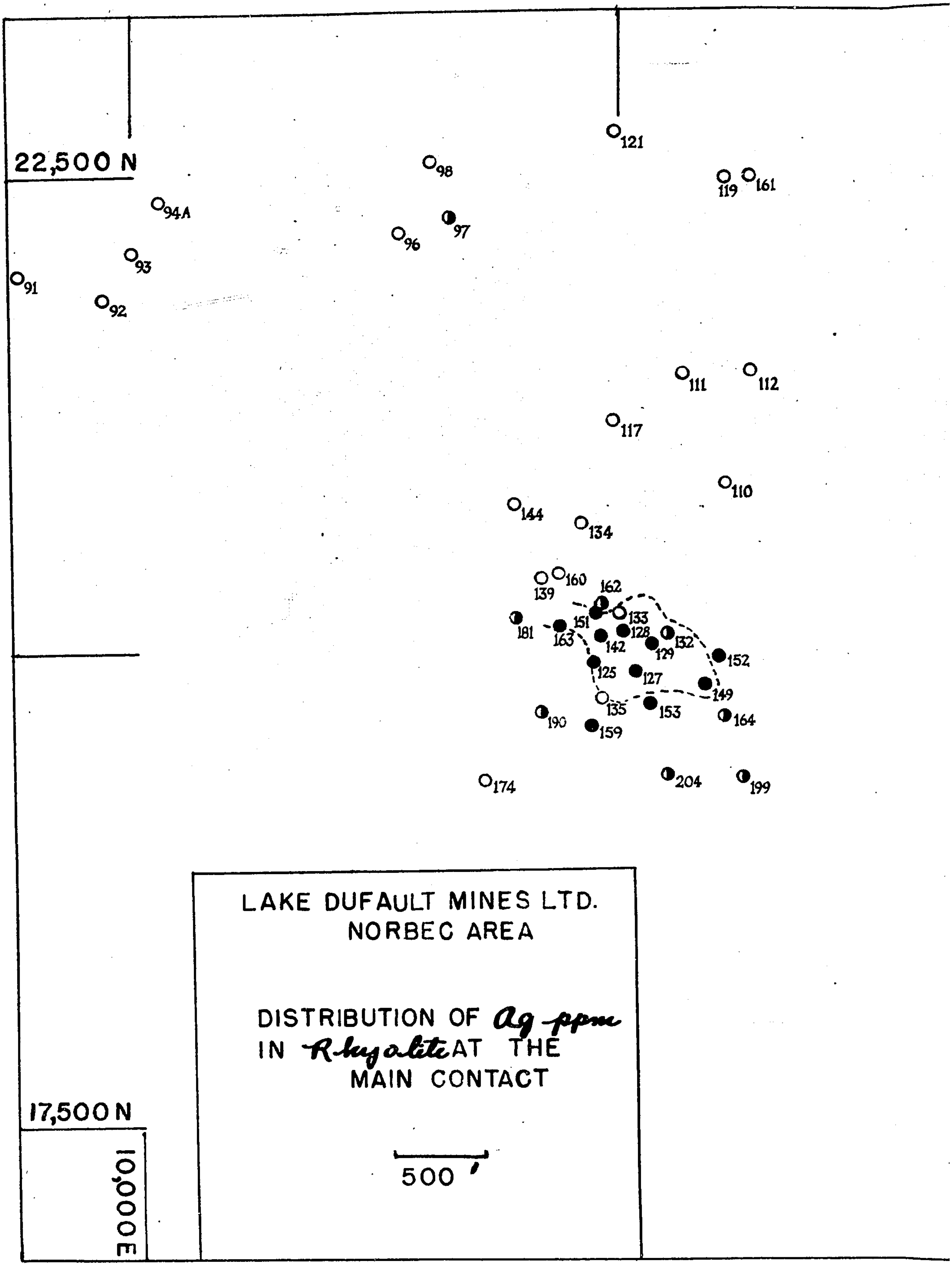
Figure 17

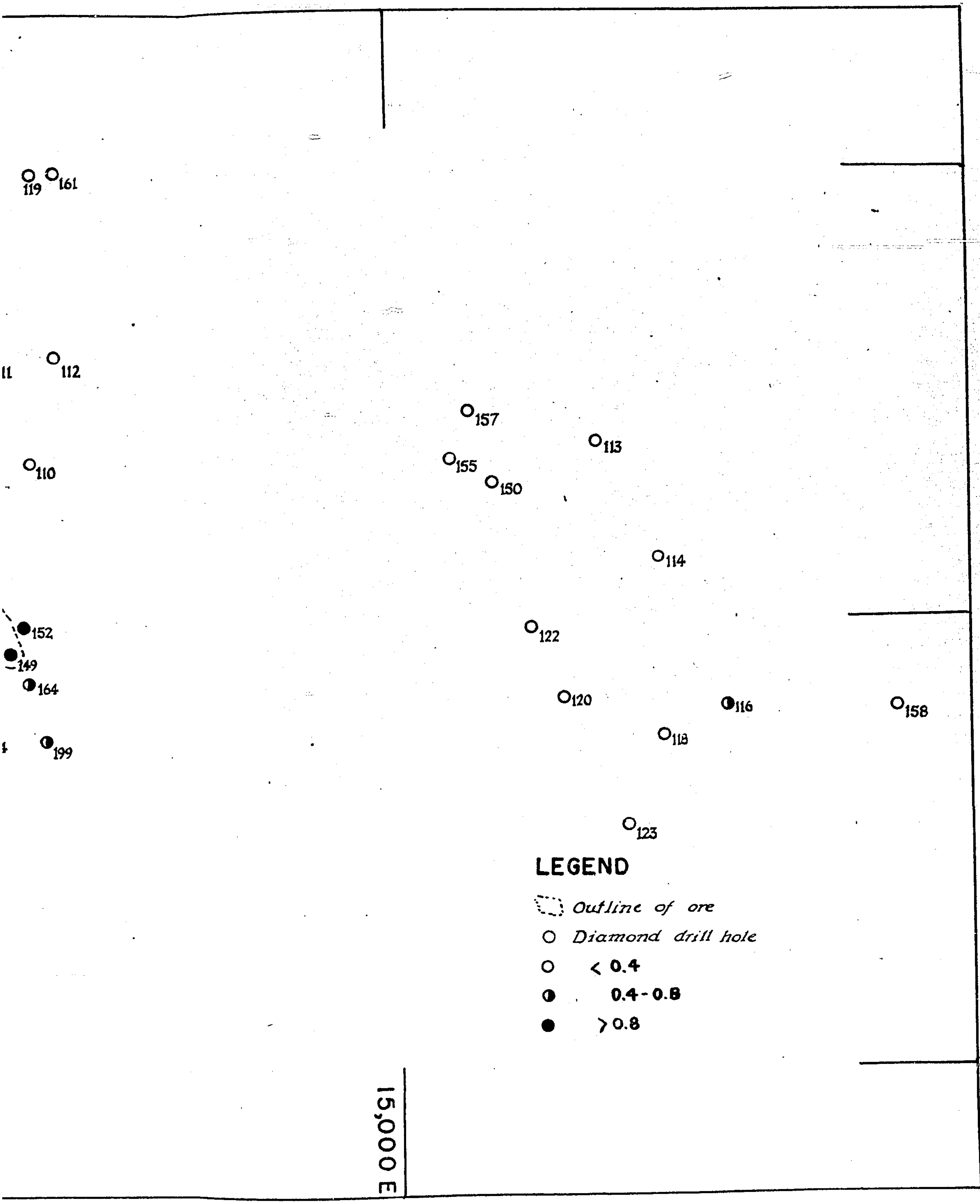

22,500 N
17,500 N
10,000 E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
133
151
128
181
163
142
129
132
152
125
127
149
135
153
190
159
164
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF MgO %
IN Rhyolite AT THE
MAIN CONTACT
500 '


161
112
199
157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 1.0
1.0- 1.50
1.51- 2.0
> 2.0
15,000 E

Ag rhyolite

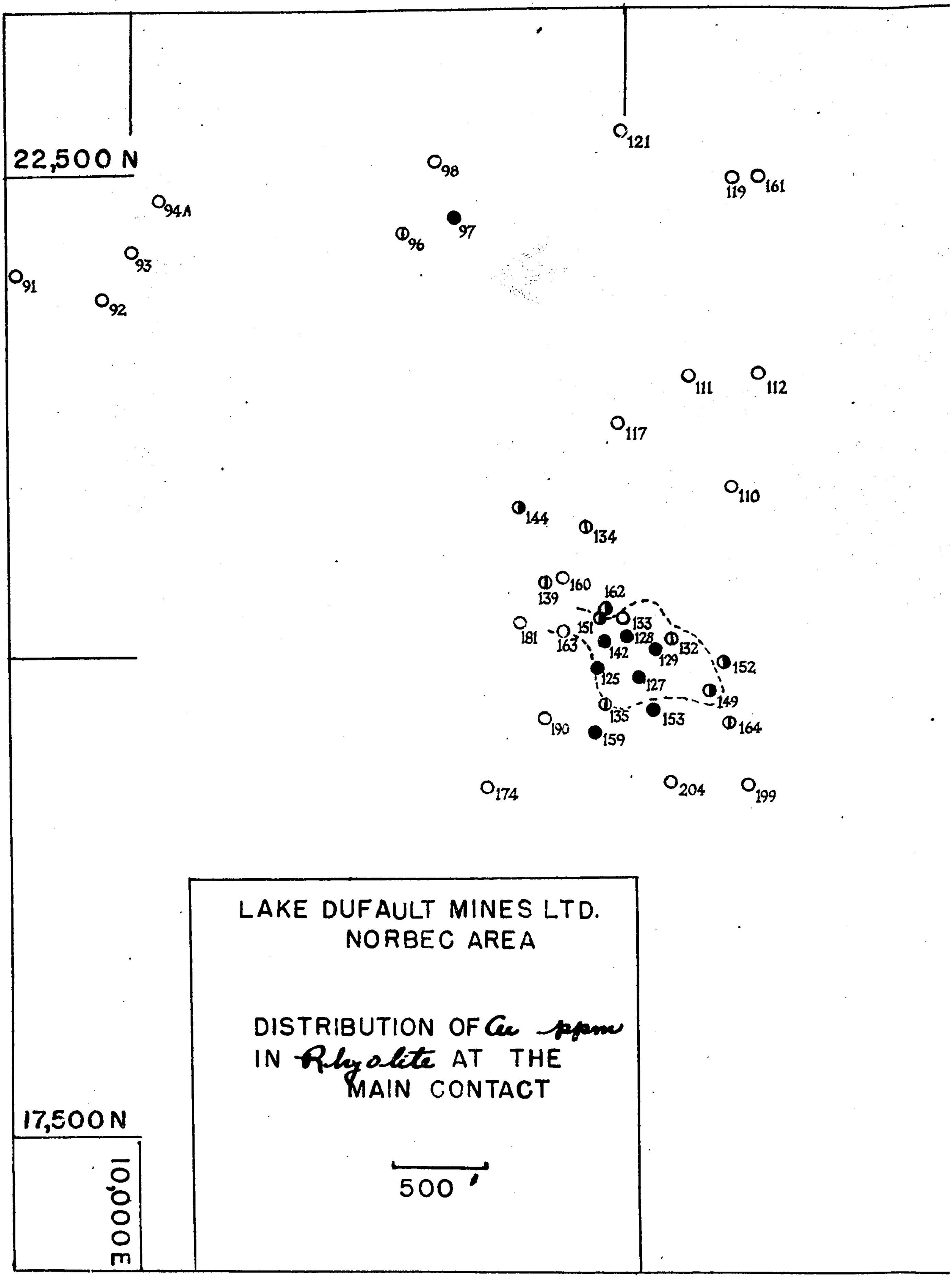
Figure 18

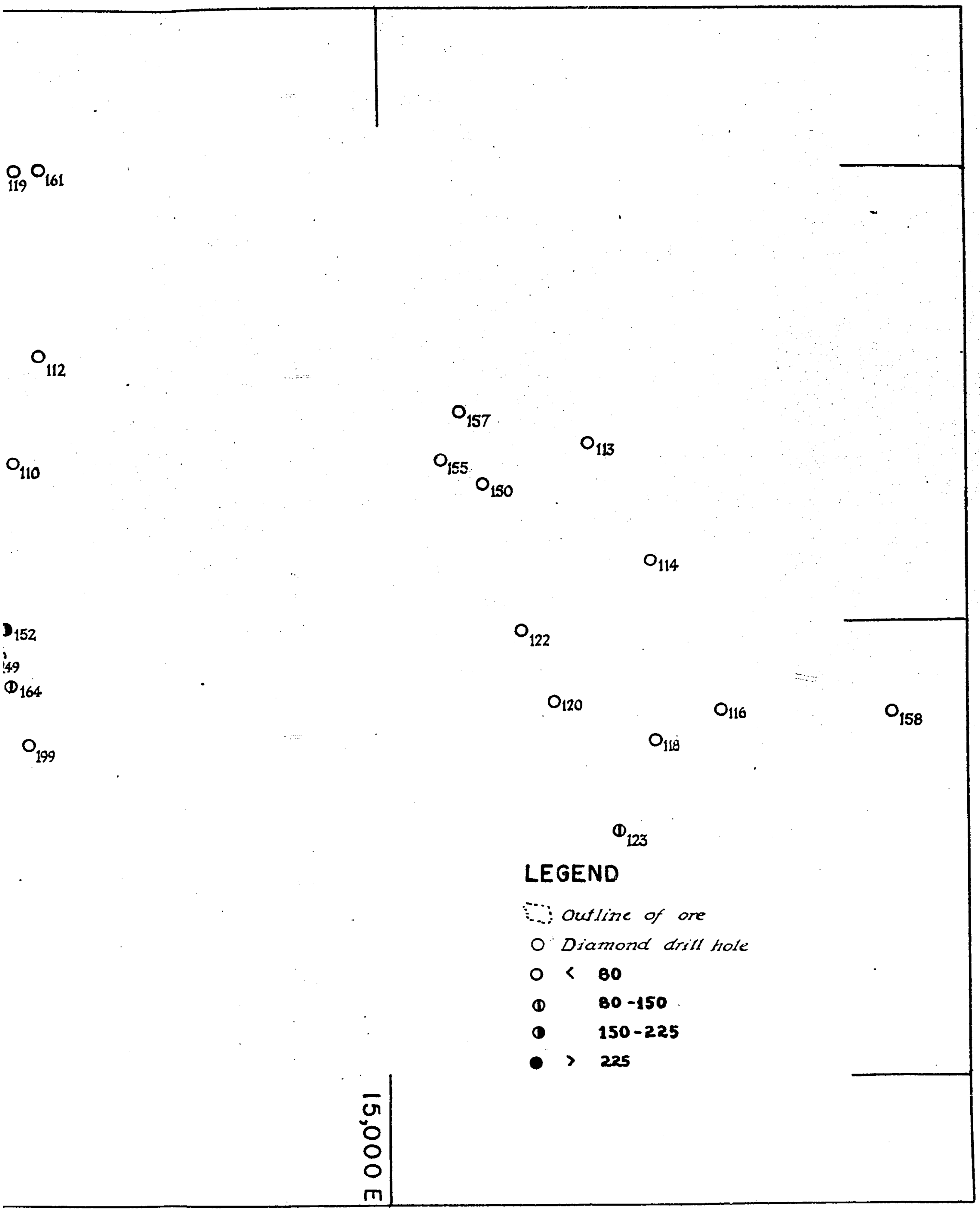

22,500 N
17,500 N
10,000E
91 92 93 94A 96 97 98 121 119 161 111 112 117 110 144 134 139 160 162 133 181 151 163 142 128 132 129 152 125 127 149 135 153 190 159 164 174 204 199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Ag ppm
IN Rhyolite AT THE
MAIN CONTACT
500 '


119
161
11
112
157
113
155
150
110
114
152
149
164
122
120
116
158
118
199
123
LEGEND
Outline of ore
Diamond drill hole
< 0.4
0.4 - 0.8
> 0.8
15,000 E

Cu rhyolite

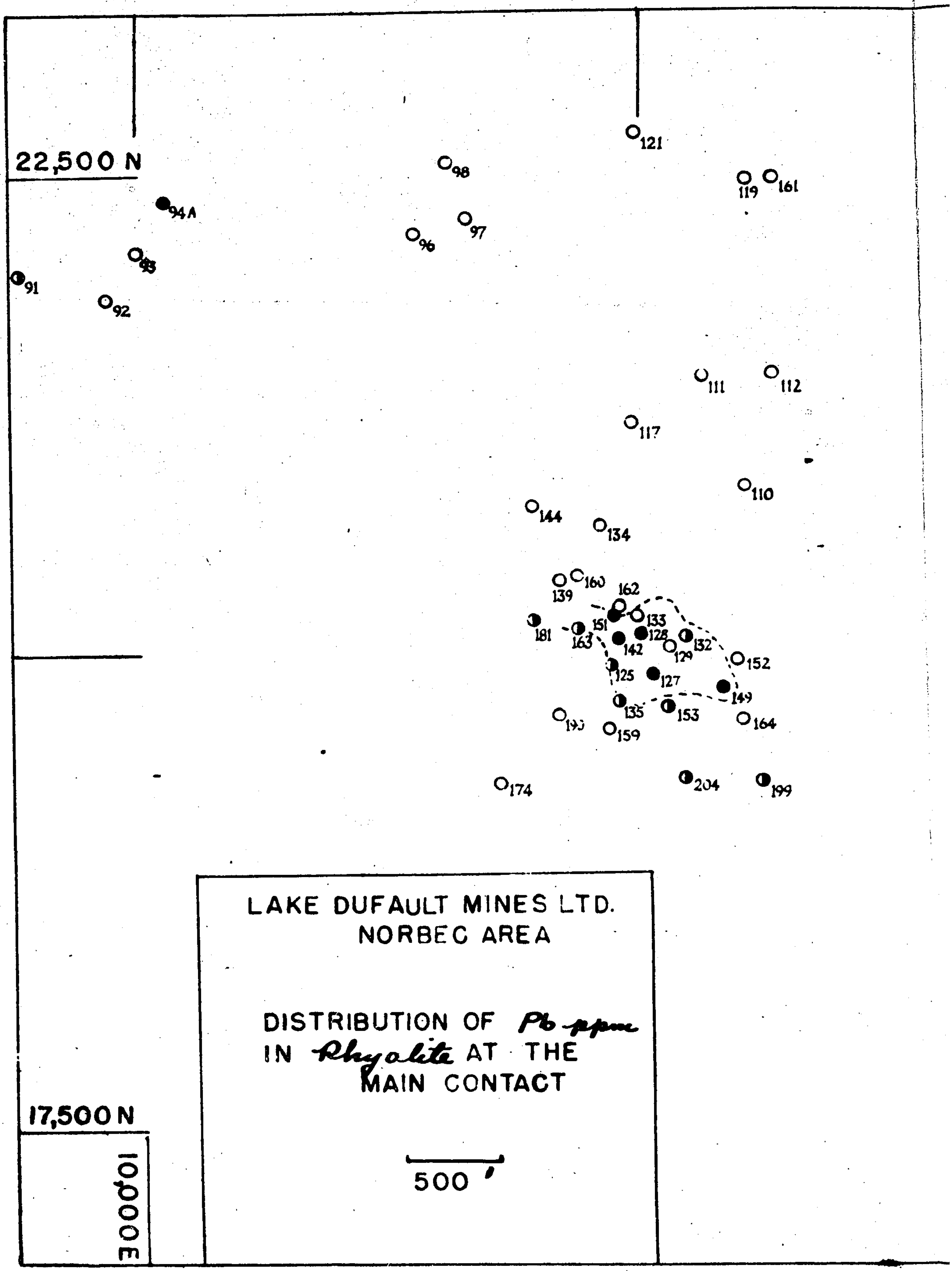
Figure 19


22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
151
133
181
163
142
128
132
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Cu ppm
IN Rhyolite AT THE
MAIN CONTACT
500'


119
161
112
110
157
155
150
113
114
152
164
122
120
116
158
118
199
123
LEGEND
Outline of ore
Diamond drill hole
< 80
80 - 150
150 - 225
> 225
15,000 E

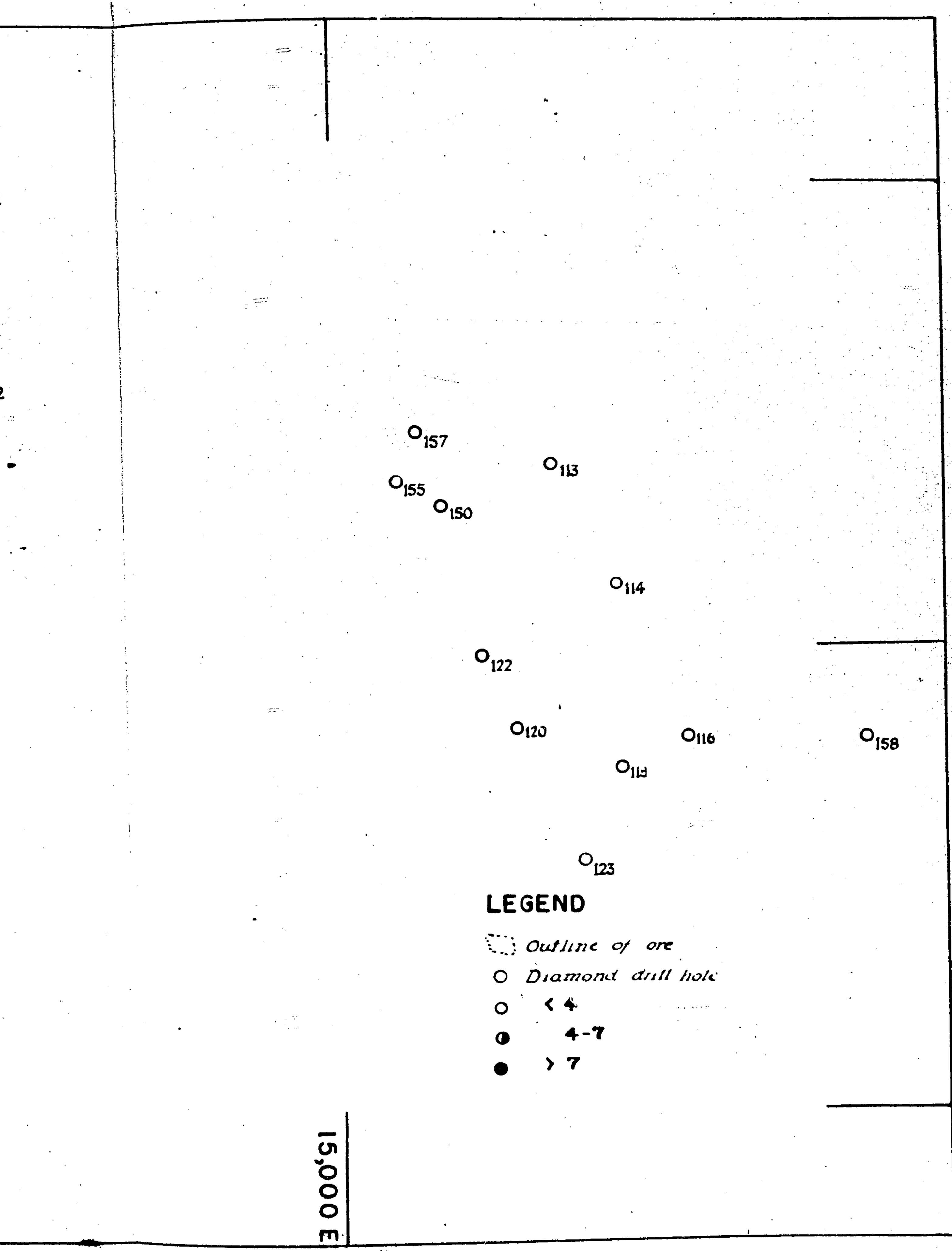
Pb rhyolite

Figure 20



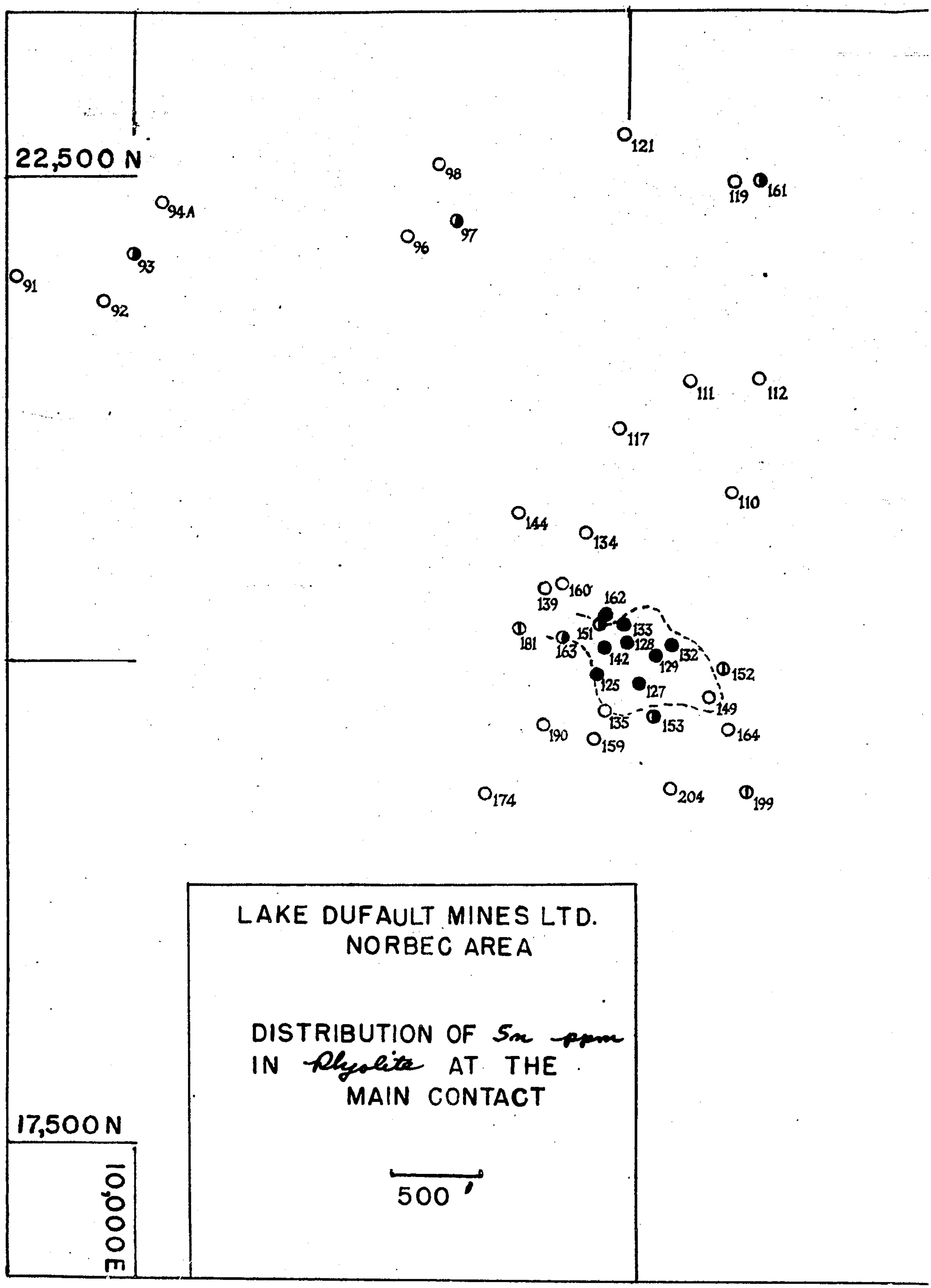
LAKE DUFAULT MINES LTD.
NORBEC AREA

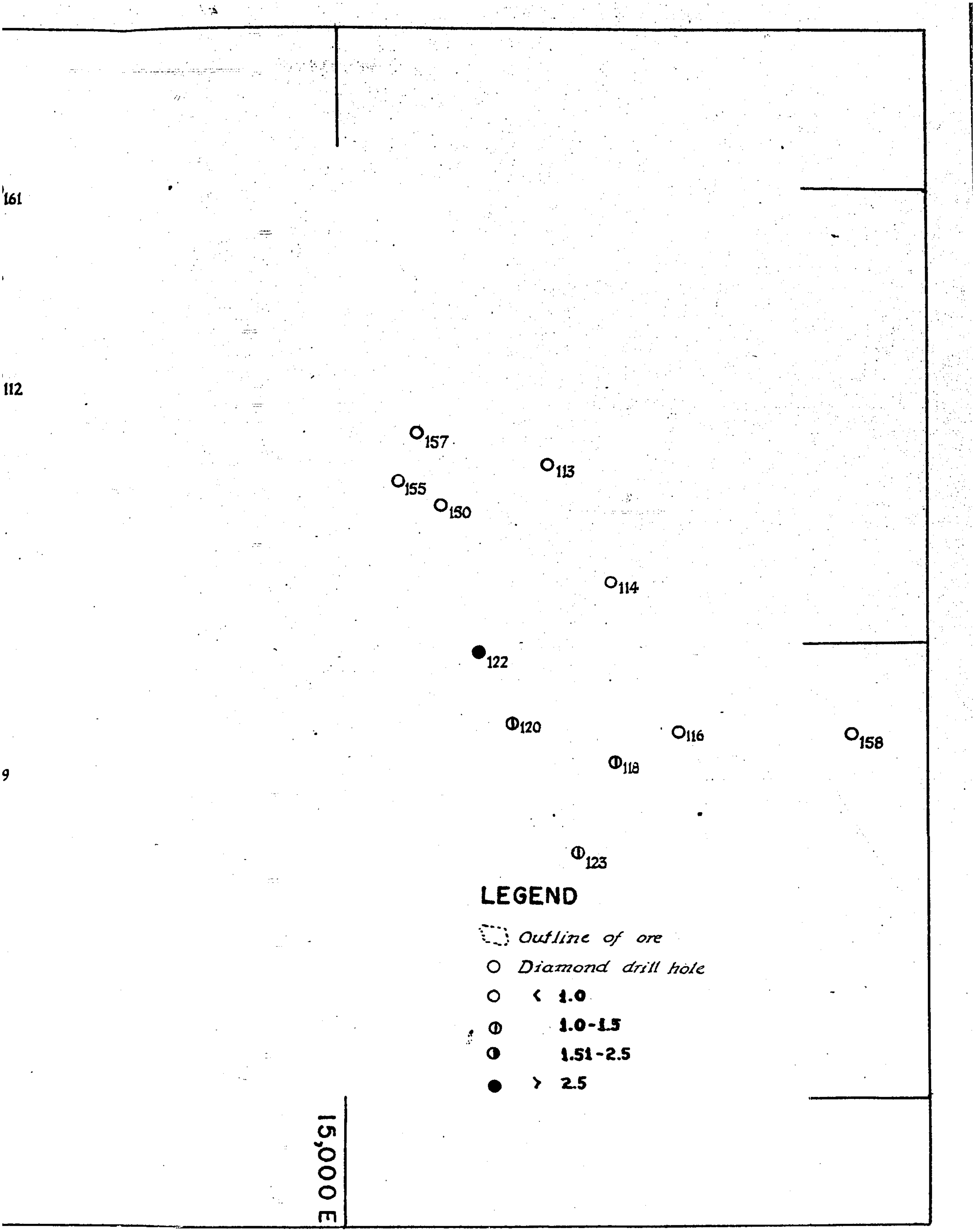
DISTRIBUTION OF Pb-ppm
IN Rhyolite AT THE
MAIN CONTACT


157
113
155
150
114
122
120
116
158
123
LEGEND
Outline of ore
Diamond drill hole
< 4
4-7
> 7
15,000 E

Sn rhyolite

Figure 21

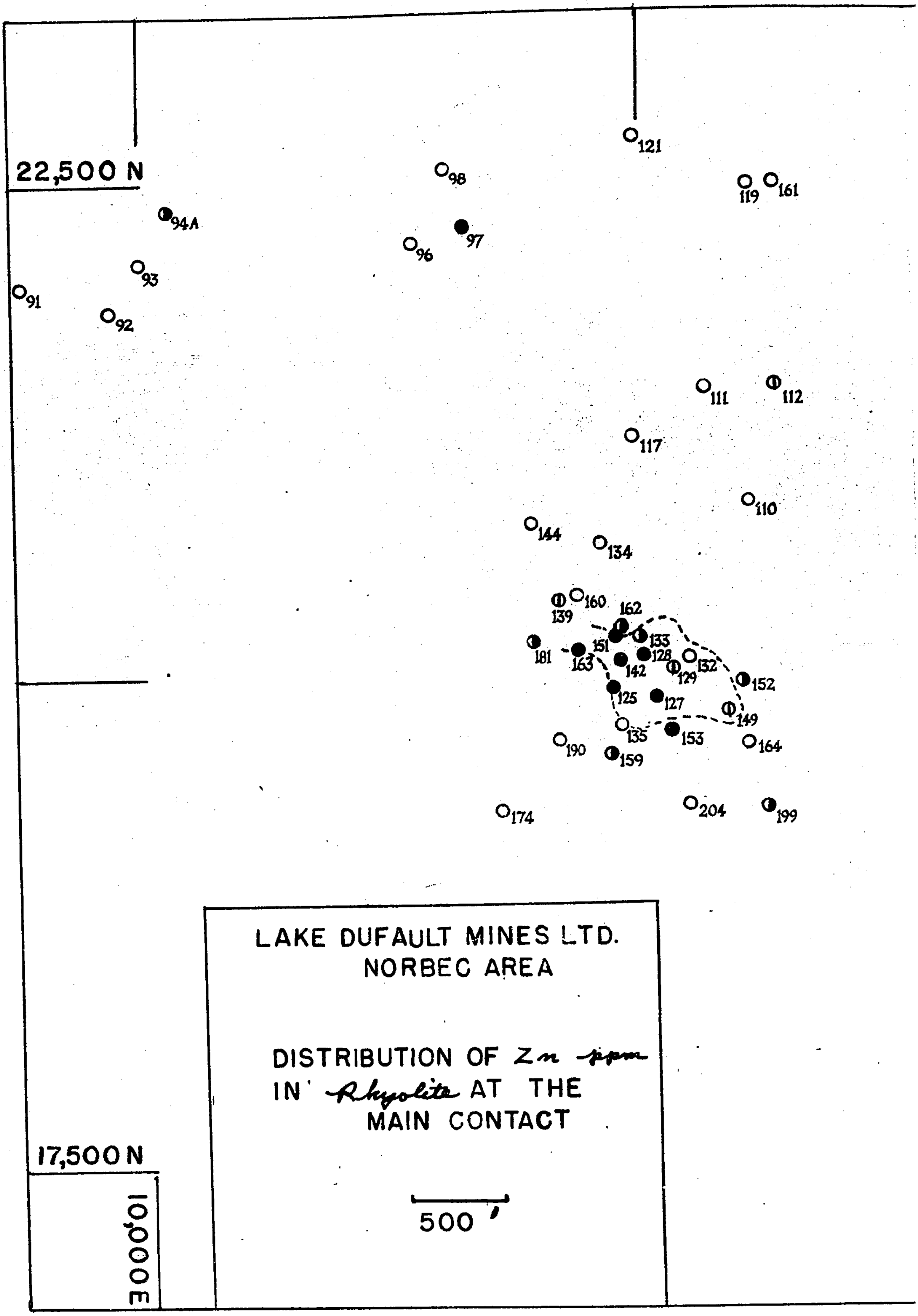

22,500 N
17,500 N
10,000 E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
133
151
181
163
142
128
132
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Sn ppm
IN Rhyolite AT THE
MAIN CONTACT
500'



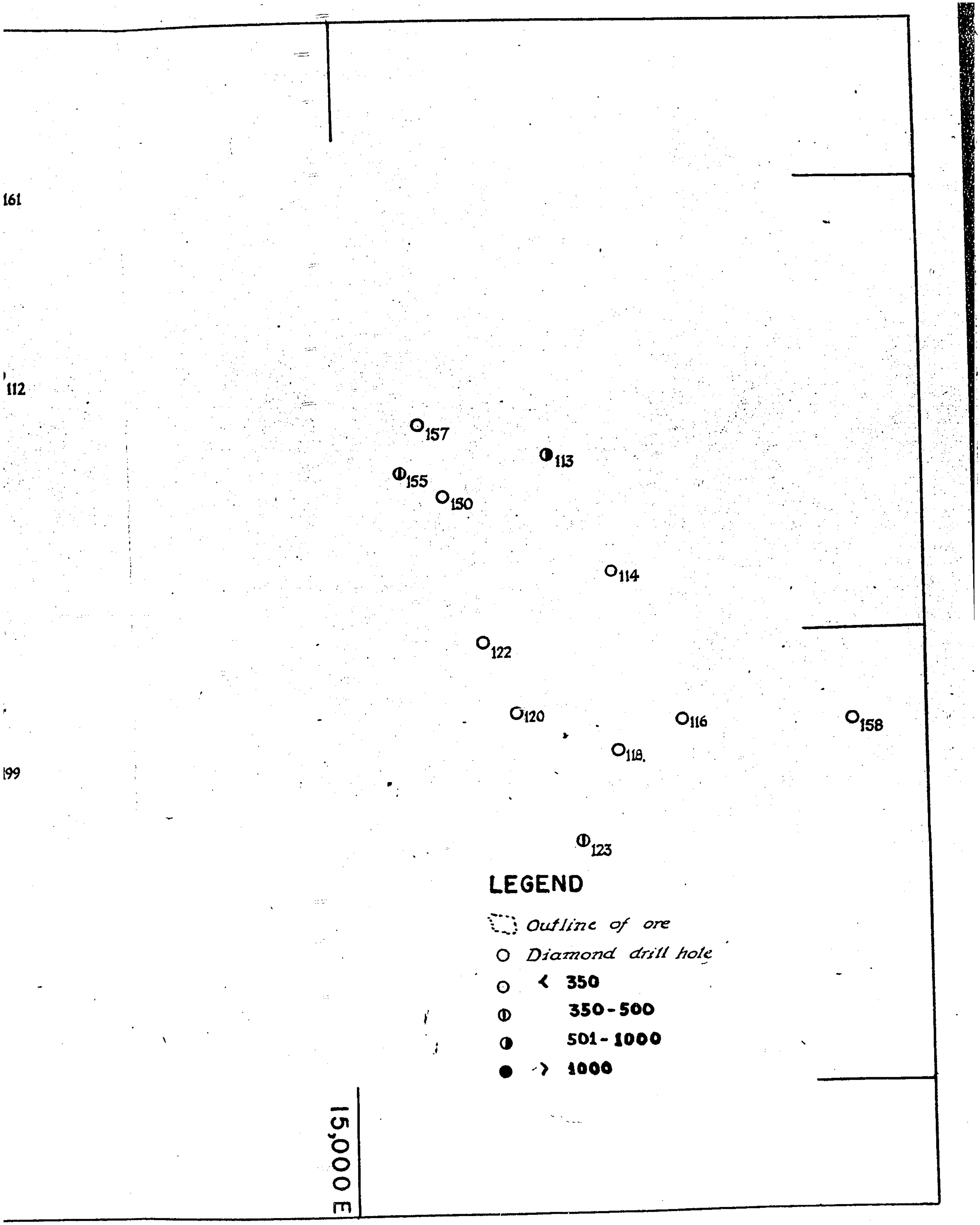
161
112
9
157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 1.0
1.0-1.5
1.51-2.5
> 2.5
15,000 E

Zn rhyolite

Figure 22

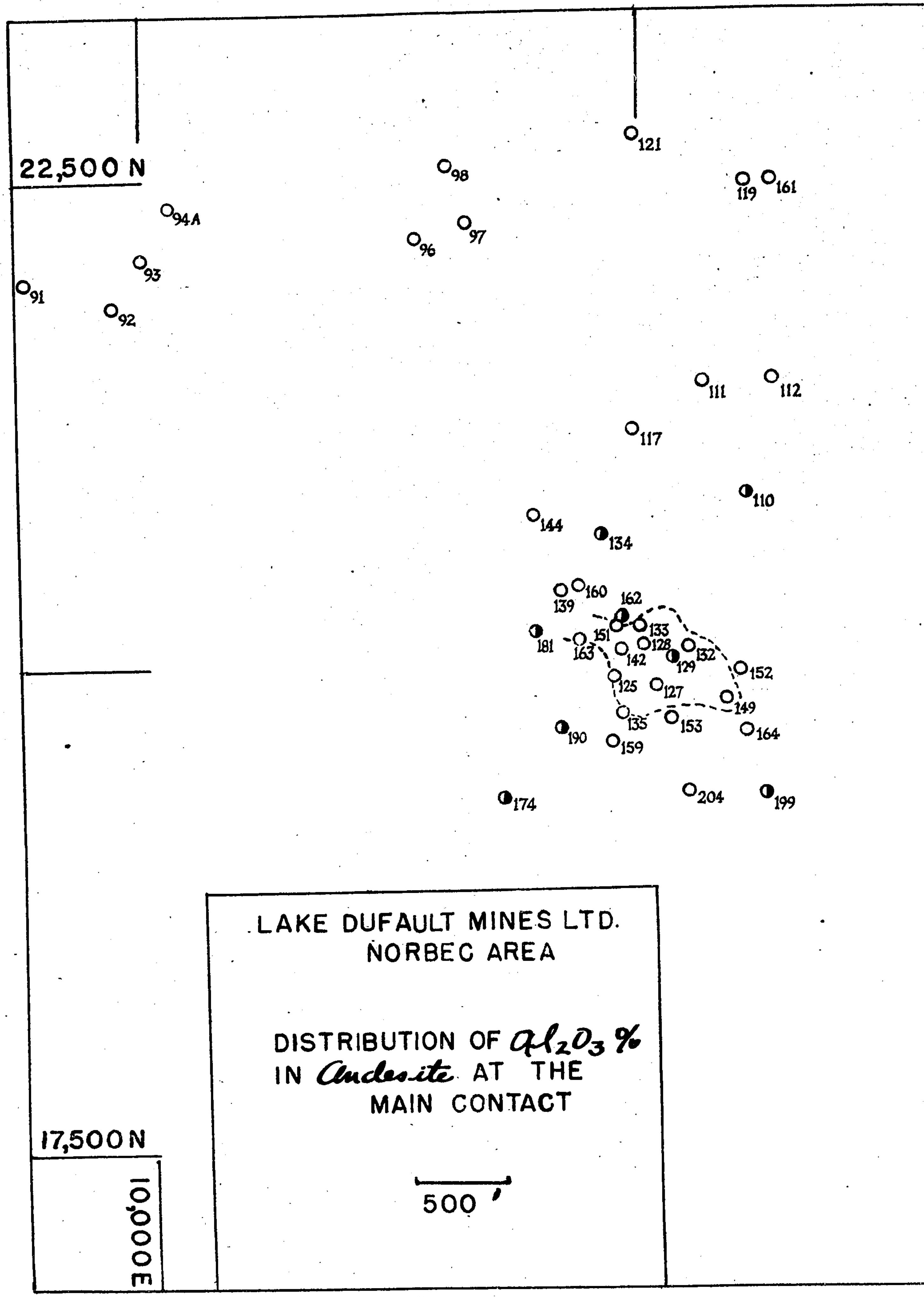


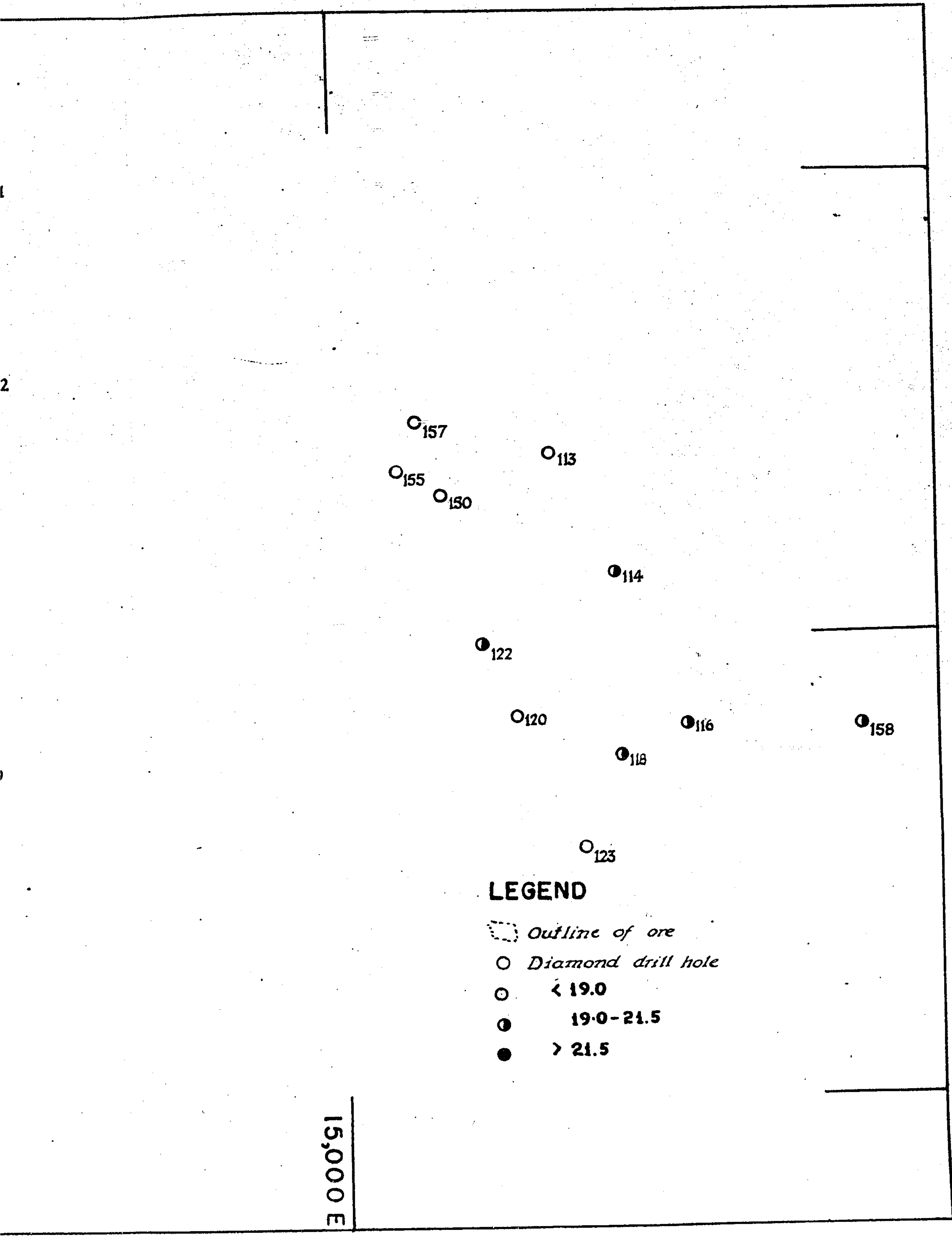
22,500 N
17,500 N
10,000 E
94A
91
92
93
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
151
133
163
128
142
132
129
152
125
127
149
135
153
190
159
164
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Zn ppm
IN Rhyolite AT THE
MAIN CONTACT
500 '


161
112
199
157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 350
350 - 500
501 - 1000
> 1000
15,000 E

Al_2O_3 andesite

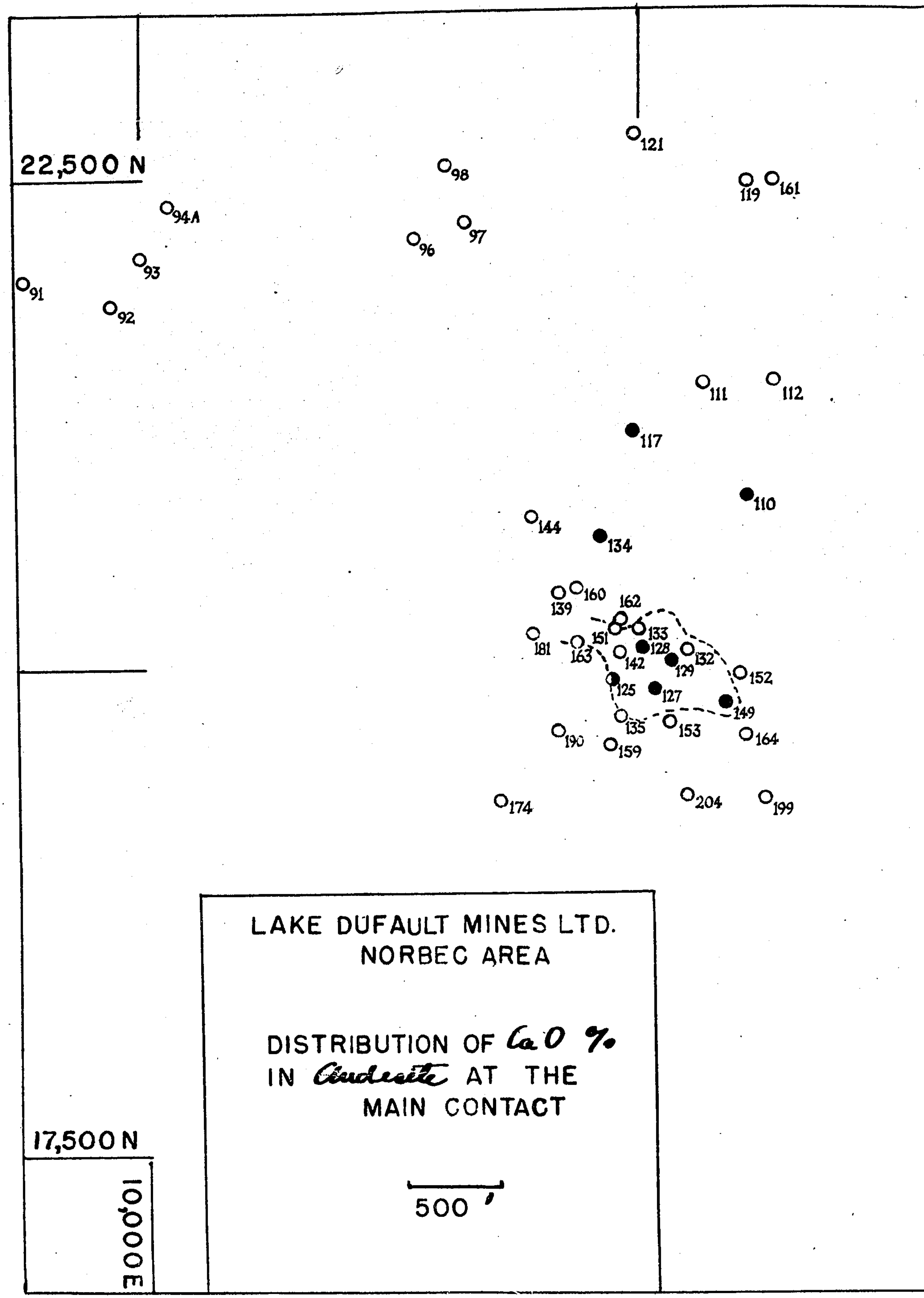
Figure 23

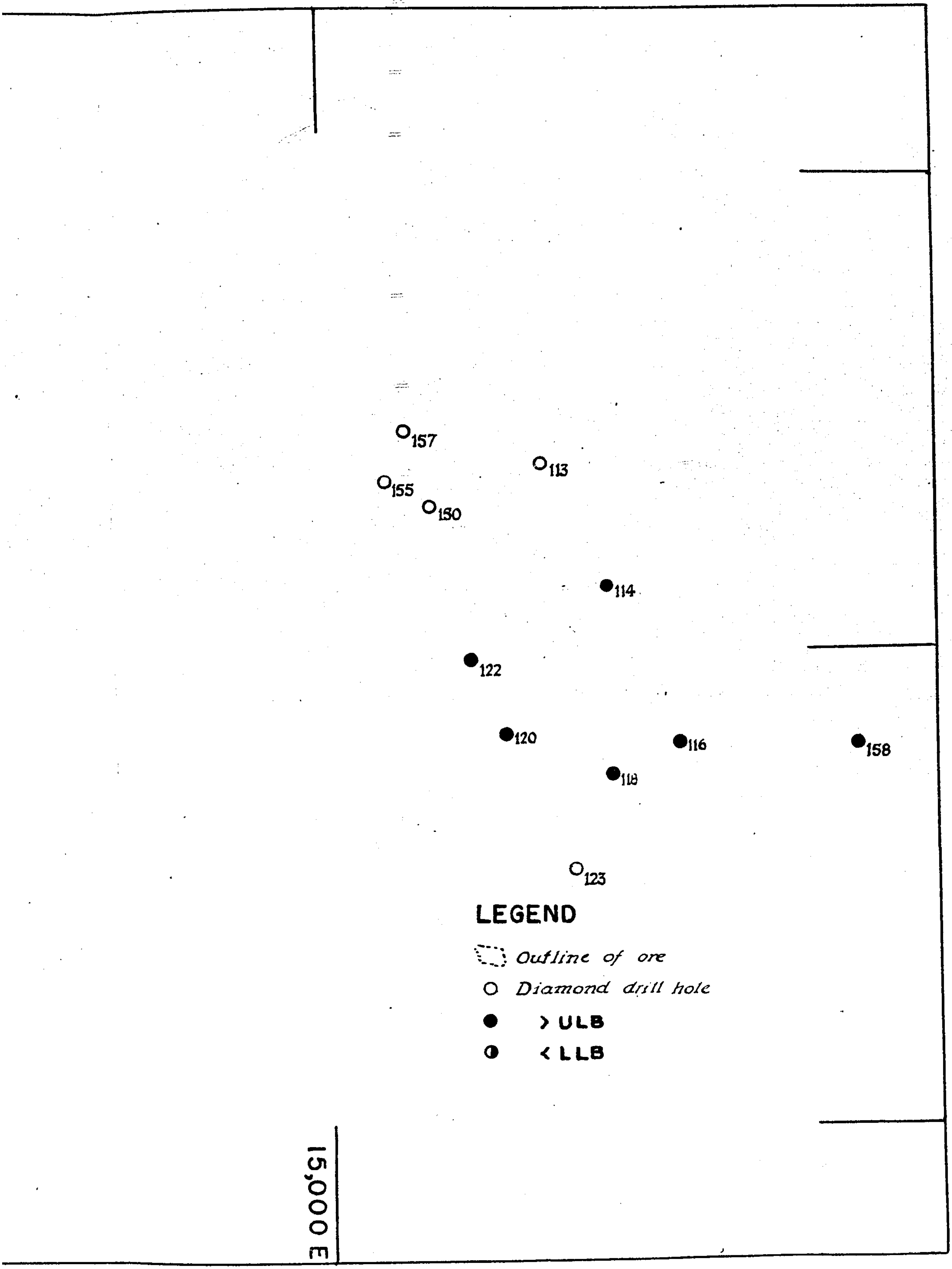

22,500 N
121
98
119
161
94A
97
96
93
91
92
111
112
117
110
144
134
160
139
162
133
181
151
163
128
142
132
129
152
125
127
149
135
153
164
190
159
174
204
199
17,500 N
10,000E
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Al_2O_3 %
IN Andesite AT THE
MAIN CONTACT
500 '


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 19.0
19.0 - 21.5
> 21.5
15,000 E

CaO andesite

Figure 24

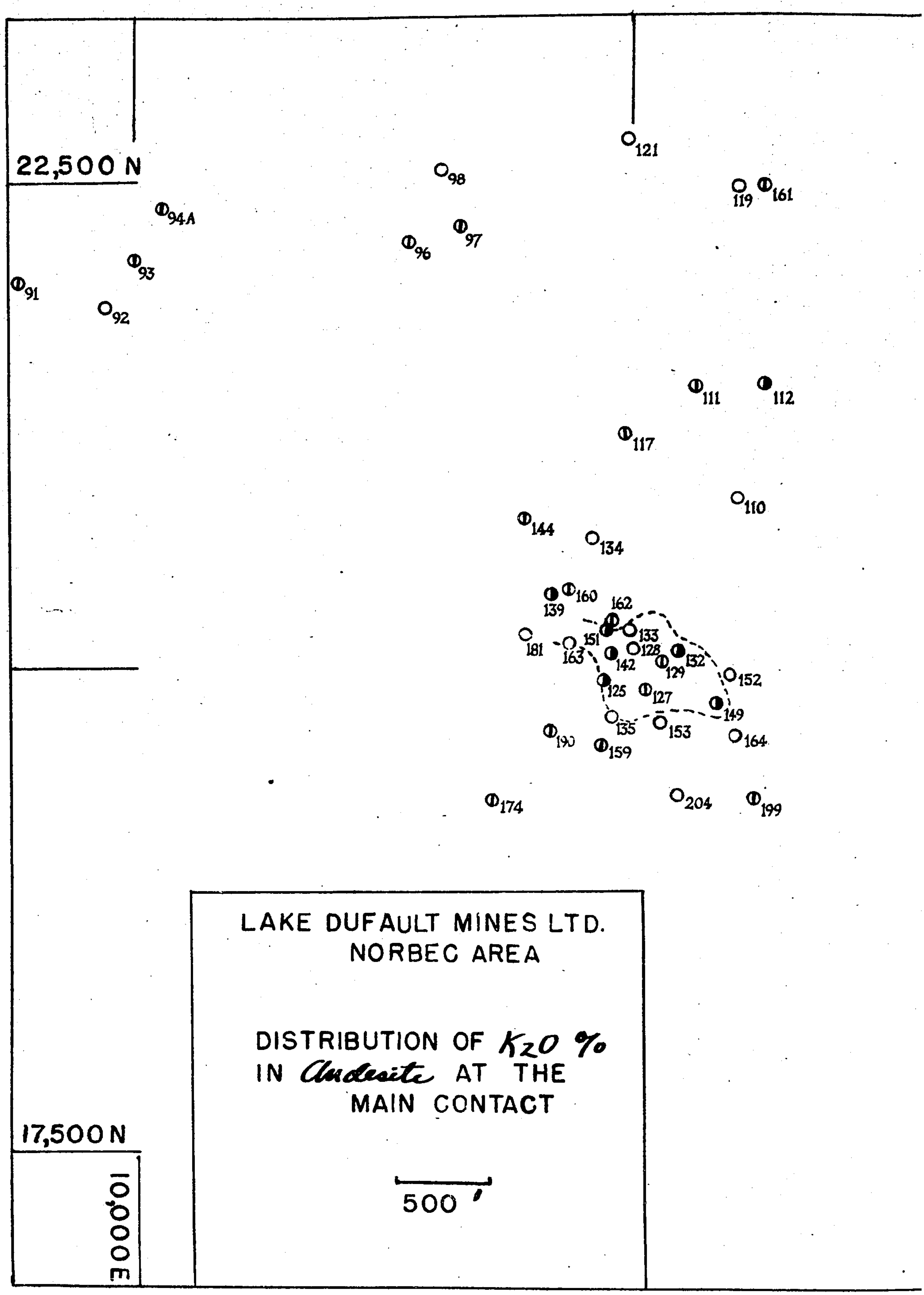

LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF CaO %
IN Andesite AT THE
MAIN CONTACT
500 '
22,500 N
17,500 N
10,000 E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
133
151
181
163
128
132
142
129
152
125
127
149
135
153
164
190
159
174
204
199

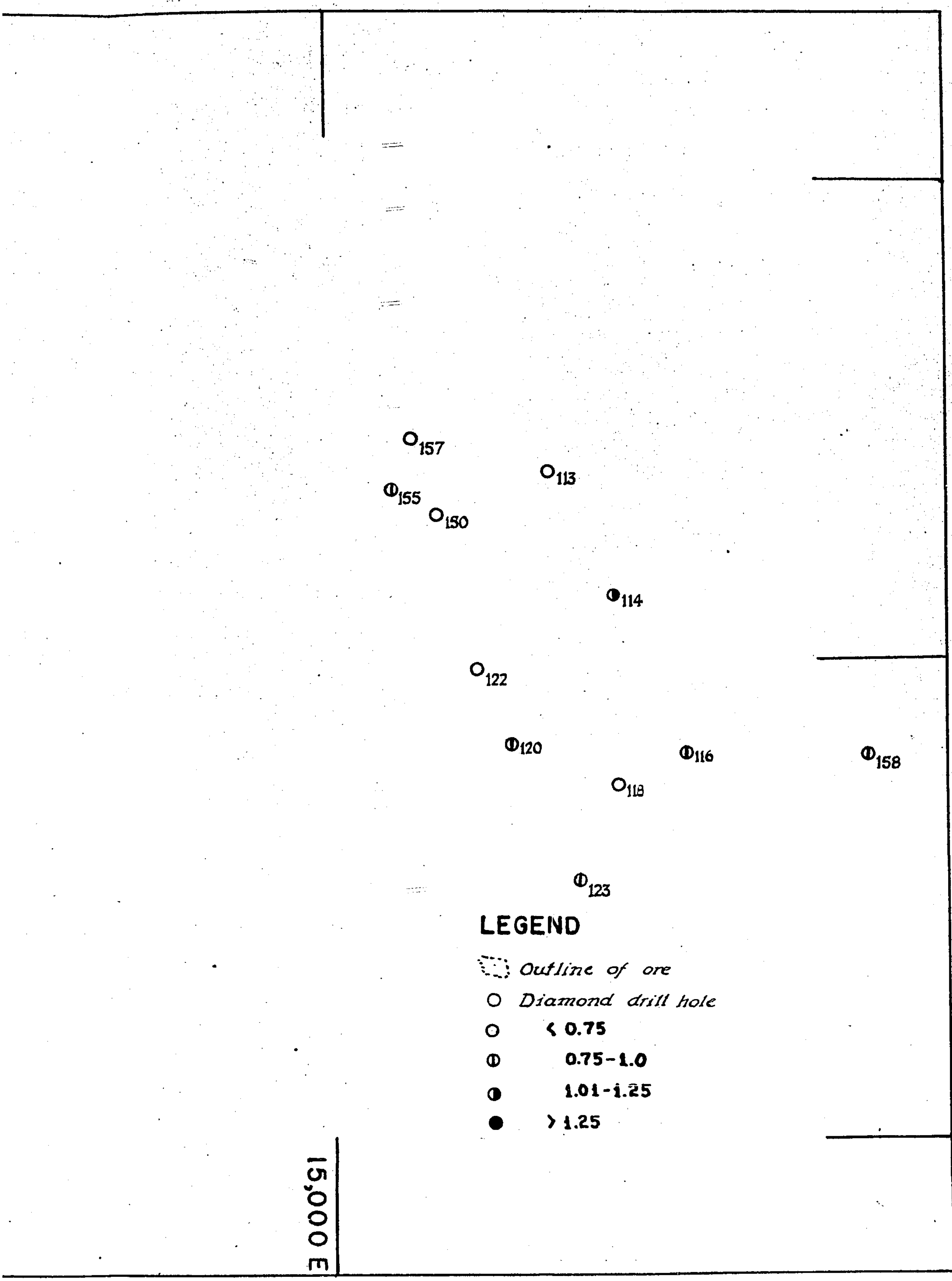


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
> ULB
< LLB
15,000 E

K_2O andesite

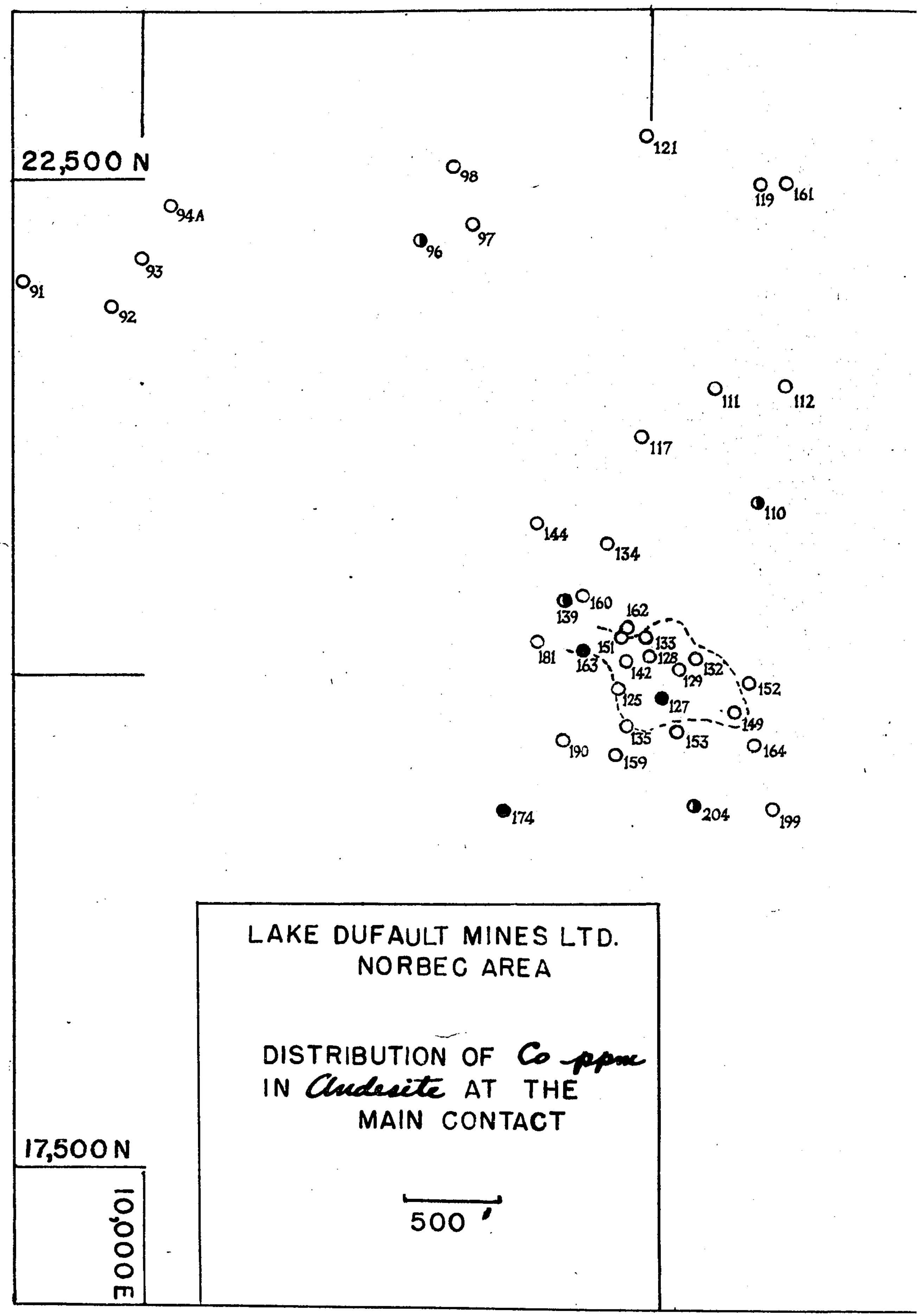
Figure 25

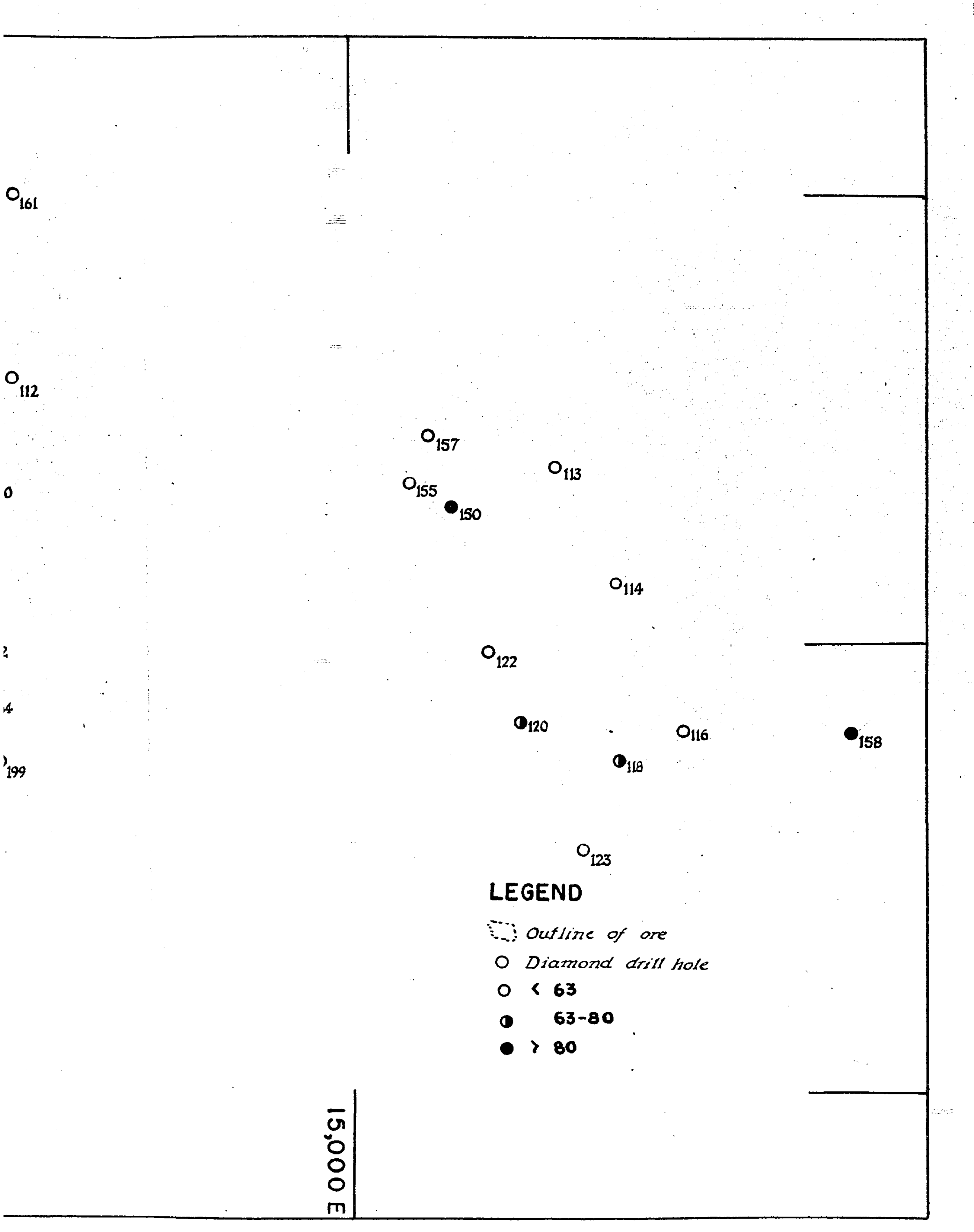

22,500 N
17,500 N
10,000 E
94A
91
92
93
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
133
181
163
151
128
132
142
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF K2O %
IN Andesite AT THE
MAIN CONTACT
500 '


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 0.75
0.75-1.0
1.01-1.25
> 1.25
15,000 E

Co andesite

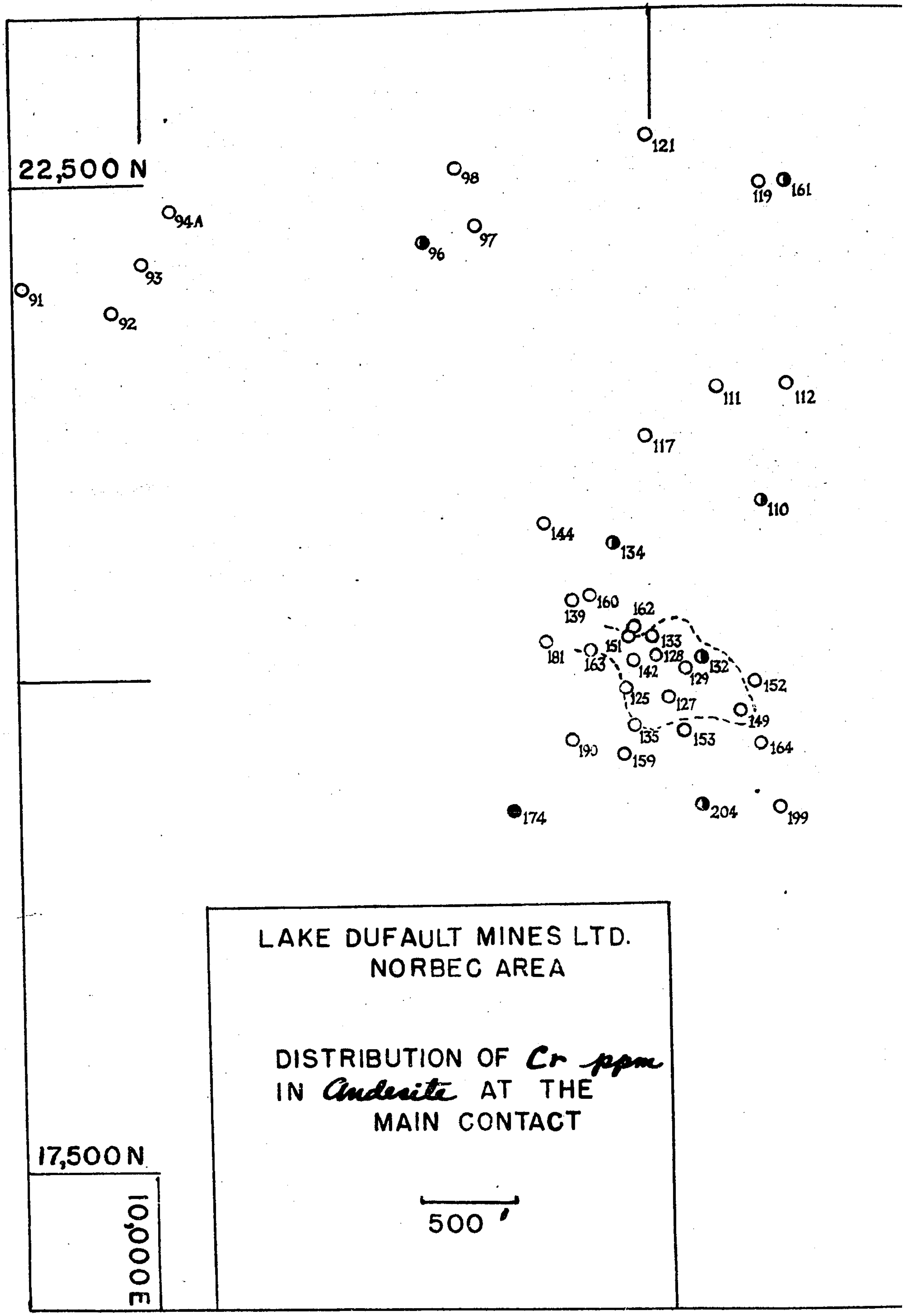
Figure 26

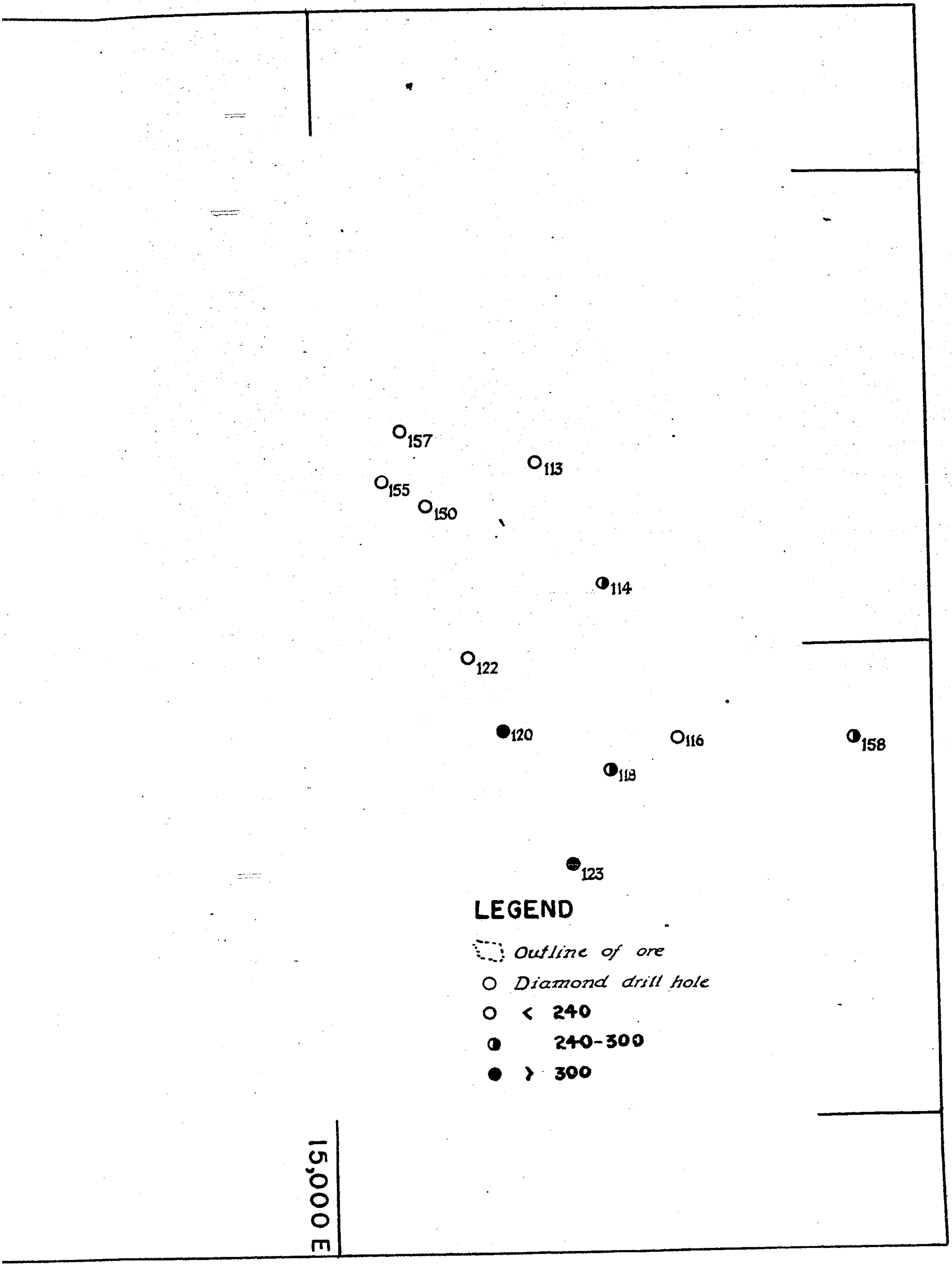

22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
163
151
133
128
132
142
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Co ppm
IN Andesite AT THE
MAIN CONTACT
500'


161
112
157
113
155
150
114
122
120
116
158
118
199
123
LEGEND
Outline of ore
Diamond drill hole
< 63
63-80
> 80
15,000 E

Cr andesite

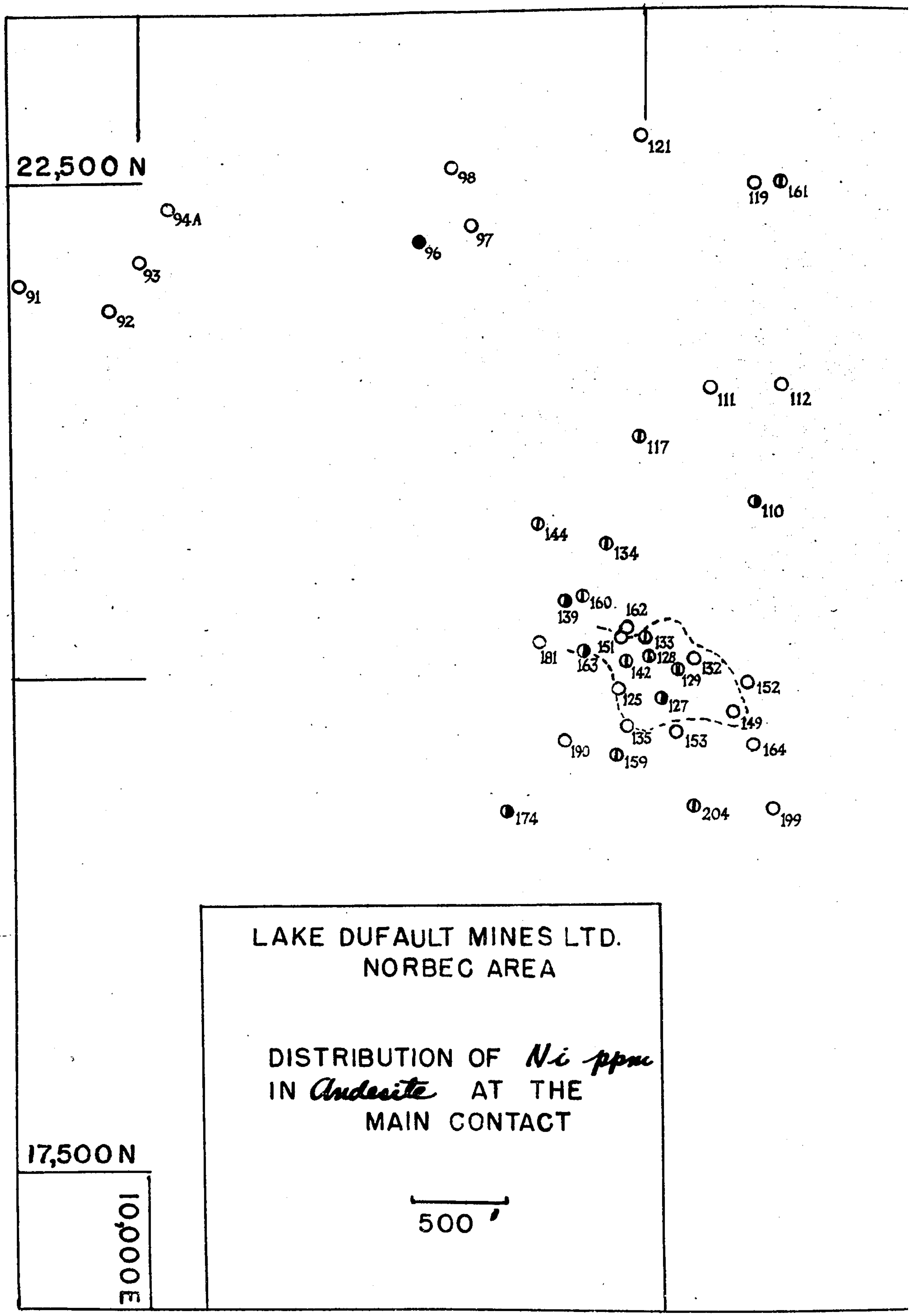
Figure 27

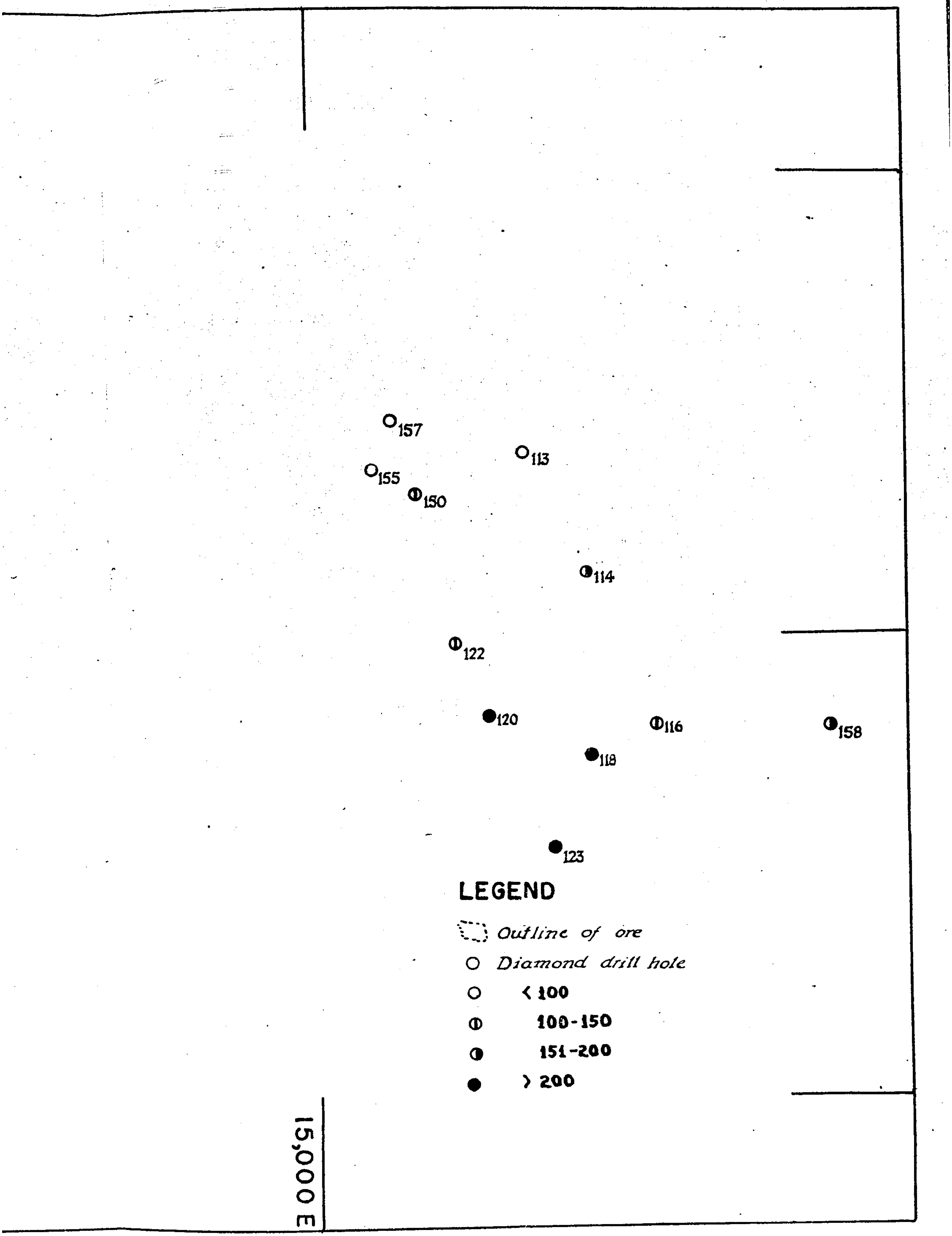

22,500 N
17,500 N
10,000 E
94A
91
92
93
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
163
151
133
128
132
142
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Cr ppm
IN Andesite AT THE
MAIN CONTACT
500 '


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 240
240-300
> 300
15,000 E

Ni andesite

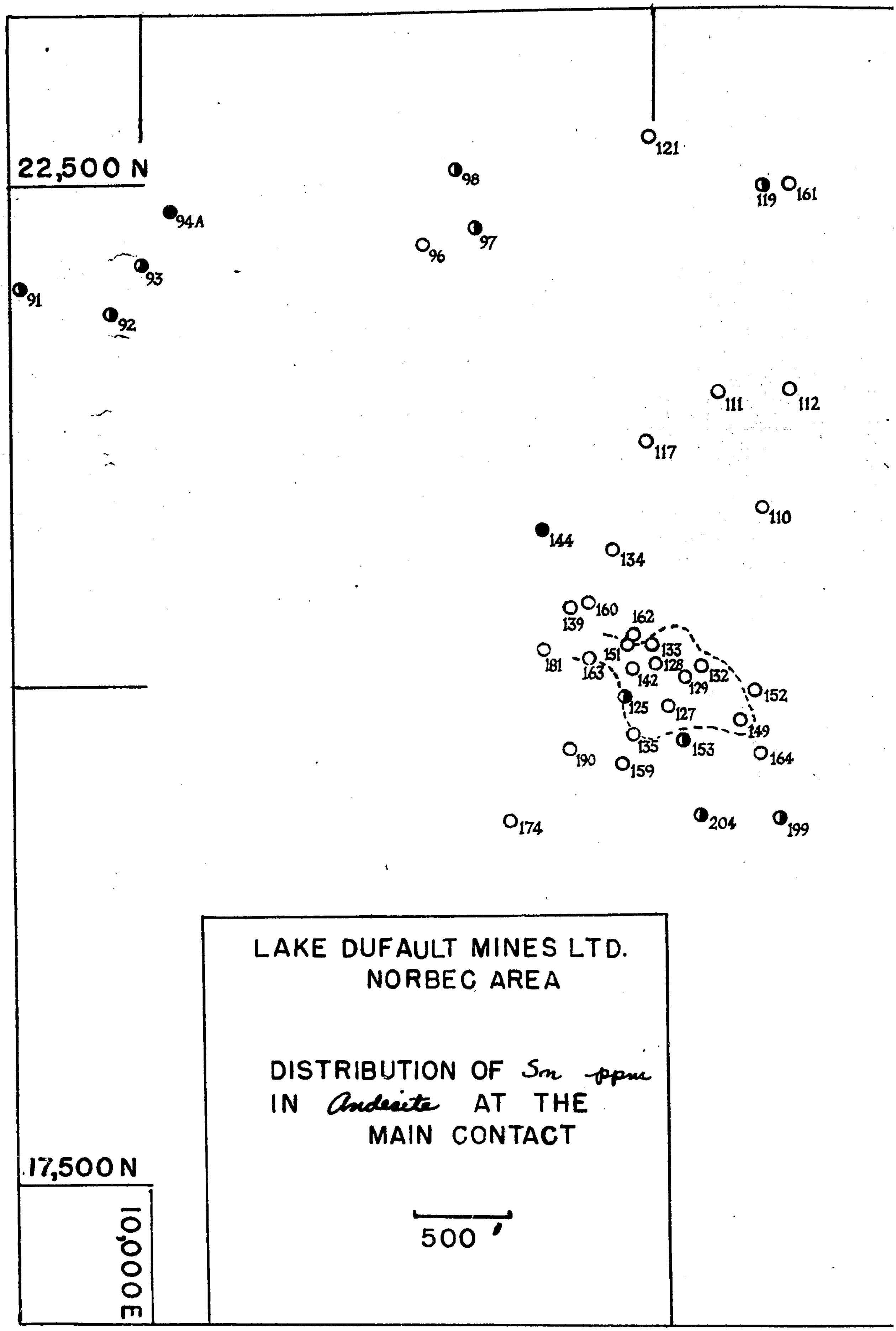
Figure 28


22,500 N
17,500 N
10,000 E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
133
151
128
132
181
163
142
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Ni ppm
IN Andesite AT THE
MAIN CONTACT
500 '


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 100
100-150
151-200
> 200
15,000 E

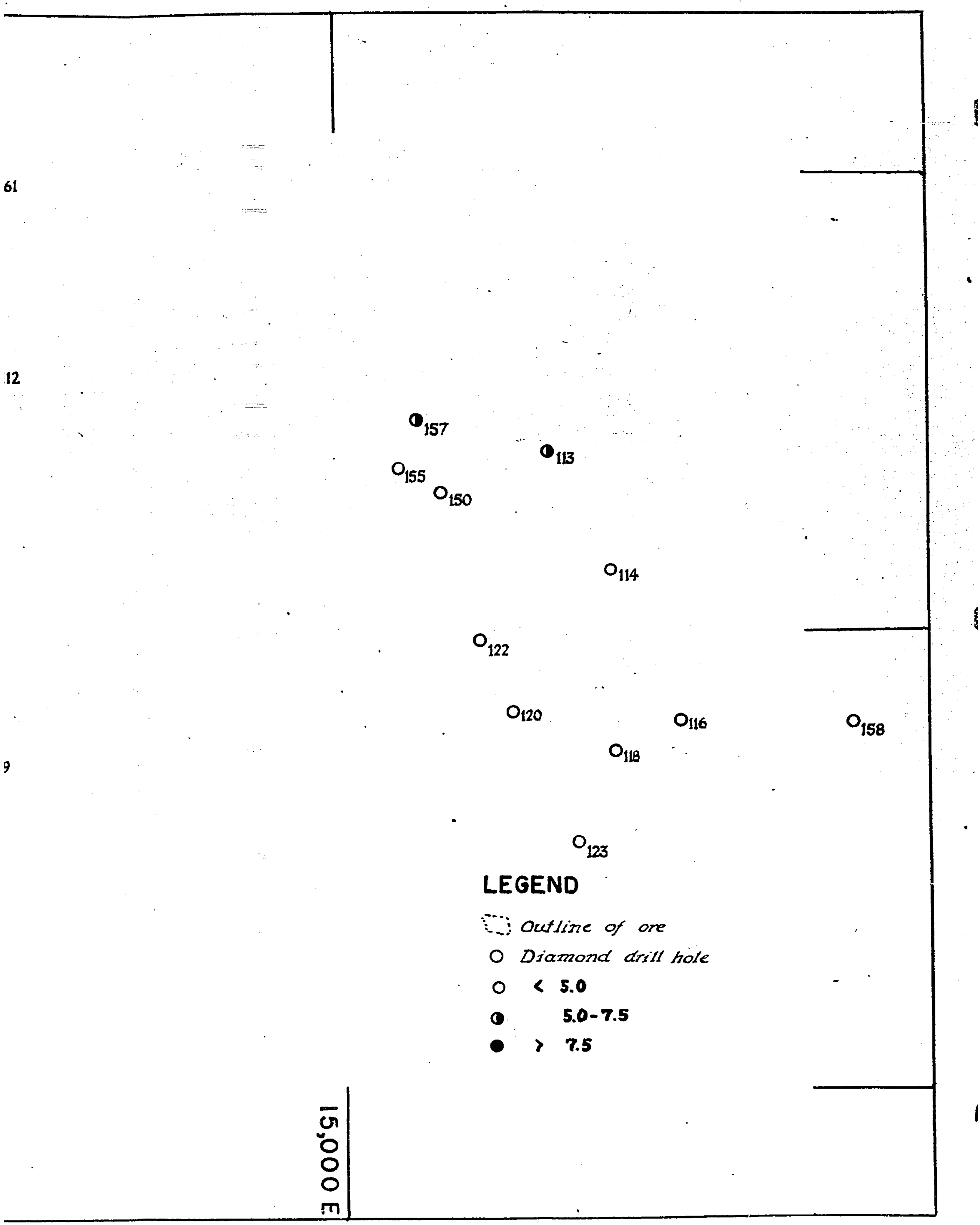
Sn andesite

Figure 29



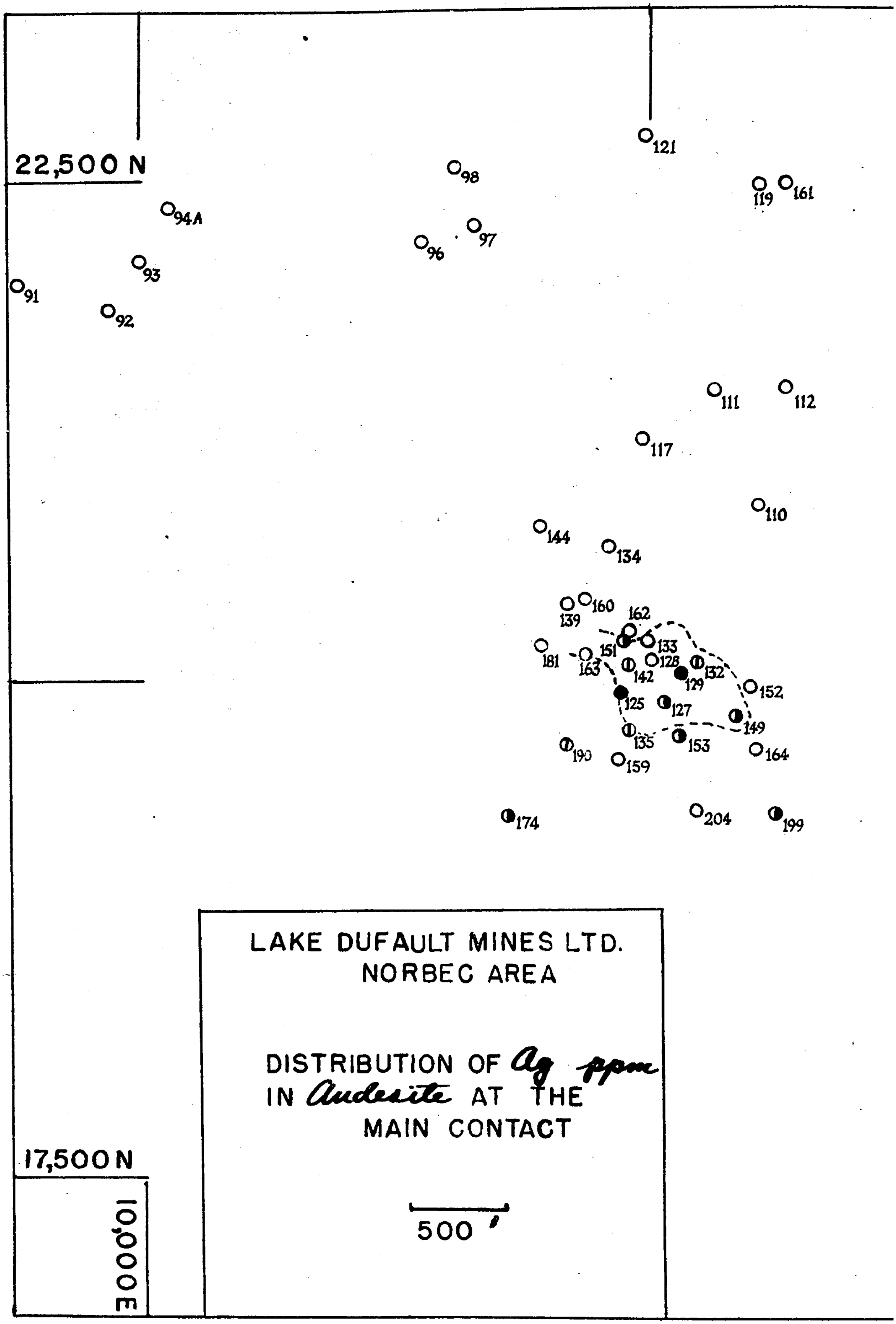
LAKE DUFAULT MINES LTD.
NORBEC AREA

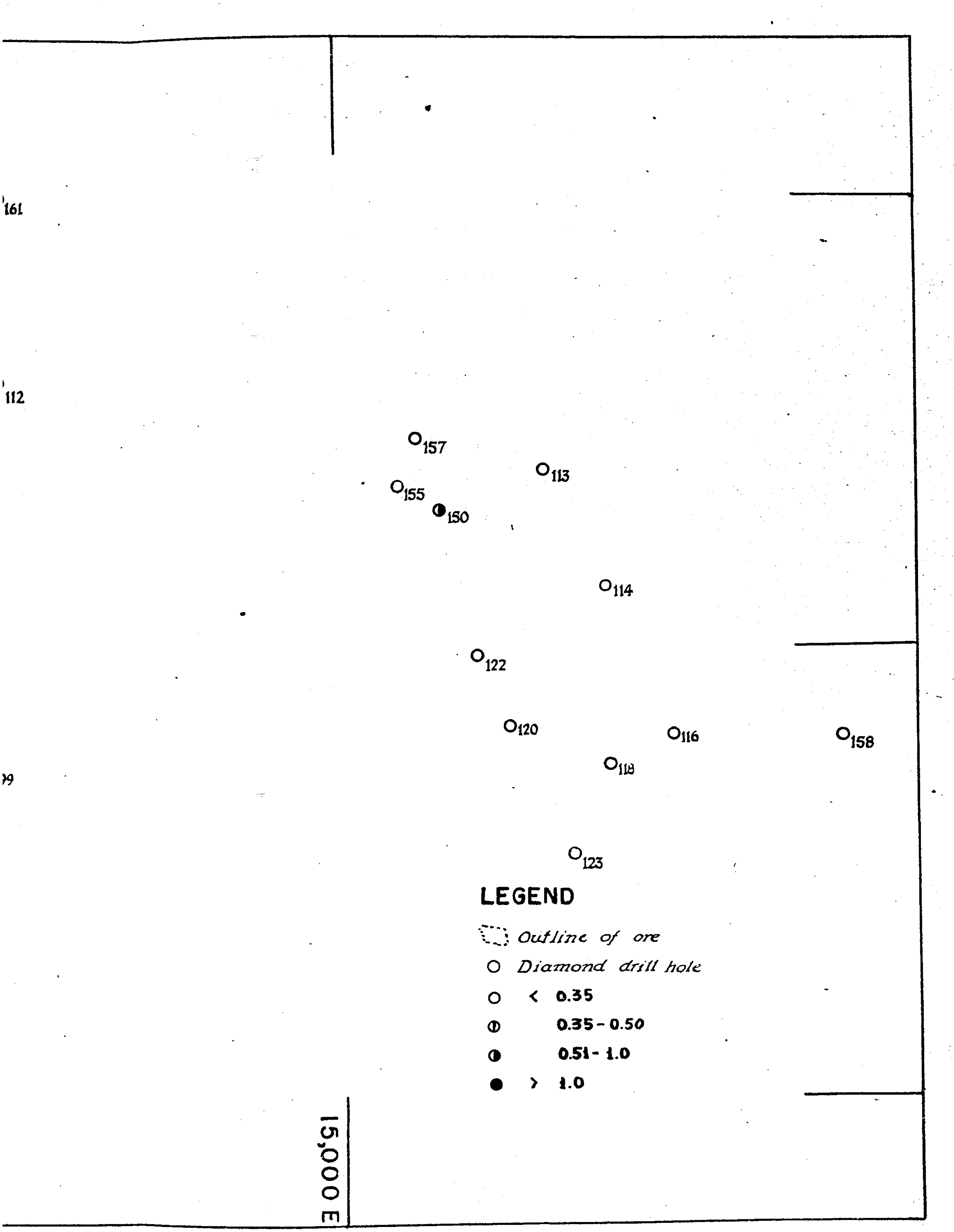
DISTRIBUTION OF *Sn ppm*
IN *Andesite* AT THE
MAIN CONTACT


61
12
9
157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 5.0
5.0-7.5
> 7.5
15,000 E

Ag andesite

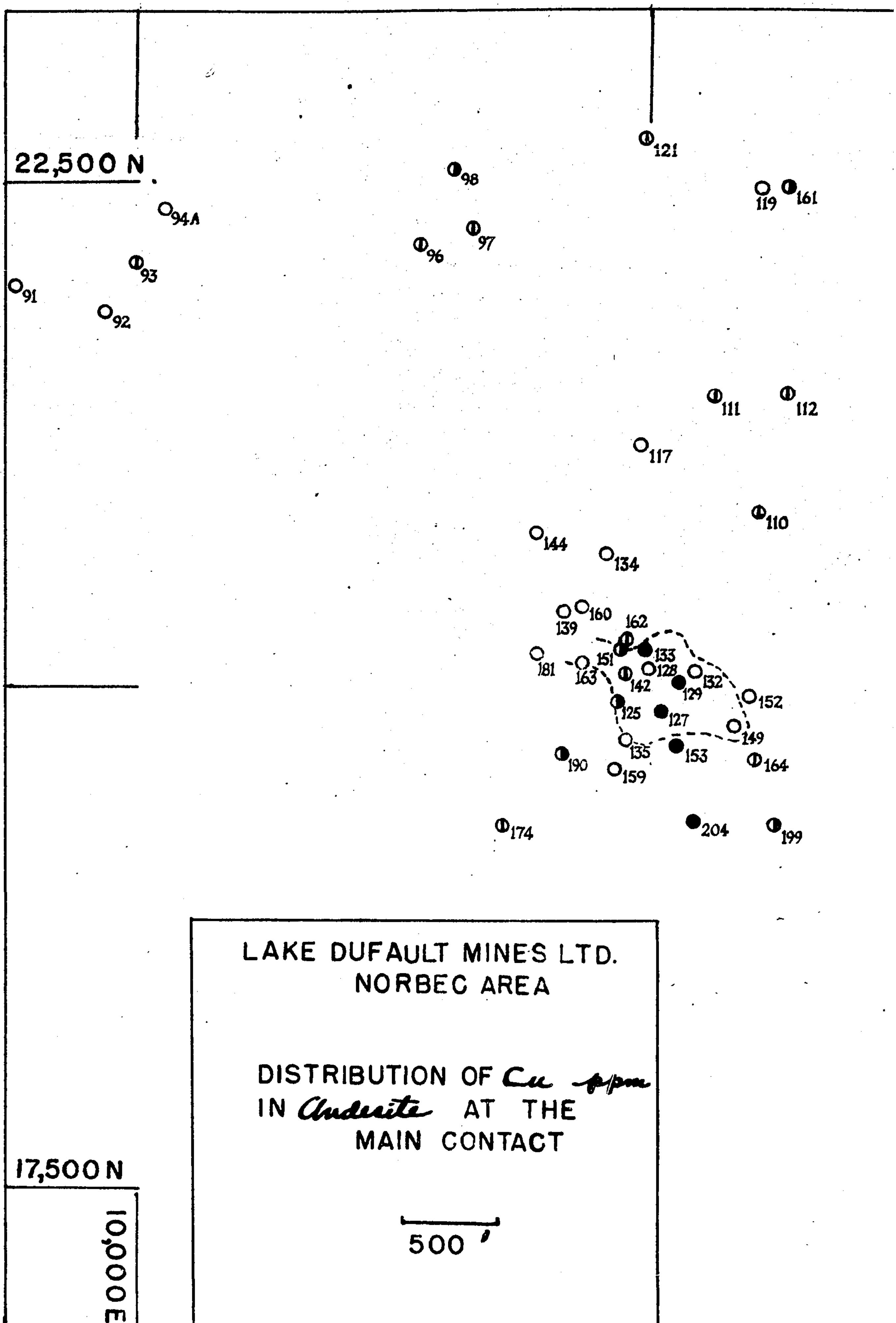
Figure 30

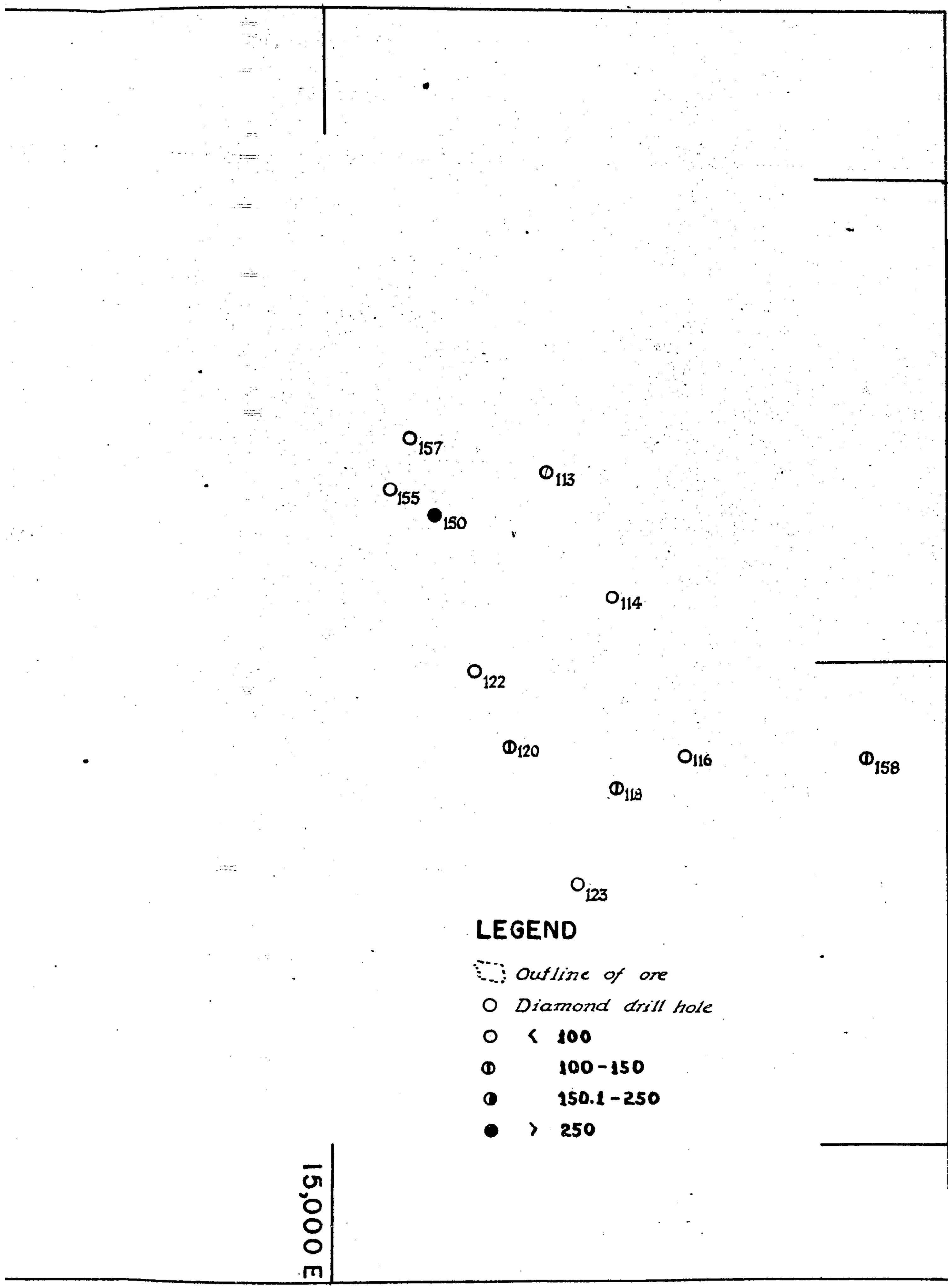

22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
163
151
133
142
128
132
129
152
125
127
149
135
153
190
159
164
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Ag ppm
IN Andesite AT THE
MAIN CONTACT
500 '


161
112
157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 0.35
0.35 - 0.50
0.51 - 1.0
> 1.0
15,000 E

Cu andesite

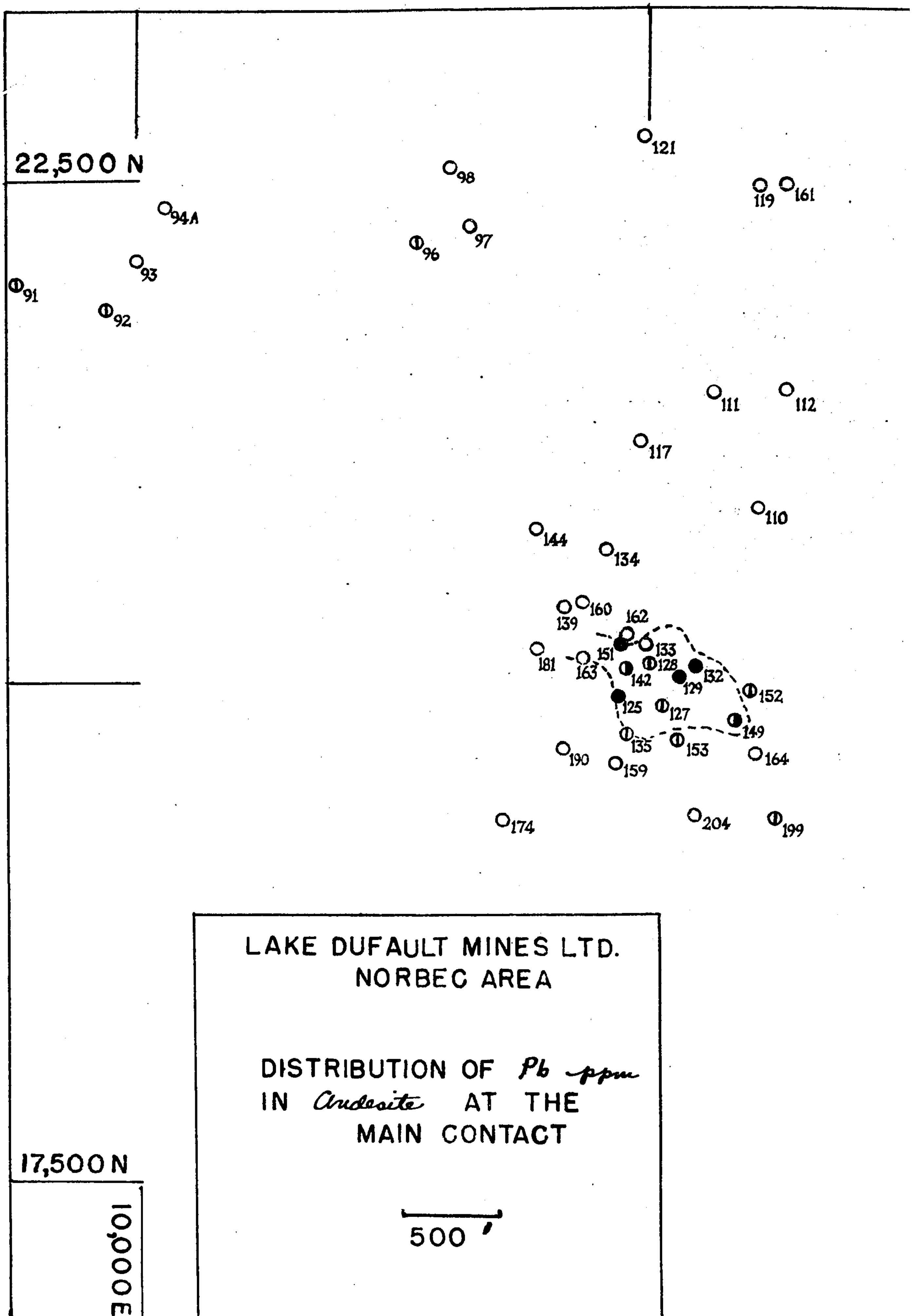
Figure 31


22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
163
151
133
142
128
132
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Cu ppm
IN Andesite AT THE
MAIN CONTACT
500 '


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 100
100 - 150
150.1 - 250
> 250
15,000 E

Pb andesite

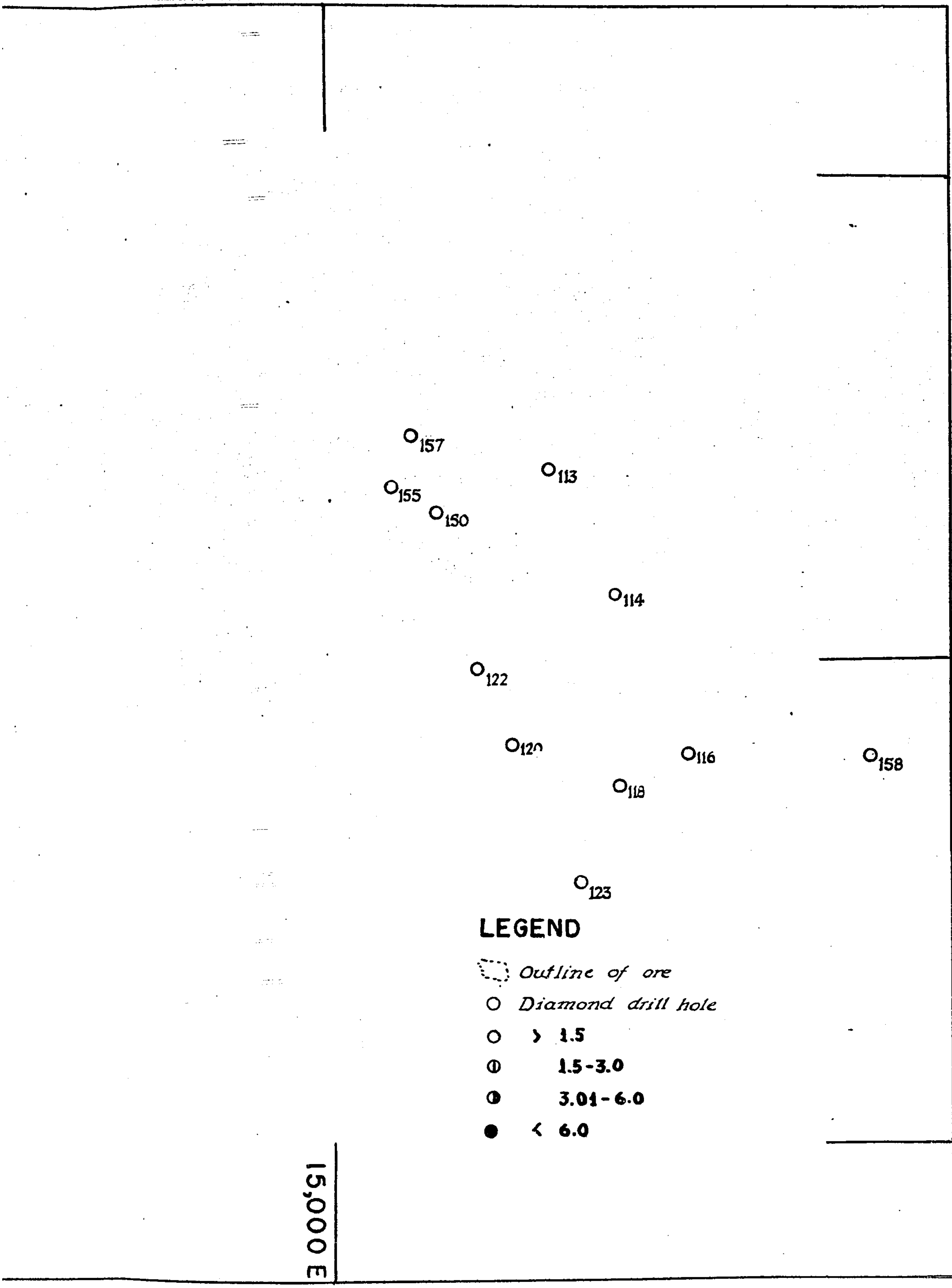
Figure 32



LAKE DUFAULT MINES LTD.
NORBEC AREA

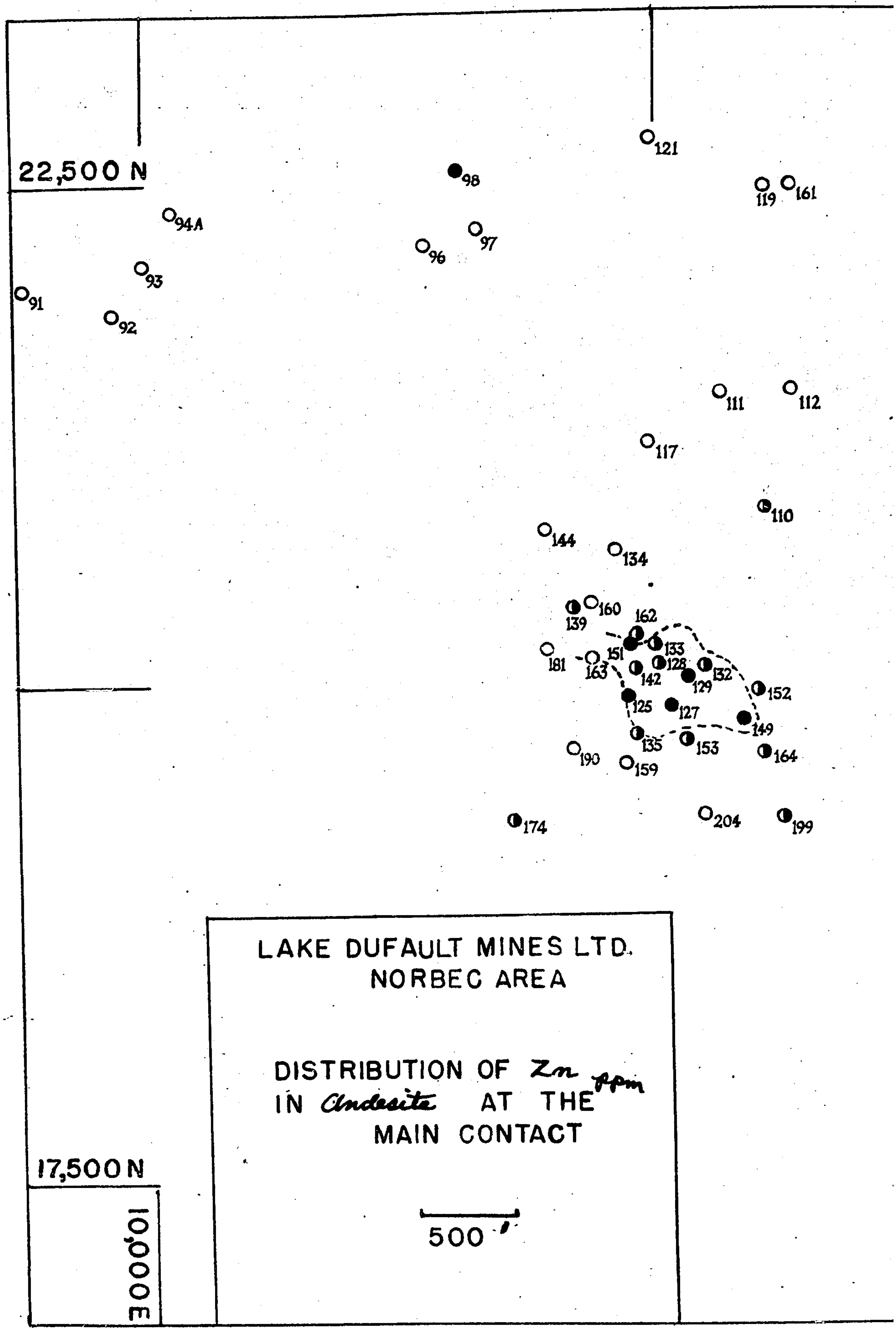
DISTRIBUTION OF Pb ppm
IN Andesite AT THE
MAIN CONTACT

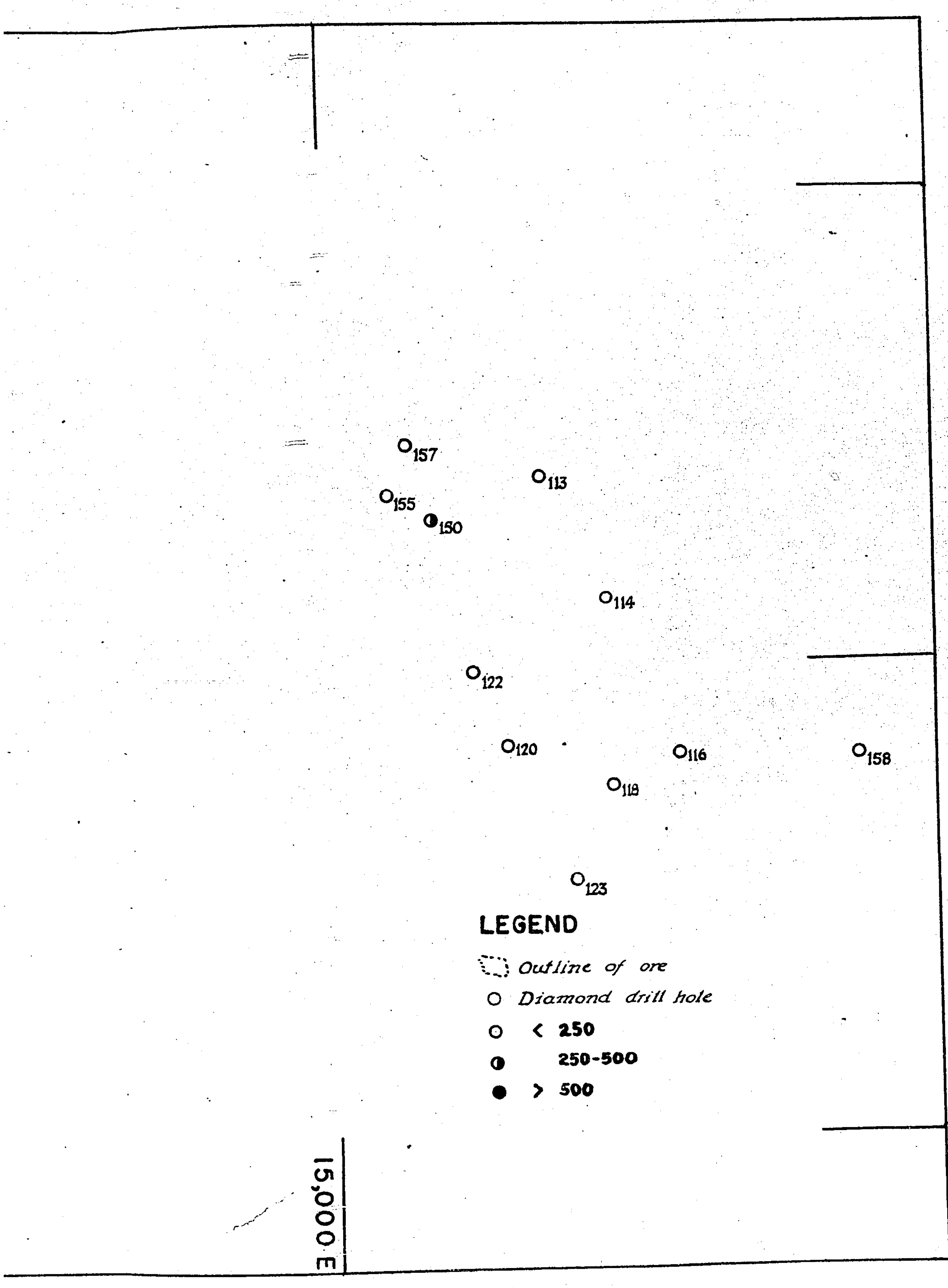
500 '


157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
> 1.5
1.5 - 3.0
3.01 - 6.0
< 6.0
15,000 E

Zn andesite

Figure 33


22,500 N
17,500 N
10,000 E
98
121
119
161
94A
97
96
93
91
92
111
112
117
110
144
134
139
160
162
133
181
163
151
142
128
132
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Zn ppm
IN Andesite AT THE
MAIN CONTACT
500 '

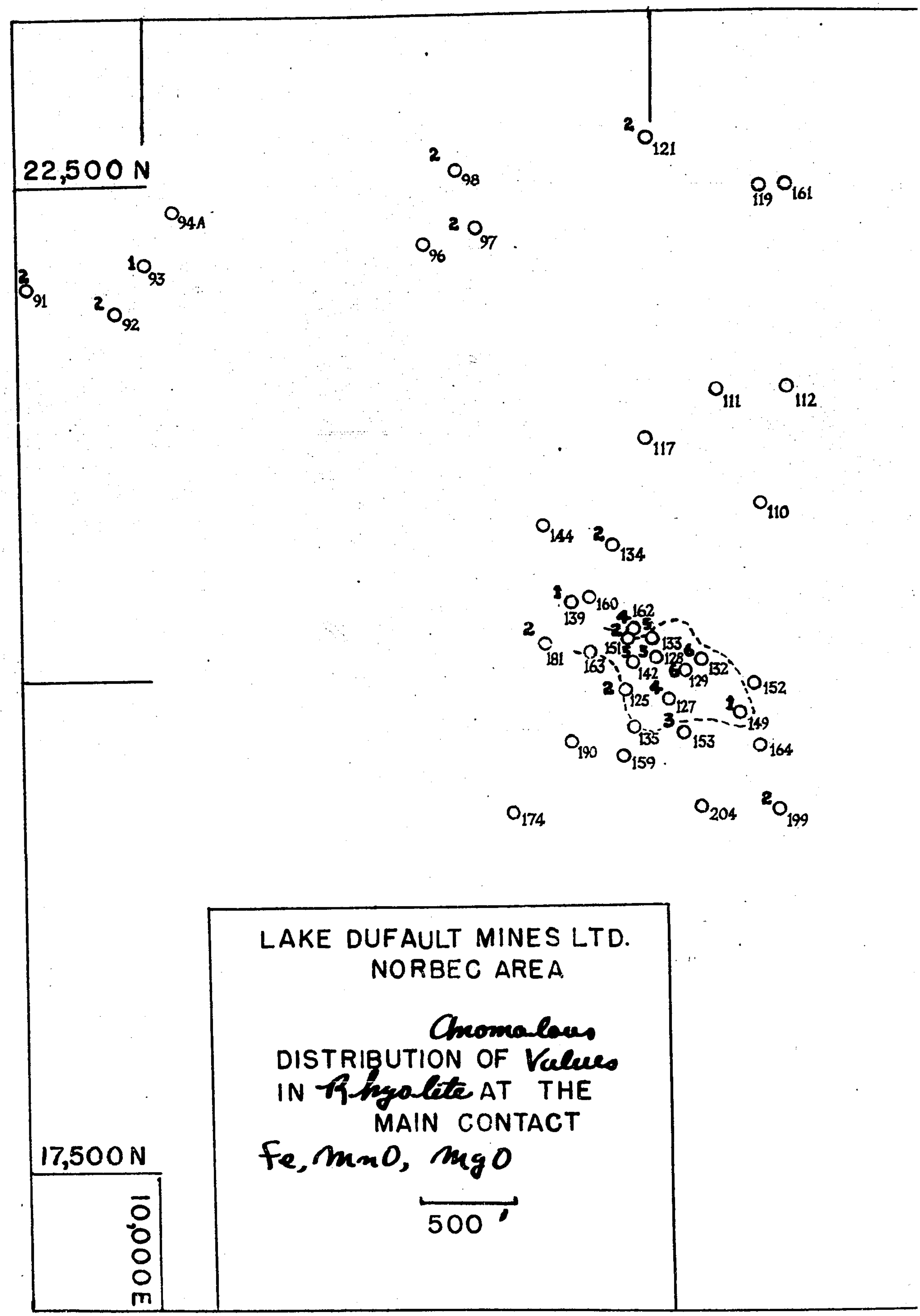

157
113
155
150
114
122
120
116
158
118
123
LEGEND
Outline of ore
Diamond drill hole
< 250
250-500
> 500
15,000 E

Anomalous Values

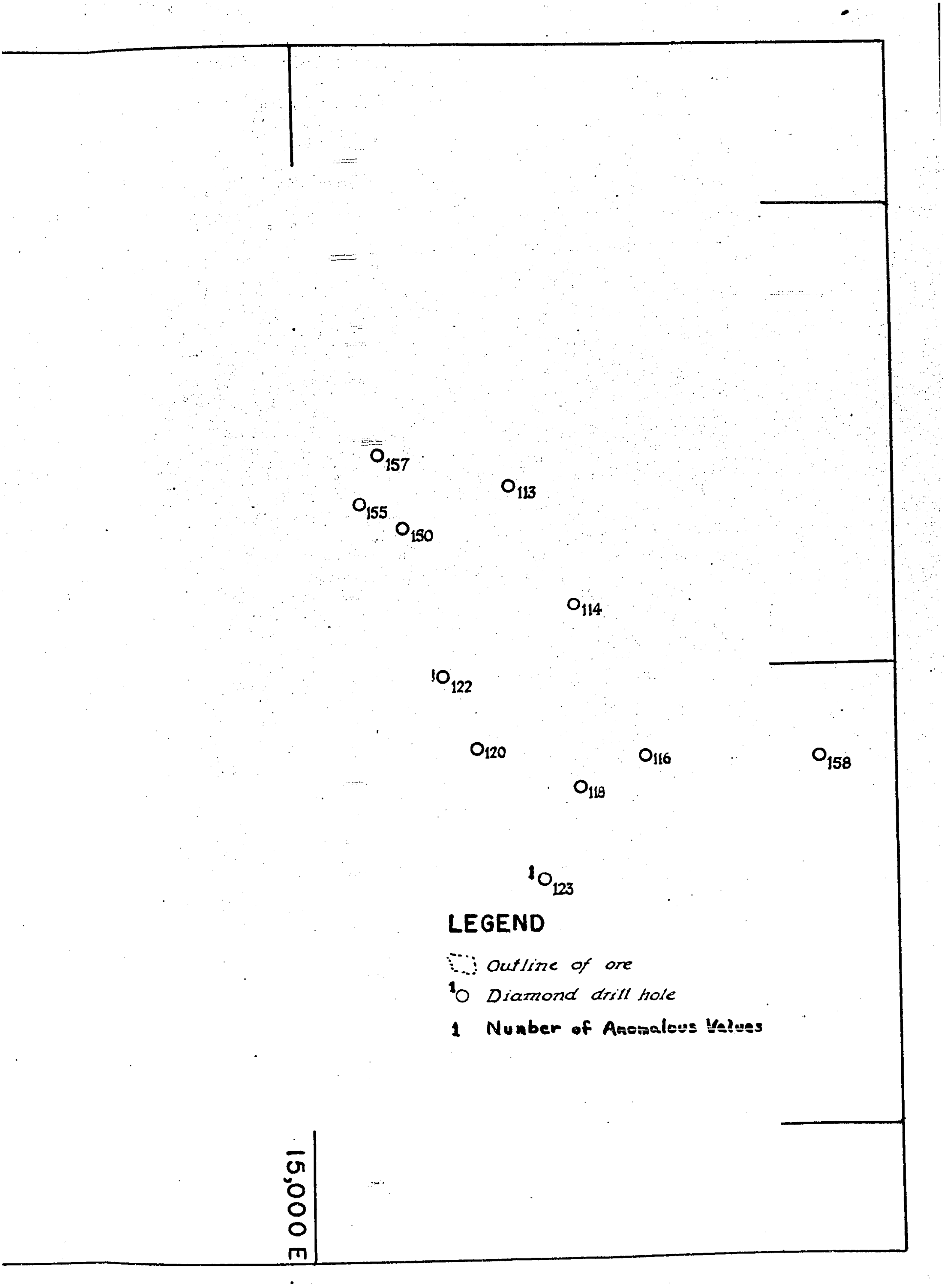
Fe, MnO, MgO

rhyolite

Figure 34



22,500 N
17,500 N
10,000E
91
92
93
94A
96
97
98
121
119
161
111
112
117
110
144
134
139
160
162
181
163
151
133
128
142
132
129
152
125
127
149
135
153
164
190
159
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
Anomalous
DISTRIBUTION OF Values
IN Rhyolite AT THE
MAIN CONTACT
Fe, MnO, MgO
500 '

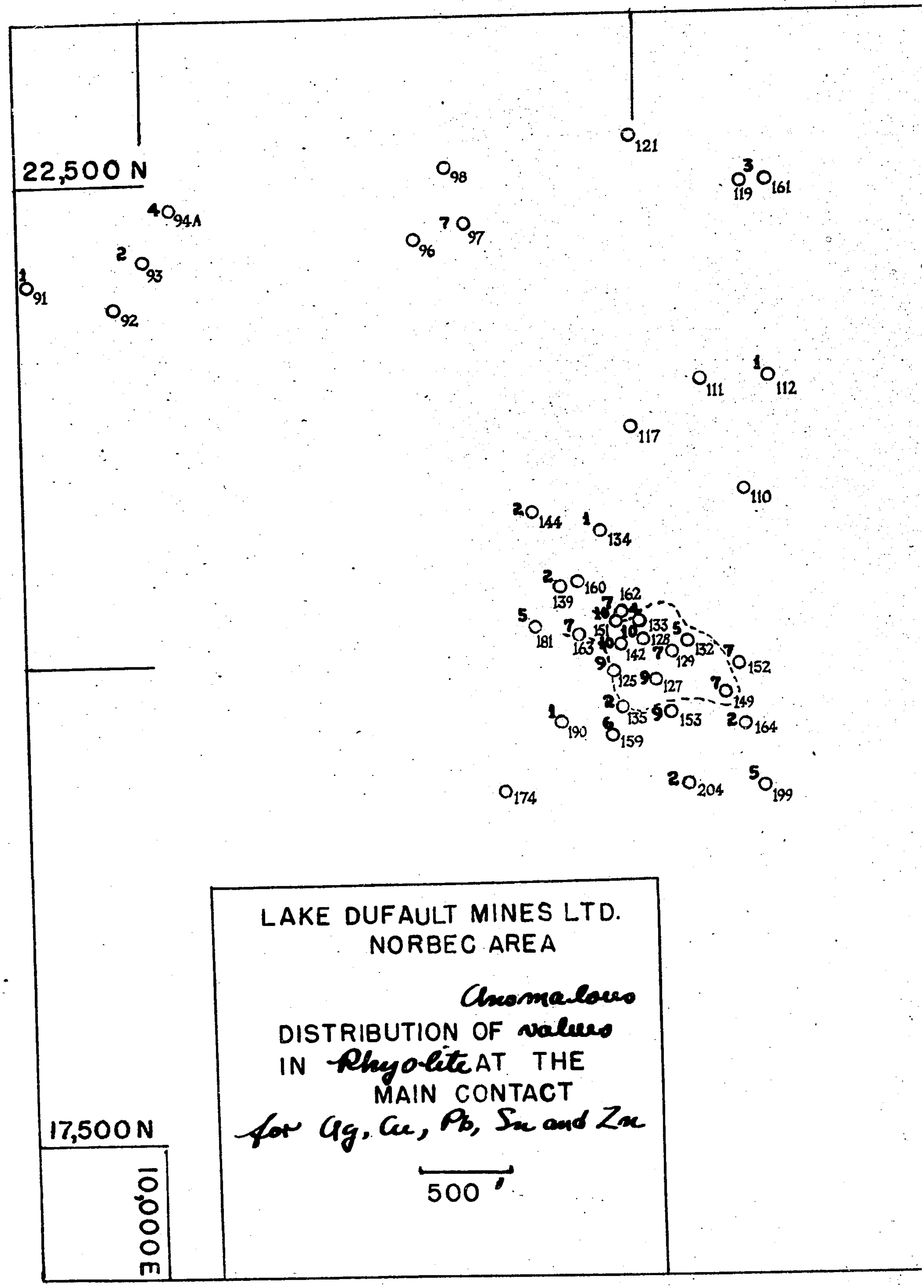

157
113
155
150
114
1 122
120
116
158
118
1 123
LEGEND
Outline of ore
Diamond drill hole
1 Number of Anomalous Values
15,000 E

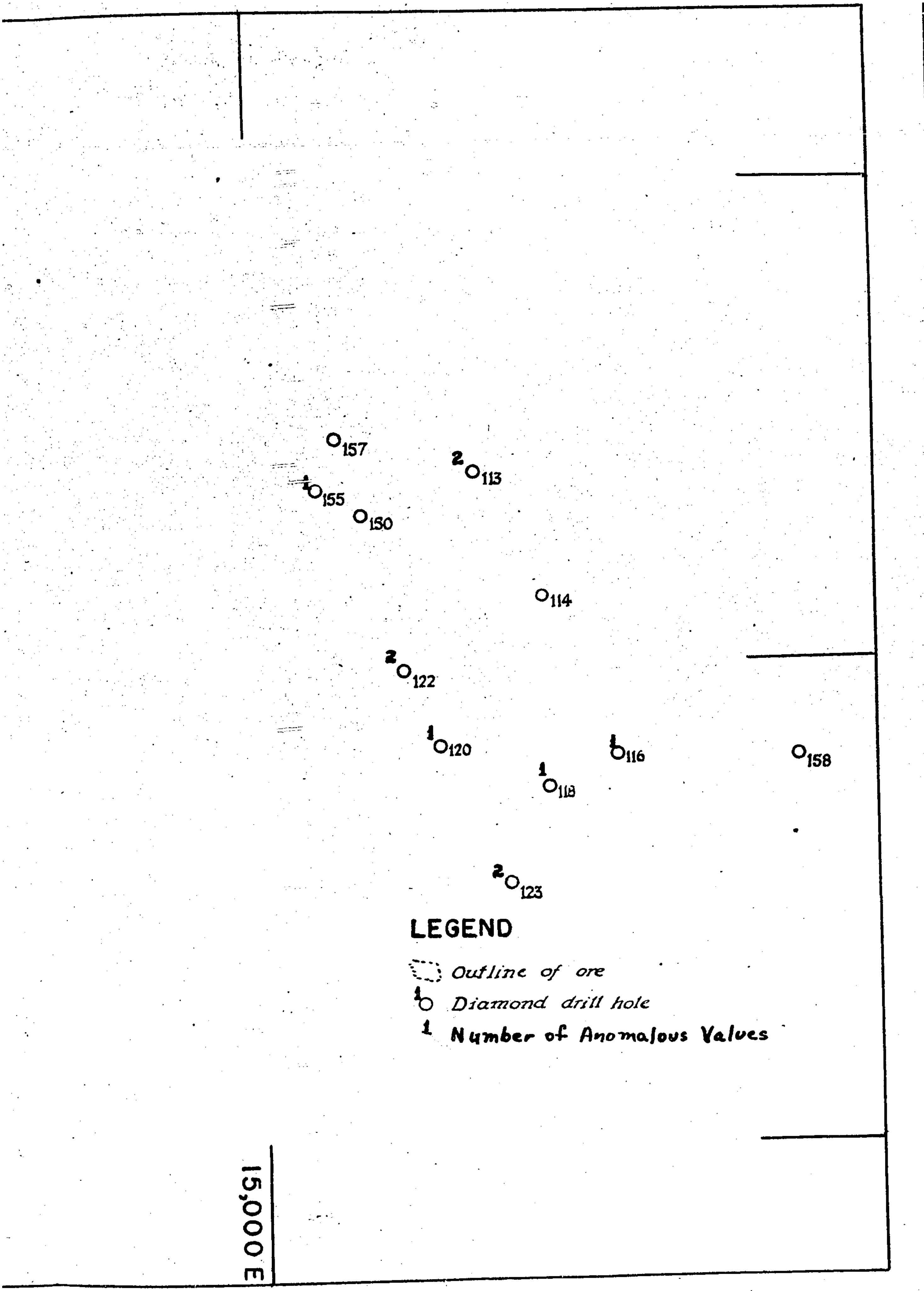
Anomalous Values

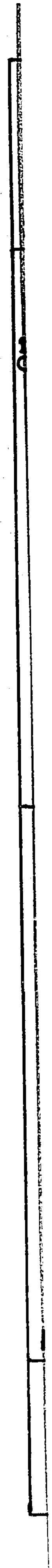
Ag, Cu, Pb, Sn, Zn

rhyolite

Figure 35


22,500 N
17,500 N
10,000 E
4 94A
2 93
1 91
92
98
7 97
96
121
3 119
161
1 112
111
117
110
2 144
1 134
2 139
160
162
5 181
7 163
151
133
128
142
5 132
7 129
7 152
9 125
9 127
7 149
2 135
9 153
2 164
1 190
6 159
174
2 204
5 199
LAKE DUFAULT MINES LTD.
NORBEC AREA
Anomalous
DISTRIBUTION OF values
IN Rhyolite AT THE
MAIN CONTACT
for Ag, Au, Pb, Sn and Zn
500 '


157
2 113
1 155
150
114
2 122
1 120
1 116
158
1 118
2 123
LEGEND
Outline of ore
Diamond drill hole
1 Number of Anomalous Values
15,000 E

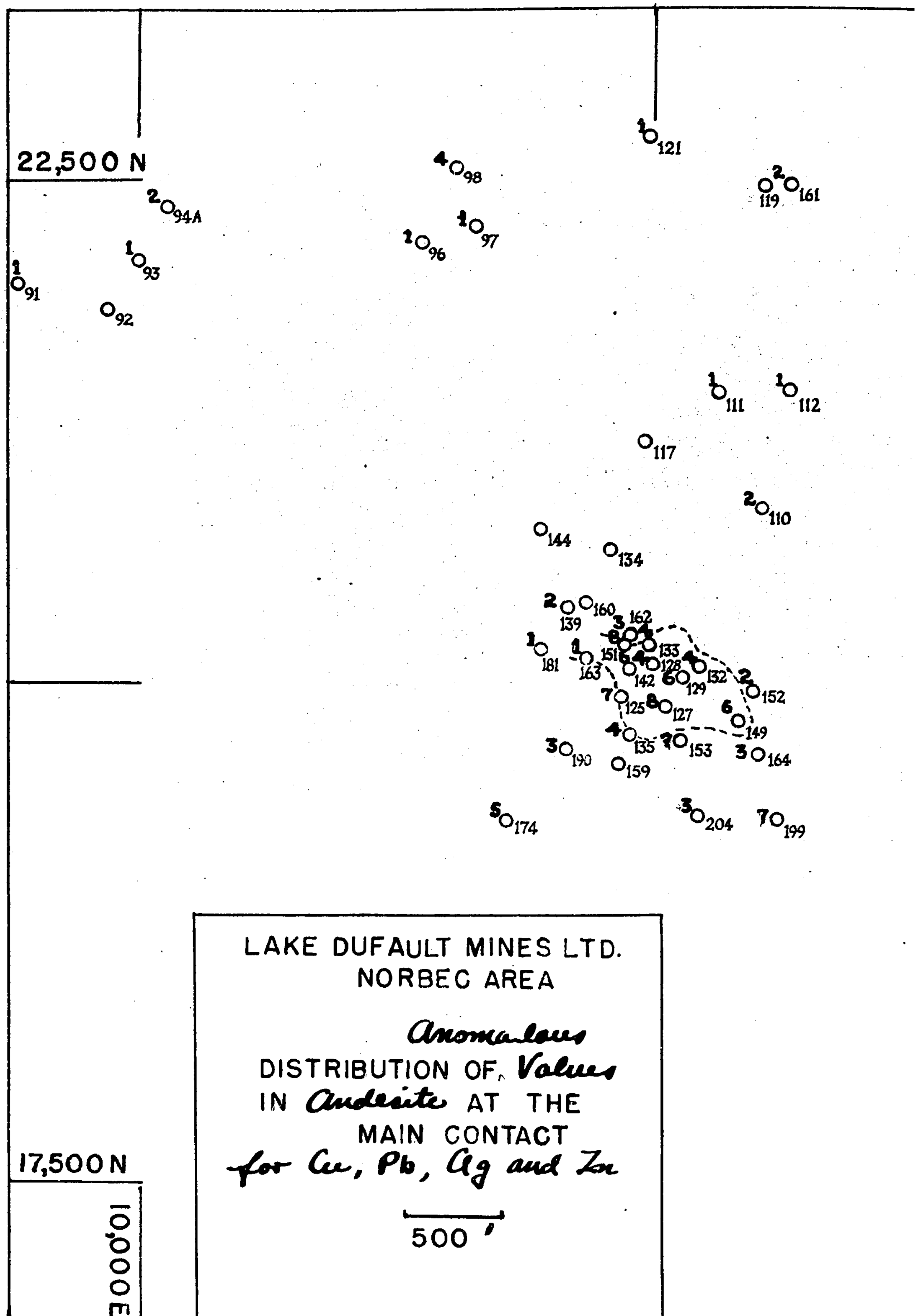


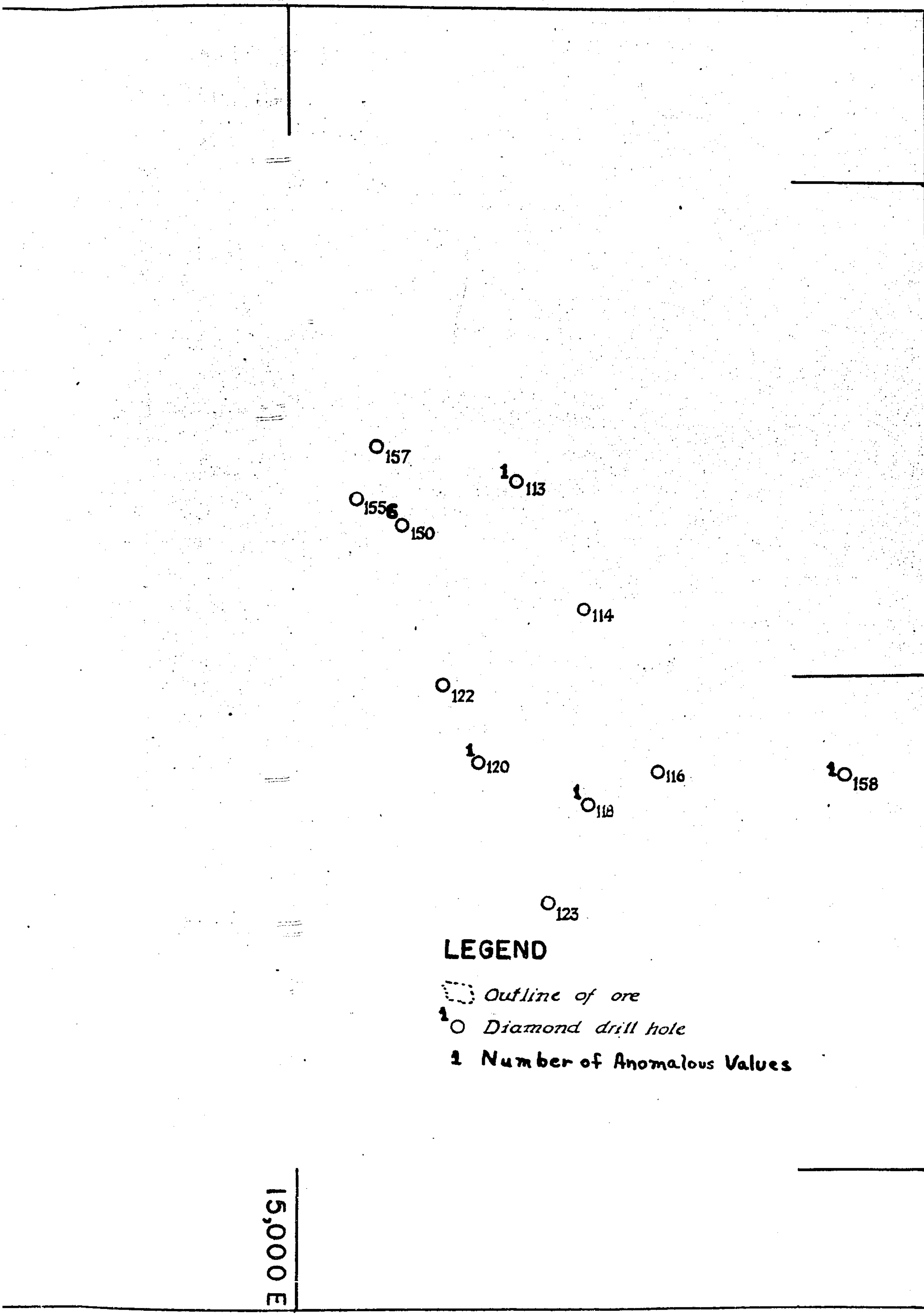
Anomalous Values

Cu, Pb, Ag, Zn

andesite

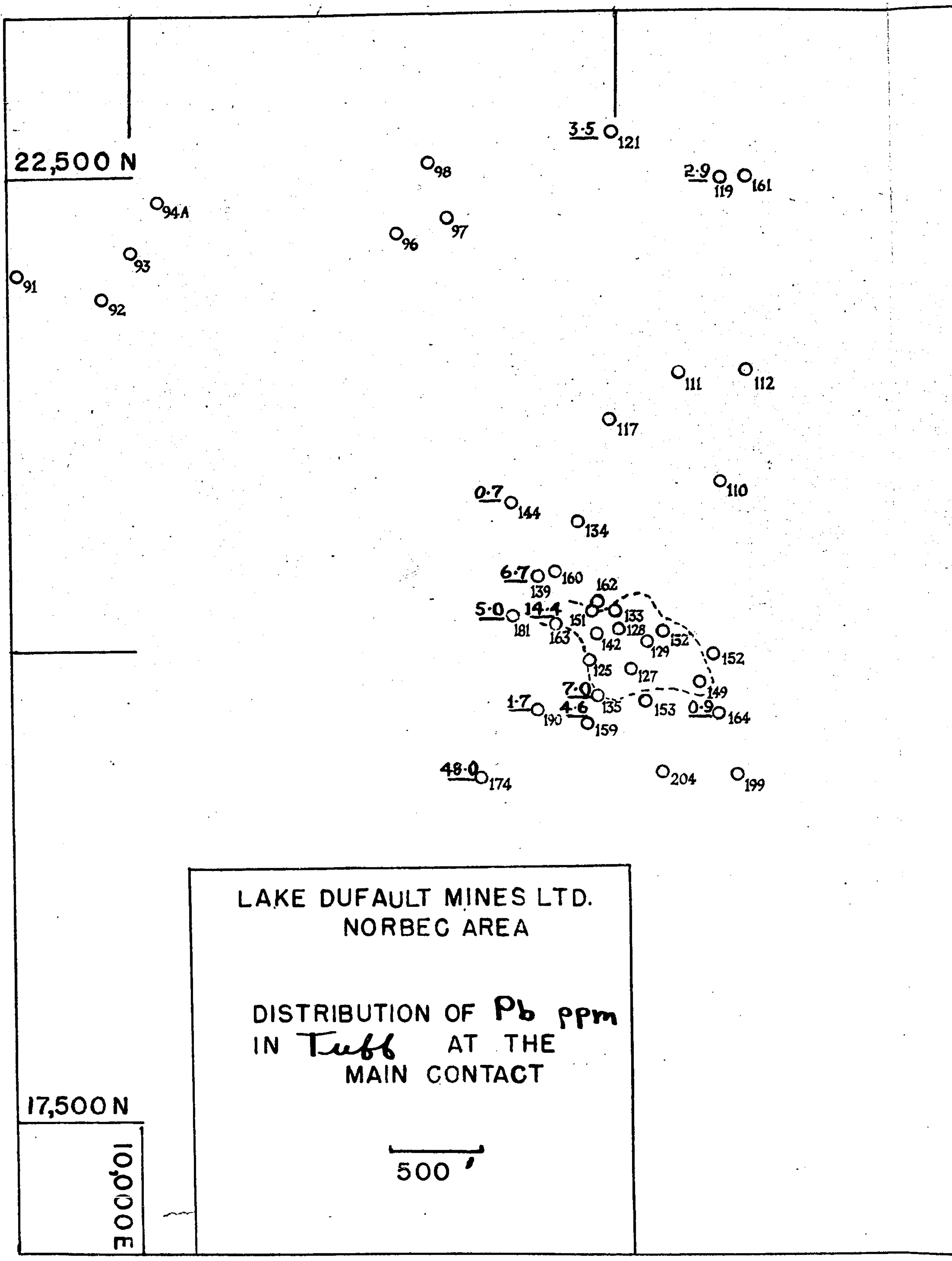
Figure36

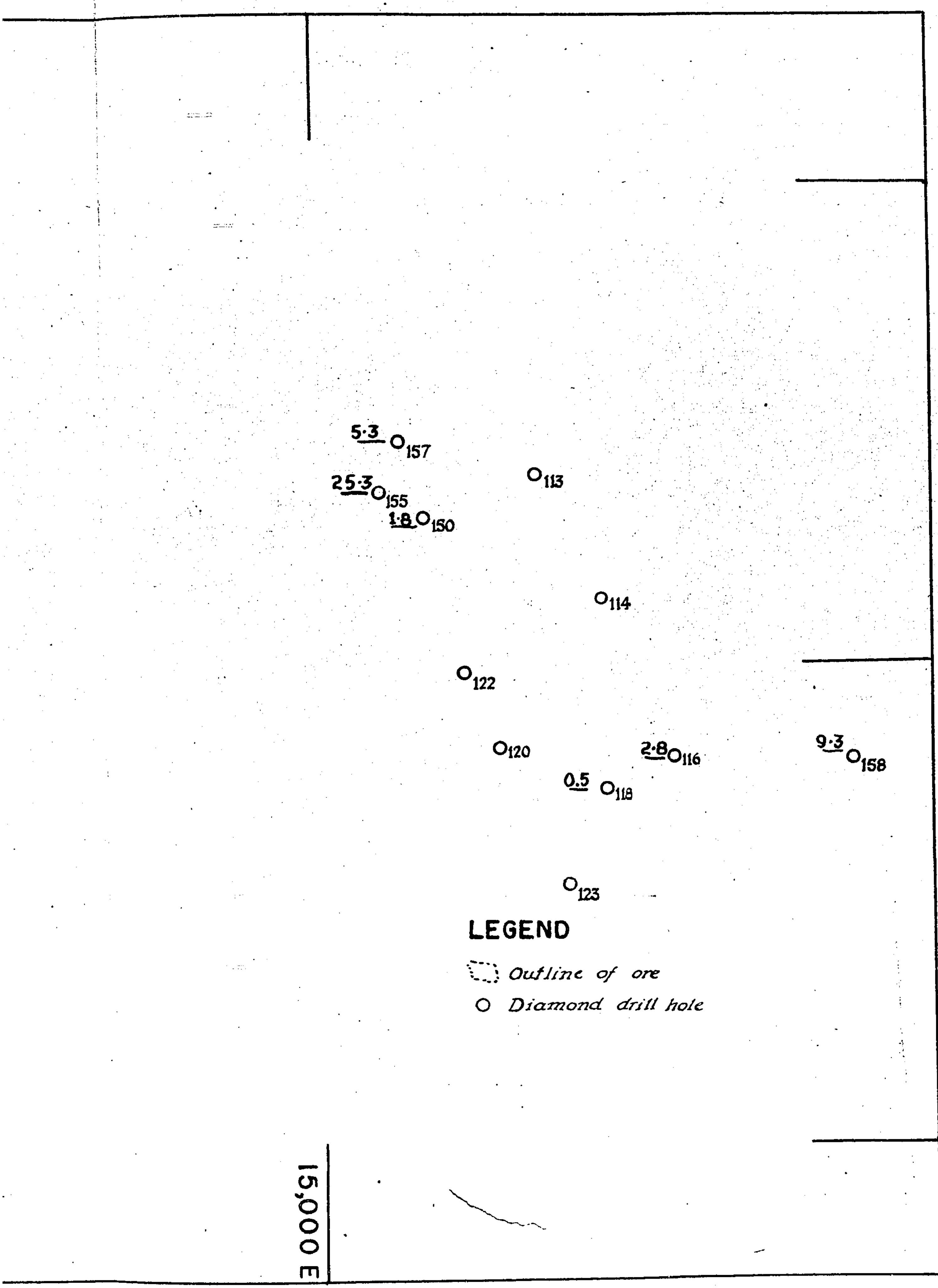

22,500 N
17,500 N
10,000 E
LAKE DUFAULT MINES LTD.
NORBEC AREA
Anomalous
DISTRIBUTION OF Values
IN Andesite AT THE
MAIN CONTACT
for Cu, Pb, Ag and Zn
500 '


157
1 113
155
150
114
122
1 120
116
1 158
1 118
123
LEGEND
Outline of ore
Diamond drill hole
1 Number of Anomalous Values
15,000 E

Pb tuff

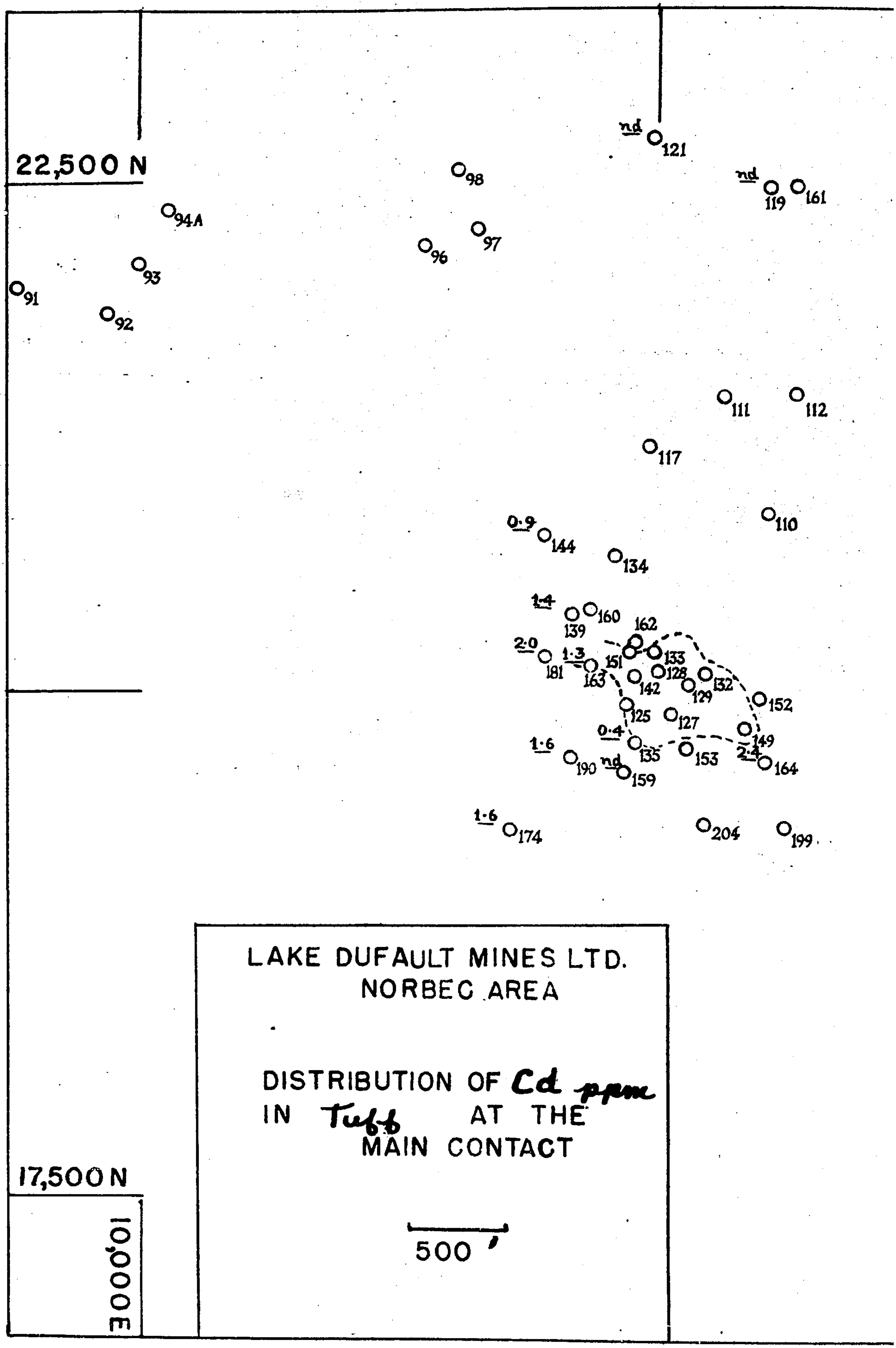
Figure 37

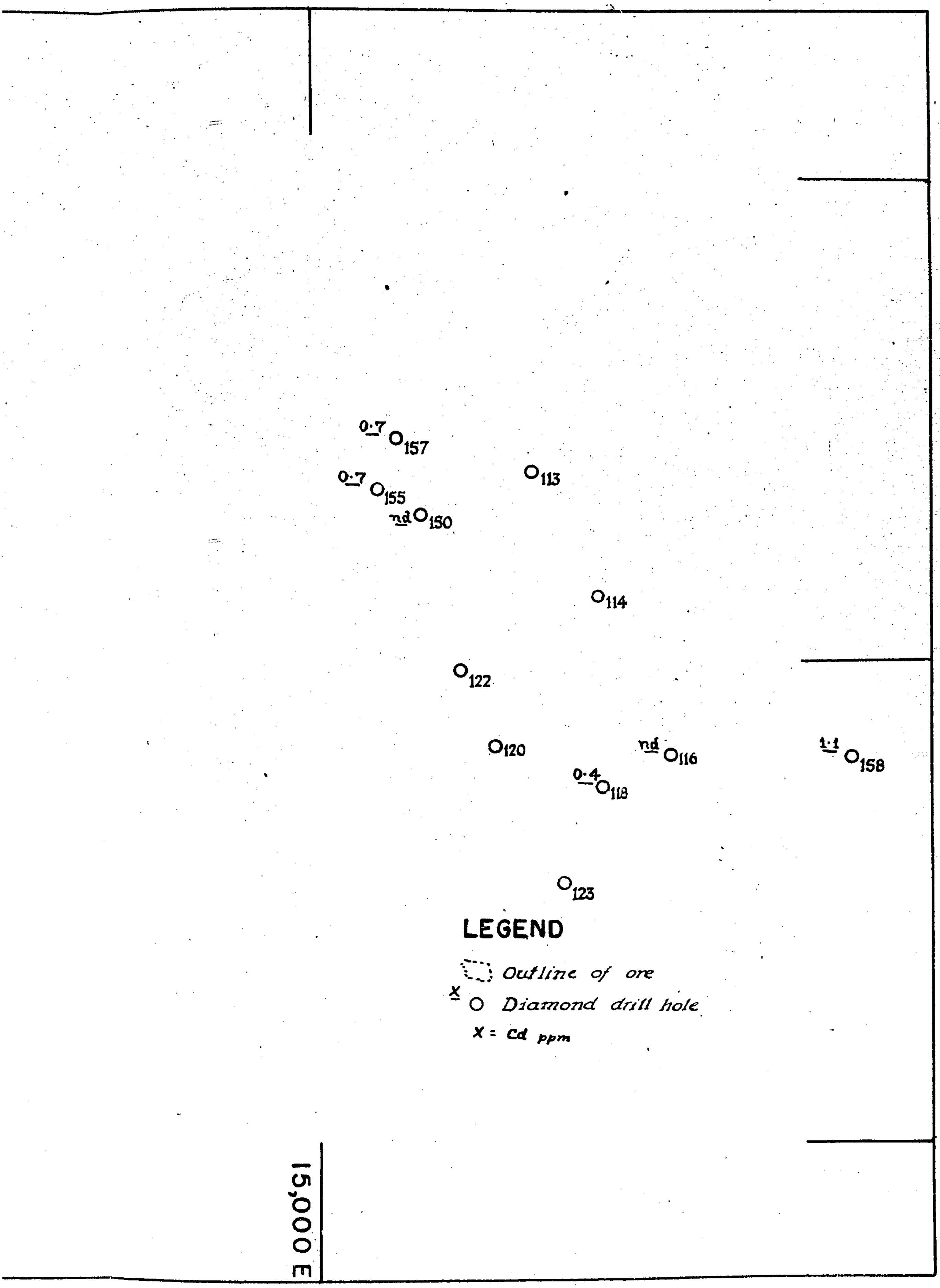

22,500 N
17,500 N
10,000 E
3·5
121
2·9
119
161
98
94A
97
96
93
91
92
111
112
117
110
0·7
144
134
6·7
139
160
162
5·0
181
14·4
163
151
133
128
142
132
129
152
125
127
149
7·0
135
153
1·7
190
4·6
159
0·9
164
48·0
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Pb ppm
IN Tuff AT THE
MAIN CONTACT
500 '


5·3
157
113
25·3
155
1·8
150
114
122
120
2·8
116
9·3
158
0.5
118
123
LEGEND
Outline of ore
Diamond drill hole
15,000 E

Cd tuff

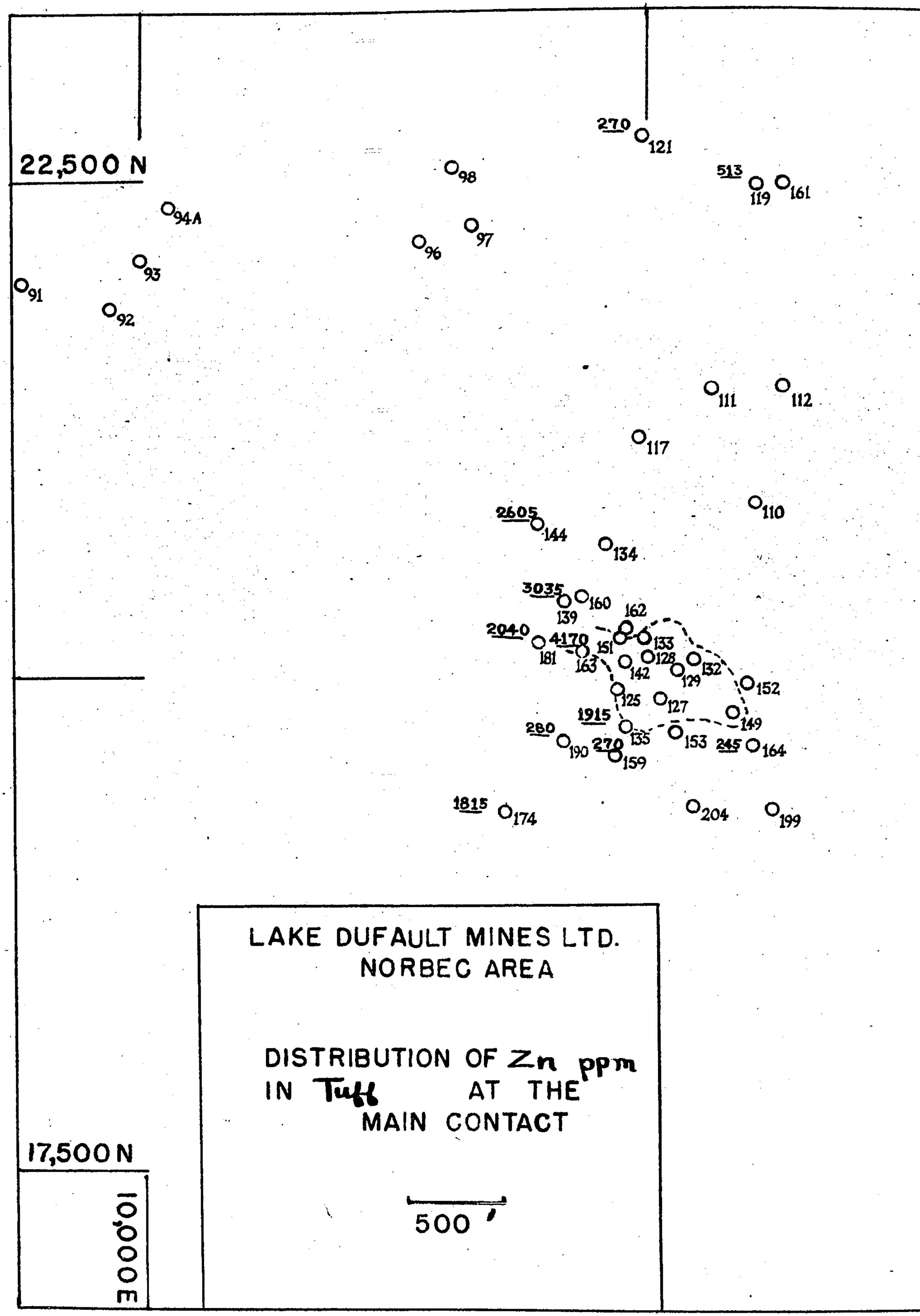
Figure 38

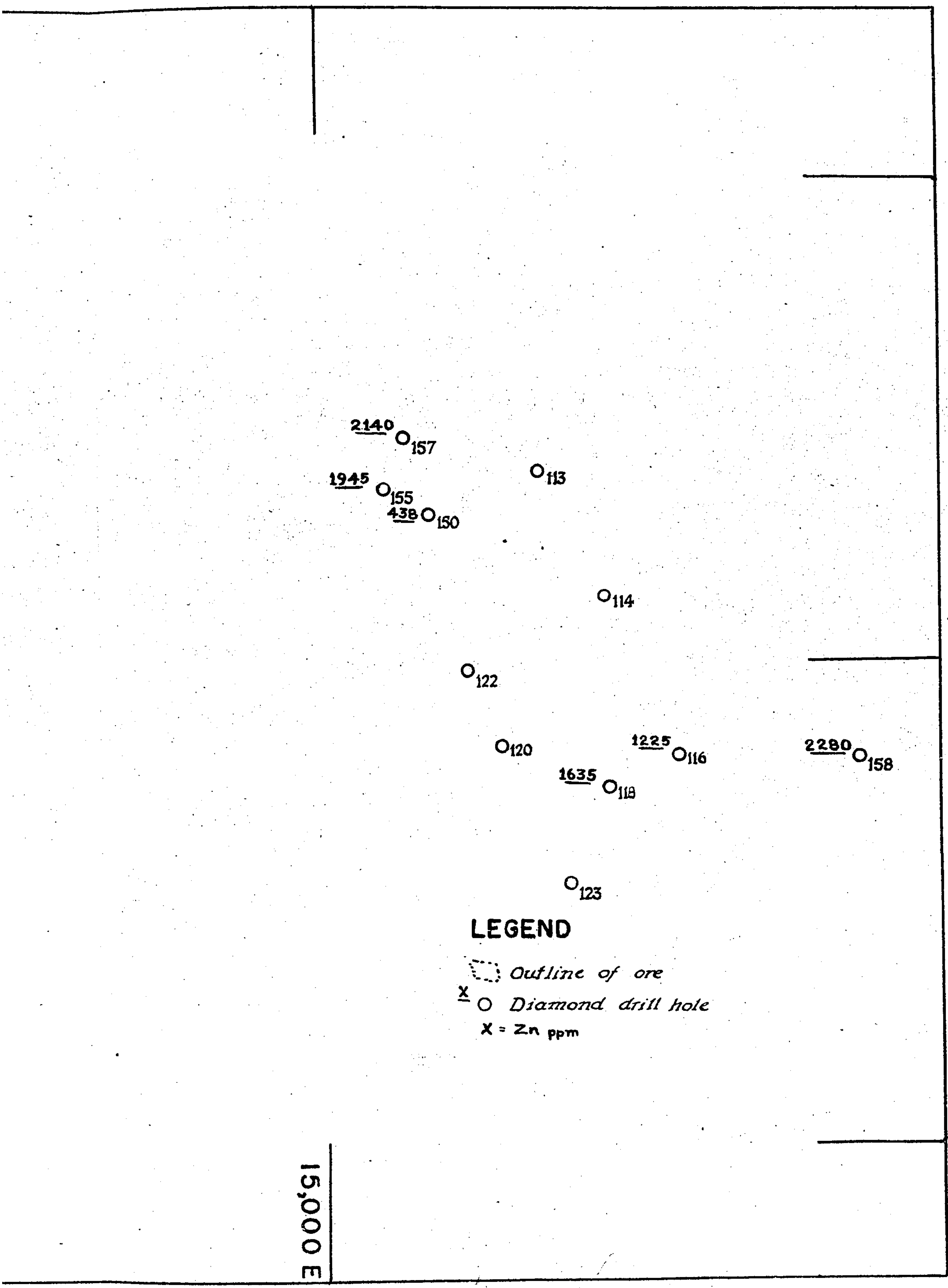

22,500 N
17,500 N
10,000 E
nd 121
98
nd 119
161
94A
97
96
93
91
92
111
112
117
110
0·9 144
134
1·4 139
160
162
2·0 181
1·3 163
151
133
128
142
132
129
152
125
127
0·4 135
149
1·6 190
nd 159
153
2·4 164
1·6 174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Cd ppm
IN Tuff AT THE
MAIN CONTACT
500 '


0·7 157
0·7 155
nd 150
113
114
122
120
nd 116
1·1 158
0·4 118
123
LEGEND
Outline of ore
x Diamond drill hole
X = Cd ppm
15,000 E

Zn tuff

Figure 39


22,500 N
17,500 N
10,000 E
270
121
98
513
119
161
94A
97
96
93
91
92
111
112
117
110
2605
144
134
3035
160
139
162
2040
4170
181
163
151
133
128
142
132
129
152
125
127
1915
149
280
190
270
135
153
245
164
159
1815
174
204
199
LAKE DUFAULT MINES LTD.
NORBEC AREA
DISTRIBUTION OF Zn ppm
IN Tuff AT THE
MAIN CONTACT
500'



2140
157
1945
155
438
150
113
114
122
120
1225
116
2280
158
1635
118
123
LEGEND
Outline of ore
Diamond drill hole
X = Zn ppm
15,000 E

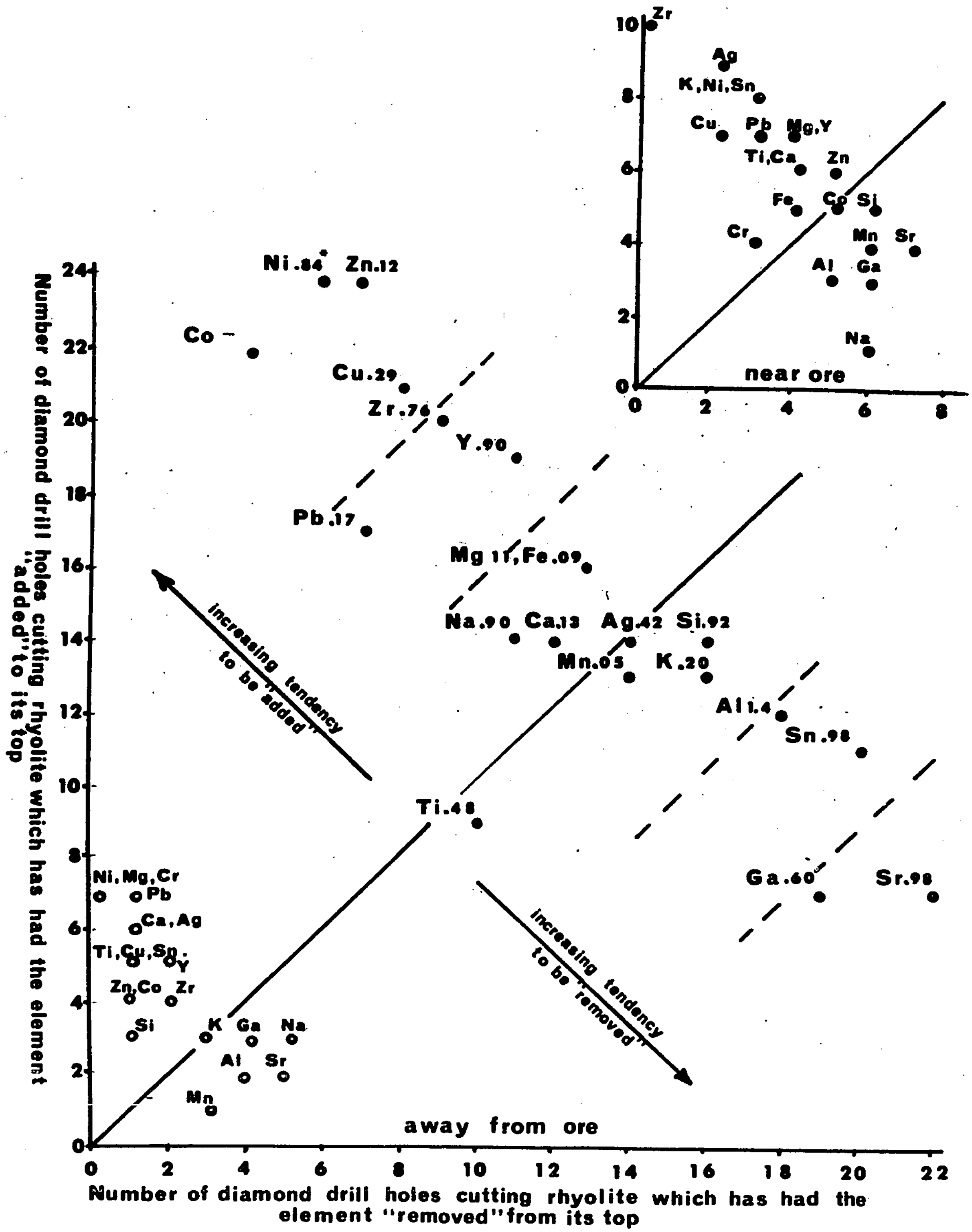


Fig. 40. Systematic Vertical Variation of the Elements in Waite Rhyolite. (o - 2 samples only)*R

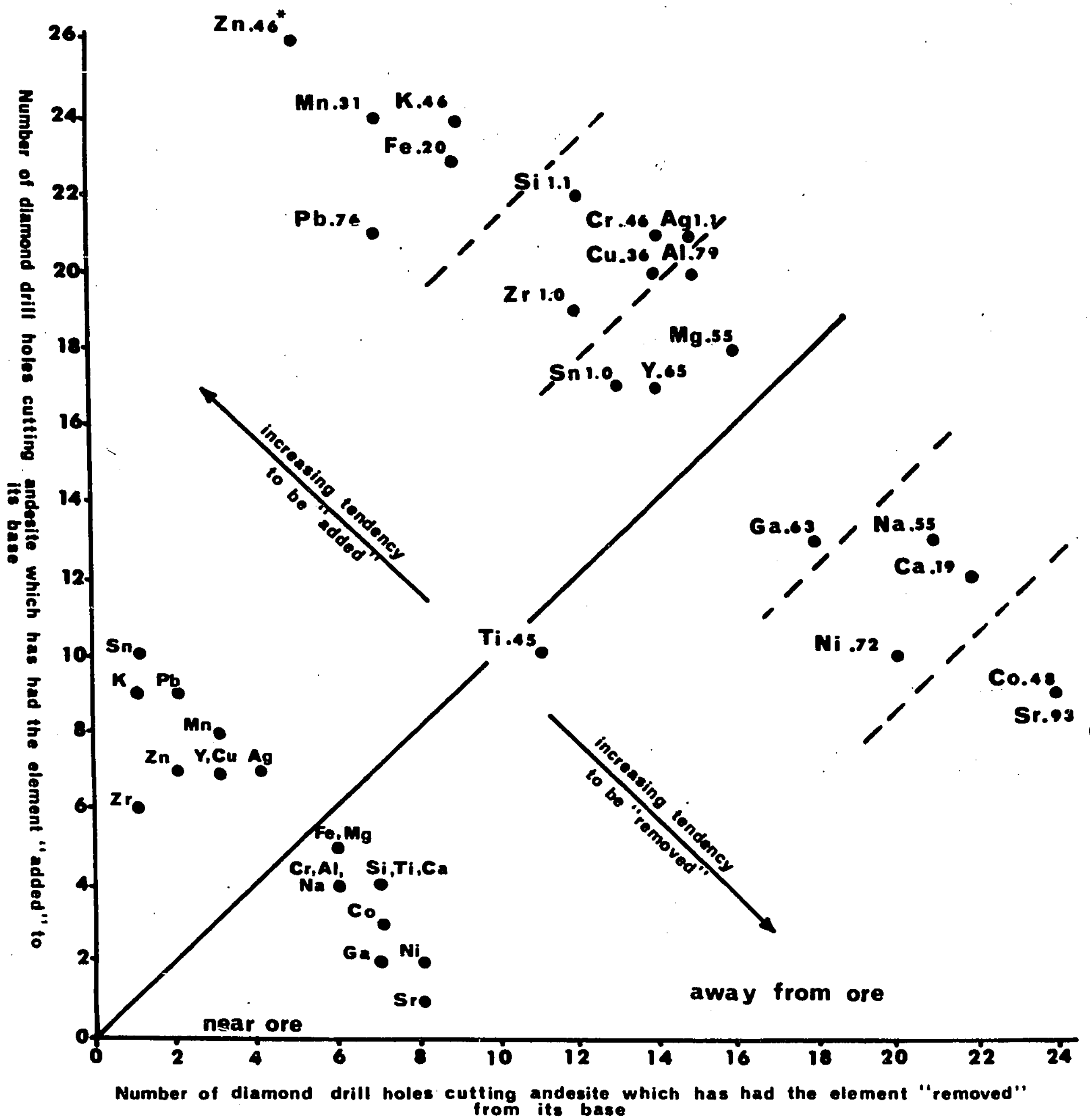


Fig. 41. Systematic Vertical Variation of the Elements in Amulet Andesite.*R

variation, the plot for that element would fall close to the forty-five degree line which extends from the origin. Results from drill holes near to the ore body are plotted separately[1] as are results from drill holes represented by only two samples.

The proportion of analytical error in a total variation, R, is given for each element on the graphs. Even though R might be large (0.7-1.0) the fact that the highest or lowest values are biased with respect to the main contact still has some significance as analytical errors in analyses performed in no special order (haphazardly) should be randomly distributed (not in a strict, statistical sense).

Results of these tests are summarized on tables 8 and 9.

DISCUSSION OF RESULTS

A review of the chemical data (tables 8 and 9) shows that there are three areas where systematic variations were detected in the contents of elements in andesite and rhyolite. These areas are:

1. An area of lateral variations close to the ore body, principally in rhyolite but also in andesite (figs. 12 to 36).

2. An area of systematic vertical variations near to and away from the ore body at the top of the rhyolite (fig. 40).

3. An area of systematic vertical variations near to and away from the ore body at the base of the andesite (fig. 41).

Area 1 overlaps areas 2 and 3.

---

1. Diamond drill hole numbers 125, 127, 128, 129, 132, 133, 135, 142, 149, 151, 163.

Table 8

SUMMARY OF CHEMICAL VARIATIONS IN THE WAITE RHYOLITE

LATERAL VARIATION		VERTICAL VARIATION TOP OF RHYOLITE			
close to ore body and in fractured and mineralized zone		away from ore		near ore (may be obscured by lateral changes toward ore)[2]	
Added	Removed	Added	Removed	Added	Removed
Fe (total as Fe_2O_3)	Na	Ni	Ga	Zr	Na
Mn	(Si?)	Zn	Sr	Ag	(Ca?)
Mg	(Ca?)	Co	(Al?)	K	(Sr?)
Zn	(Sr?)	Cu	(Sn?)	Ni	
Cu		(Zr?)		Sn	
Pb		(Y?)		(Cu?)	
Ag		(Pb?)		(Pb?)	
Sn				(Mg?)	
Co[1]				(Y?)	

1. Most of the sampled rhyolite contains less than detectable amounts of Co.

2. Because of the small number of holes involved less reliability should be placed on these results.

Table 9

SUMMARY OF CHEMICAL VARIATIONS IN THE AMULET ANDESITE

LATERAL VARIATION		VERTICAL VARIATION BASE OF ANDESITE			
over the ore body		away from ore		near ore (may be obscured by lateral changes toward ore)[1]	
Added	Removed	Added	Removed	Added	Removed
Ag		Zn	Co	Sn	Sr
Cu		Mn	Sr	K	Ni
Pb		K	(Ni?)	Pb	Ga
Zn		Fe	(Ca?)	(Zr?)	(Co?)
		Pb	(Na?)	(Zn?)	(Si?)
		(Si?)		(Mn?)	(Ca?)
		(Cr?)		(Y?)	(Ti?)
		(Ag?)		(Cu?)	
		(Cu?)		(Ag?)	
		(Zr?)			

1. Because of the small number of holes involved less reliability should be placed on these results.

Major Elements

All analyses for major elements in this report are expressed as oxide weight per cent. Major element analyses in other studies of rock alteration have been converted from oxide weight per cents to ion grams per cubic centimeter, standard cells, etcetera, but Tooker (1963) shows that, regardless of the conversion, the data show the same gross relationships. No large scale change in porosity has been observed in the sampled volcanic rocks. Tooker (1963) gives a review of pertinent literature on the subject of hydrothermal wallrock alteration.

Silicon

No major mobilization of silicon was detected in the Lake Dufault rocks but small scale additions or subtractions could have gone undetected because of insufficiently precise analyses. Lower amounts of silicon are found in fractured rhyolite beneath the massive ore body but the sulphide-filled fractures which cut the rock could easily be the result of the filling of open spaces rather than the replacement of silicate minerals. The presence of mosaics of unstrained, clear quartz suggests, however, that a breakdown of silicate structures has occurred in this fractured zone. The data suggest a possible addition of silicon to the base of the Amulet andesite.

Aluminum

No major mobilization of aluminum was detected but, as was the case with silicon, a small scale variation might be masked by analytical errors. Aluminum is mobile in strongly acid thermal waters commonly found at the surface in volcanic areas (Zelenov, 1965) and the degree to which aluminum has been leached gives an idea of the extent of acid alteration in the rock. It is possible that aluminum was removed slightly from the top of the Waite rhyolite. That extreme acid leaching conditions existed at a few places in the Noranda volcanic district is suggested by the occurrence of talc in the alteration zones of the Quemont Mine (Riddell, 1952) and the Horne Mine (Price, 1933). Aluminum is stable in areas of <u>subaerial</u> solfataric-hydrothermal alteration only as alunite, a mineral which has not been found in the Noranda area.

Sodium

Sodium practically has been eliminated from rhyolite in the altered zone under the massive sulphide ore body. The removal of sodium from the top of the rhyolite occurred only near the ore body. Sodium may have been removed from the alteration zone at the base of the andesite away from the known ore body. The loss of sodium from the Lake Dufault rocks follows the pattern of sodium loss in many other examples of wall rock alteration (Tooker, 1963) as well as the weathering of soils and rocks and accompanies the alteration of these materials to clay minerals. Sodium is one of the first elements to be leached from wall rock undergoing argillic alteration by acid solutions (Mukaiyama, 1959) and it is possible that at least the rhyolite below massive ore has been altered in this way.

Areas of present day <u>subaerial</u> hydrothermal activity have been described in the Kamchatka and Kurile Islands (Naboko, 1962; Zelenov, 1965), Japan (Mukaiyama, 1959), the Valley of the 10,000 Smokes (Lovering, 1957) and at Wairakei (Steiner, 1953). Surface rocks in these areas are characterized by the acid leaching of alkali metal and alkali earth elements, and, in some places iron, silicon, aluminum and titanium.

Ames et al (1958) describes the <u>subaqueous</u> alteration of a tuff in which the alkali metal and alkali-earth elements were not leached.

<u>Potassium</u>

Except for a possible addition to the top of the rhyolite near ore, potassium metasomatism does not seem to have occurred in the rhyolite even under the extreme conditions found in the altered and mineralized zone beneath the massive ore body. On the other hand, the base of the andesite near to and away from the ore body is characterized by sharp increases in potassium. Not all of the andesite which forms the ~~foot~~ hanging wall of massive ore has an unusually high content of potassium.

Potassium in rocks is concentrated mainly in potassic feldspars and micas which are much more stable in altered zones than sodic rock-forming minerals. However, even potassic feldspars break down under extreme alteration, releasing potassium to the traversing solutions. The fact that it was not removed from the altered and mineralized zone below the Lake Dufault massive ore body requires a special explanation. A very reasonable one is offered by Hemley (1964). The mobility of potassium is directly related to the stability of sericite. The stability of sericite is controlled largely by the K^+/H^+ activity ratio, and the relative activities of Ca^{++}, Na^+, and Mg^{++} as well as K^+ ions. If the activities of the Ca^{++}, Na^+, and Mg^{++} ions are high enough, the stability field of sericite may be displaced by that of a clay mineral or chlorite and K^+ may be leached from the rocks. If these suggestions are correct, the fact that a large amount of sodium is leached in the altered rocks (particularly beneath the massive ore) while potassium is fixed means that the activity of K^+ relative to H^+, Na^+, Ca^{++}, and Mg^{++} ions in solution was great enough to allow the formation of sericite.

Magnesium

Large amounts of magnesium have been added to the rhyolite beneath the massive sulphide ore body while smaller amounts may have been added to the top of the rhyolite near ore. The andesite shows no effect of magnesium metasomatism. The addition of magnesium in the altered zone beneath the ore body is marked by the development of chlorite, biotite, cordierite and anthophyllite. As suggested in a previous section, the assemblage cordierite-anthophyllite-biotite was probably produced by the thermal metamorphism of a pre-existing chlorite-sericite alteration zone. If the explanation offered for the distribution of sodium and potassium beneath the massive ore is correct, the presence of large amounts of magnesium presents a problem.

In recent years much theoretical and experimental work has been applied to the problem of the transportation and deposition of ore elements. Helgeson (1964) presents a good review of the various mechanisms which have been suggested to account for certain features common to many ore deposits. In spite of recent advances in the chemistry of hydrothermal solutions, no single mechanism has been suggested which would explain magnesium metasomatism as typified by the Lake Dufault deposit and others in the Noranda area. It is not known if a solution capable of leaching large amounts of sodium while

Table 10

FeO CONTENT OF WAITE RHYOLITE

	DDH	FeO(%)[1]	Fe_2O_3(%)[2]	$Fe_2O_3/(Fe_2O_3+FeO)$
top ↑	164	3.33	1.4	.298
		3.74	0.3	.075
		1.59	0.9	.360
		2.00	1.1	.355
top ↑	134	4.08	0.0	.00
		3.54	0.9	.205
		3.04	5.8	.659
		3.03	1.1	.268
top ↑	132	3.50	1.7	.327
		10.09	4.2	.294
		4.33	2.0	.316
		7.23	2.7	.273
top ↑	153	3.52	3.1	.470
		2.90	2.5	.463
		3.31	1.4	.290
		5.54	6.2	.30

1. Analyses by H. Soutar, Dept. Geol. Sciences, McGill University.

2. Calculated from total Fe as Fe_2O_3 by X-ray fluorescence.

Table 11

FeO CONTENT OF AMULET ANDESITE

	DDH	FeO(%)[1]	Fe_2O_3(%)[2]	$Fe_2O_3/(Fe_2O_3+FeO)$
base ↓	164	7.21	1.5	.172
		7.30	3.1	.298
		6.91	1.4	.169
base ↓	134	5.56	1.8	.243
		6.26	1.5	.192
		7.61	2.2	.224
		8.73	2.6	.230
base ↓	132	7.86	2.0	.202
		7.95	2.4	.231
base ↓	153	7.41	3.6	.327
		6.75	1.8	.209

1. Analyses by H. Soutar, Dept. Geol. Sciences, McGill University.

2. Calculated from total Fe as Fe_2O_3 by X-ray fluorescence.

favoring the development of sericite could also, at the same time, be introducing large amounts of magnesium into the wall rocks. At the present time the writer favors the idea that the rhyolite beneath the massive ore has undergone two stages of metasomatism, the first characterized by the leaching of sodium and the second characterized by the addition of magnesium.

Magnesium metasomatism, marked by the development of montmorillonite and/or chlorite, has been described from areas of recent hydrothermal activity (Steiner, 1953, Wairakei; Naboko, 1962, Kamchatka and Kurile Islands). This type of alteration, which occurs below zones of acid leaching, is generated by near neutral sodium-chloride hydrothermal solutions. According to Ames (1958) a magnesium-rich bentonite from California was formed by additions of magnesium from the water of an alkaline lake.

Calcium

The result of calcium metasomatism in the Waite rhyolite is too complicated to be outlined by the sampling scheme followed in this work. Calcium has been leached and, in adjacent areas, added to the rhyolite under the massive sulphide ore body (chart 11, Appendix B). Calcium may have been removed in some places at the bottom of the andesite.

Iron (total as Fe_2O_3)

Iron has been added in large amounts to fractured rhyolite beneath the massive sulphide ore body and most likely is present in chlorite, biotite, cordierite and anthophyllite as well as in sulphides. A small amount has been added to the base of the andesite. A few wet chemical analyses of FeO are presented in tables 10 and 11. These analyses suggest that Fe^{++} may be concentrated in places at the top of the rhyolite. Away from the altered zone below the massive ore body, iron in rhyolite is most likely present in pyrite, pyrrhotite, magnetite, and chlorite. The same is probably true of extra amounts of iron in the base of the andesite.

Manganese

Rhyolite below the massive sulphide ore body has received additional amounts of manganese. Manganese has also been added to the base of the andesite near to and away from ore. Garnets have been identified from the alteration zone beneath the ore body. Sphalerite, which often contains significant amounts of manganese, is distributed widely in the altered zone and close examination probably would result in the finding of manganese oxides or carbonates.

Titanium

Titanium was immobile in all alteration zones in the Lake Dufault rocks. Titanium is found mostly in refractory minerals such as ilmenite, sphene, rutile and leucoxene but it also replaces iron in magnetite, and silicon, aluminum, iron and magnesium in biotite and amphibole. Ultra-acid thermal waters in volcanic areas can leach titanium from rocks (Zelenov, 1965) and the fact that titanium, like aluminum, was immobile in the alteration zones of the Lake Dufault mine shows that the solutions causing alteration were not extremely acid.

Trace Elements

Because analyses of mineral separates were not attempted in this work, statements as to the mode of occurrence of trace elements (as well as major elements) in the Lake Dufault rocks are speculative and subject to test. For convenience, the trace elements are split into three groups: A. trace elements "added" to altered zones, B. trace elements "removed" from altered zones, and C. trace elements "removed" from one zone and "added" to others.

Group A: Trace elements "added" to altered zones (Cu, Zn, Pb, Ag, Sn, Cr, Zr, Y)

Of the group A elements only copper, zinc and lead are added consistently to all three alteration zones. Silver has been added to all zones except the top of the rhyolite away from the ore body. Of these four elements zinc is added most consistently and in the greatest amounts, copper less so, lead much less so and silver barely so. It is interesting to note that both the amount and consistency of metasomatism involving zinc, copper, lead and silver are proportional to their concentration in the Lake Dufault ore body. Fractured rhyolite under the ore body contains the largest concentrations of these elements whereas much smaller amounts are found at the top of the rhyolite and the bottom of the andesite. Sphalerite is the most important carrier of zinc in these altered zones. The zinc spinel, gahnite, has been reported in an alteration zone at the Amulet mine (Riddell, 1952). Sphalerite, chalcopyrite, pyrite and pyrrhotite are disseminated and in fractures in rhyolite beneath the massive ore body and at the base of the andesite. The writer wishes to emphasize the previously noted fact that, although the rhyolite is fractured in many places, sulphides are disseminated widely and finely and are present very rarely in veinlet form in rhyolite away from the altered and mineralized zone below massive ore. When breccias are noticeable in the rhyolite, sulphides can be seen to be confined to the breccia matrix. Quartz-carbonate-chlorite veinlets, essentially barren with respect to sulphides, are found often in rhyolite which contains relatively large amounts of finely disseminated sulphides.

Tin was added to the rhyolite and to the bottom of the andesite near the ore body but possibly was removed from the top of the rhyolite away from the ore.

Chromium is present in detectable amounts in the rhyolite mainly near the ore body and may have been added to the base of the andesite.

Zirconium may have been concentrated at the bottom of the andesite and the top of the rhyolite near to and away from the ore. As most zirconium in rocks is present in the refractory accessory mineral zircon, it is difficult to account for its apparent enrichment in these altered zones. Griffitts and Rader (1963) may have found a similar situation in Utah where beryllium and fluorine (as well as Fe, Mn, Zn, Pb, Sn and the rare earths) are concentrated in the top twenty five feet of a 150 foot thick tuff.

Yttrium may have been added to the base of the andesite and the top of the rhyolite.

<u>Group B: Trace elements "removed" from altered zones (Sr, Ga)</u>

Strontium was leached in places from all three alteration zones. Strontium is known to accompany calcium in minerals, especially feldspar and mica, and would be leached along with calcium during the alteration of these minerals.

Gallium has been removed from the top of the rhyolite near to and away from ore and from the base of the andesite near ore. Gallium ions may replace Al^{+++} in minerals having a mica structure as well as Fe^{+++} and Zn^{++} in magnetite and sphalerite. Tooker (1963) reports that gallium generally is leached from sericitized rock of the Front Range Mineral Belt, Colorado. Gallium becomes separated from aluminum during supergene alteration in both acid and alkaline environments (Borisenok, 1959).

Group C: Trace elements "added" to or "removed" from altered zones (Co, Ni)

Cobalt has been added to the rhyolite beneath the ore body. Both nickel and cobalt have been added to the top of the rhyolite and have been removed from the base of the andesite.

Cobalt and nickel can occur in hornblende and biotite as well as sulphides and their behavior in the alteration zones of the Lake Dufault mine probably is a reflection of this dual nature. Cobalt and nickel are removed readily from host minerals during alteration. It is probable that the same solutions which added potassium to the base of the andesite removed cobalt and nickel along with sodium, calcium, strontium and gallium. Originally containing very low amounts of cobalt and nickel, the top of the rhyolite probably received additions of these elements in the form of sulphides along with the sulphides of iron, zinc, copper, lead, and silver.

Summary and Conclusions

Stratigraphically below and adjoining the Lake Dufault massive sulphide ore body is a highly altered, fractured and mineralized zone that most certainly was the channel for the ore-forming solutions. The ore elements plus tin, lead, cobalt, iron, manganese and magnesium have been added in large amounts to this zone; sodium and possibly calcium and strontium have been removed and, significantly, aluminum, titanium and potassium were immobile. These chemical features place certain limits on the nature of the ore-forming solution.

The immobility of aluminum, titanium and potassium in the altered zone indicates that the ore-forming solutions were never extremely acid or alkaline. The leaching of sodium and the addition of magnesium is explained best by assuming two stages of hydrothermal activity or at least a separation of early acid and late, near neutral or alkaline, magnesium-rich solutions, possibly as suggested by Korzhinskii (1963) (the "acid-base filtration effect"). The separation of copper and zinc on both mine and district scales and the association of magnesium metasomatism only with copper mineralization strongly suggests that some mechanism of hydrothermal differentiation involved both ore and major elements and played a significant part in the formation of the sulphide ores in the Noranda area. The mineral assemblage now present in the highly altered channel is probably the result of the thermal metamorphism of a pre-existing chlorite and sericite alteration.

Strontium, gallium and, possibly, slight amounts of aluminum have been removed from the top of the rhyolite in places throughout the Norbec area. Sodium has been removed from the top of the rhyolite only near ore. Iron, magnesium, potassium, silicon and titanium have not been removed from the top of the rhyolite.

Studies of areas of subaerial hydrothermal activity show that surface rocks in these areas are characterized by the acid leaching of alkali metal and alkali earth elements, and, in some places, iron, silicon, aluminum and titanium. This may not be true of weakly acid, neutral, or alkaline, subaqueous environments. Sulphur-rich solutions passing into a water cover instead of the atmosphere would be less likely to leach the acid-soluble elements from the rocks because the restricted availability of oxygen would inhibit the production of acid sulphate ions.

The writer concludes that the aforementioned chemical features of the top of the Waite rhyolite, along with the presence of bedded, cherty tuff within and on top of the rhyolite and the presence of pillows at the base of the andesite, all suggest that the deposition of the Waite rhyolite and any solfataric-hydrothermal activity at its surface occurred under water. According to Mukaiyama (1959), accumulations of sulphur which form one of the major classes of recent Japanese sulphur deposits are formed in crater lakes or ponds. Sulphur sinks to the bottom of the lake to form a "sedimentary" deposit.

Zirconium and yttrium may be concentrated at the top of the rhyolite but neither the mode of occurrence of these elements nor the reason for their concentration is apparent.

Nickel, cobalt, copper, zinc and possibly lead, elements which are present in the Lake Dufault ore body, have been added to the top of the rhyolite in many places throughout the Norbec area. The greatest amounts of these elements, in addition to certain amounts of iron, manganese, magnesium, silver and tin, occur close to the Lake Dufault ore body.

It has been emphasized in previous sections that, excepting the highly mineralized zone below the massive sulphide ore body, sulphides are present in the Waite rhyolite as fine disseminations in the matrix of pyroclastic breccias and very rarely are found in fractures. Sulphide minerals which have been identified in the rhyolite are pyrite, pyrrhotite, sphalerite and chalcopyrite.

The writer concludes that the elements which have been added to the top of the rhyolite either are present in or are associated closely with sulphides which are genetically related to sulphide ore and which were introduced before fractures were developed in the rhyolite, possibly before the complete lithification of water-saturated pyroclastic breccias.

The Amulet andesite is altered at its base but this alteration neither is confined to nor always present in the area where andesite forms the hanging wall of massive ore. The alteration is characterized by the formation of sericite, the addition of potassium and the removal of cobalt, nickel and, possibly, strontium, calcium and sodium. Sericite alteration is developed on a smaller scale well within the andesite. The presence of a "Dalmatianite pipe" in andesite between the "Upper A" and "Lower A" ore bodies of the Amulet mine shows that the andesite is susceptible to magnesium metasomatism.

The lack of added magnesium in altered andesite which is in contact with massive ore and the complete absence of altered andesite in places directly over massive ore leads the writer to conclude that it is possible that the massive sulphide ore body was formed prior to the formation of the overlying andesite.

Minor amounts of silver, copper, lead and zinc have been added to the base of the andesite over the massive sulphide ore body and in some places away from ore. This feature of the andesite does not conflict with the writer's interpretation, as a certain amount of contamination of andesite lava would be expected where it came into contact with concentrations of sulphides.

Bedded, cherty tuff contains higher amounts of zinc, cadmium, and lead near the massive ore body. The writer suggests that the tuff was deposited in the later stages of mineralization, possibly at the same time as layered pyrite-pyrrhotite-sphalerite was being formed at the top of the massive sulphides.

In summary, the writer feels that the distribution of the chemical elements in the host rocks of the Lake Dufault mine can be explained most satisfactorily on the basis of the following assumptions. Sulphur-rich hydrothermal solutions ascended through a local channel in the Waite rhyolite and into a water cover whereupon sulphur and other elements associated with ore were deposited. The character of the solutions changed from an early acid stage to a later magnesium-rich, near neutral or alkaline stage. In any case, the solutions were never extremely acid or alkaline. Certain amounts of the elements were dispersed in the water cover and deposited in the water-saturated top of unconsolidated pyroclastic breccia. Cherty, bedded tuff was formed at the later stages of hydrothermal activity along with layered ore at the top of massive sulphides. Andesite lava passed into the water cover and onto the massive sulphide body. Where andesite lava came into contact with sulphides the base of the flow was contaminated with the ore elements. A later alteration of the andesite is not directly related to the presence of ore.

ORE DEPOSITS SIMILAR TO THOSE OF THE NORANDA AREA

Many ore deposits other than those of the Noranda district have been described as having "strata-bound," tabular, zoned ore bodies associated with pyroclastic rock and magnesium metasomatism. Of these, ore bodies of the Mattagami, Buchans, North Coldstream, Shasta and Jerome areas have been noted as occurring with potassium-poor siliceous rock.

Most Japanese copper-pyrite deposits, including the "Kuroko type," are closely related to Mesozoic and Cenozoic pyroclastic rock ("greentuff," "green rock") and are very similar to the Noranda deposits (Hayashi, 1961, 1962a, 1962b; Hashimoto et al, 1962; Ishikawa, 1960).

"Noranda-style" ore deposits occurring in metamorphic terrains are associated with spotted rocks containing biotite, cordierite and anthophyllite. This association has been reported in Paleozoic rocks in Japan (Hitachi mine, Kuroda, 1961), in Precambrian "leptite" rocks in Scandinavia (Skelefte and Orijarvi districts, Geizer, 1962, 1963; Gavelin, 1939; Eskola, 1963) and in Precambrian, high grade metamorphic rocks in Canada (Coronation mine, Froese and Whitmore, 1964).

GEOCHEMICAL PROSPECTING APPLICATIONS

A systematic geochemical survey of the Lake Dufault mine area would aid in the search for new, blind ore bodies. Elements which occur in large amounts in the massive sulphide ore body are present in higher than normal amounts in the wall rocks next to ore. It is difficult to judge from this work the exact shape or extent of this anomalous zone but figure 35 suggests that it extends at least five hundred feet laterally away from ore in rhyolite. Perusal of the data charts (Appendix B) shows that anomalous values for "ore-trace" elements can be present at least fifty or seventy-five feet into the andesite above massive ore.

This project serves to emphasize an important point regarding the use of dispersion patterns around ore bodies as prospecting aids; that is, there must be a strong geological control over sampling and interpretation of results.

SUMMARY

In the last decade, and particularly in the last few years, some geologists have come to regard certain features of the Noranda massive sulphide deposits as indicative of a close time-space relationship between the massive ore bodies and their host rocks. These features are:

1. Most massive sulphide bodies are located at the top of a siliceous pyroclastic unit, often where the pyroclastic rock is unusually thick;

2. The ore bodies are tabular and their largest dimensions are essentially parallel to the nearest stratification or flow contact;

3. A large scale stratigraphic zoning is present in many deposits regardless of their present attitude;

4. Sulphide fragments with contrasting mineral compositions are found side by side in agglomerate; and

5. Some deposits exhibit alteration zones containing large amounts of iron and magnesium stratigraphically below but not above massive sulphide ore bodies.

"Dalmatianite" alteration, found near the Lake Dufault, Waite and Amulet ore bodies, is suggested to be the result of the thermal metamorphism of pre-existing chlorite-sericite alteration, the source of heat being the nearby Lake Dufault granodiorite stock.

The Lake Dufault ore deposit is typical of the massive sulphide deposits in the Noranda area.

Variation diagrams and various indices obtained from published chemical analyses of the igneous rocks in the Noranda area show that essentially all of the units sampled belong to one, calc-alkalic, volcanic suite derived from a common parent magma by extreme fractional crystallization. Basaltic rock from the Noranda area contains less sodium and titanium than the average spilite.

The most significant chemical characteristic in the Noranda volcanic rocks is a deficiency of potassium. This deficiency is most apparent in the Waite rhyolite. Young volcanic rock suites having the same characteristic have been reported almost exclusively in the Circum-Pacific region, most notably on the ocean side of island arcs. Some similarity in trace element composition, particularly in the case of lead, has been noted between these low potassium rocks and the Waite rhyolite and Amulet andesite. In volcanic areas at the edges of continents a parental tholeiitic magma could differentiate by fractional crystallization with a minimum of contamination with material from the sial and yet with a sufficient quantity of water to allow the differentiation process to produce extremely siliceous rock. Accumulation of volatile substances during such a differentiation process would result in much explosive volcanic and hydrothermal activity. It is suggested that the Noranda massive sulphide deposits were formed in an environment similar to that of the relatively young sulphur and sulphide deposits of the Circum-Pacific volcanic islands.

Unusually low amounts of cobalt, chromium and nickel in the Waite rhyolite compared with the average felsic rock may be explained by the tendency of these elements to become depleted in residual melts produced by fractional crystallization. Unusually high amounts of silver, copper and zinc have been added to the Waite rhyolite and Amulet andesite.

A highly altered zone below the massive sulphide ore body marks the channel of the ore-forming solutions. The ore elements plus tin, lead, cobalt, iron, manganese and magnesium have been added to rhyolite in this zone; sodium and possibly calcium have been removed and aluminum, titanium, potassium and possibly silicon were stable. The chemical features of this zone are explained best by assuming two stages of hydrothermal activity or at least a separation of early acid and late, near neutral or alkaline, magnesium rich solutions. The solutions were neither extremely acid nor extremely alkaline. The original alteration minerals were probably chlorite and sericite, the present mineral assemblage being the result of a later thermal metamorphism.

Strontium, gallium and, possibly, slight amounts of aluminum have been removed from the top of the rhyolite in places throughout the Norbec area. Sodium has been removed from the top of the rhyolite only near ore. Iron, magnesium, potassium, silicon and titanium have not been removed from the top of the rhyolite. Nickel, cobalt, copper, zinc and possibly lead, elements which are present in the Lake Dufault ore body, have been added to the top of the rhyolite in many places throughout the Norbec area. The greatest amounts of these elements, in addition to certain amounts of iron, manganese, magnesium, silver and tin, occur close to the Lake Dufault ore body.

The Amulet andesite is altered at its base but this alteration neither is confined to nor always present in the area where andesite forms the hanging wall of massive ore. The alteration is characterized by the formation of sericite, the addition of potassium and the removal of cobalt, nickel and, possibly, strontium, calcium and sodium. Minor amounts of silver, copper, lead and zinc have been added to the base of the andesite over the massive sulphide ore body and in some places away from ore.

Bedded, cherty tuff contains higher amounts of zinc, cadmium and lead near the massive ore body.

After consideration of the geological features of the Noranda district and the Lake Dufault mine area, the writer feels that the distribution of chemical elements in the host rocks of the Lake Dufault mine can be explained most satisfactorily on the basis of the following assumptions. Sulphur-rich hydrothermal solutions ascended through a local channel in the Waite rhyolite and into a water cover whereupon sulphur and other elements associated with ore were deposited. Certain amounts of the elements were dispersed in the water cover and deposited in the water-saturated top of unconsolidated rhyolite breccia. In the later stages of hydrothermal activity, the formation of cherty, bedded tuff in many places at the top of the rhyolite was accompanied by the formation of layered ore at the top of massive sulphides. Andesite lava passed into the water cover and onto the massive sulphide body. Where andesite lava came into contact with sulphides, the base of the flow was contaminated with the ore elements. A later alteration of the andesite is not directly related to the presence of ore.

The presence of certain elements in higher amounts at the top of the rhyolite and to a lesser extent at the base of the andesite near the Lake Dufault ore body suggests that a systematic geochemical survey of the Lake Dufault mine area would be useful in the search for new, blind ore bodies.

CLAIM OF ORIGINAL WORK AND CONTRIBUTION TO KNOWLEDGE

The candidate claims that the following is original work:

1. The synthesis of published chemical analyses and geological facts regarding the Noranda area;

2. The examination and sampling of thousands of feet of diamond drill core from the property of Lake Dufault mines, examination of surface and underground exposures, and the study of polished sections and thin sections of samples selected from the Lake Dufault mine area;

3. The basic design of the sampling procedure and methods of presentation of results; and

4. The performance of all unpublished chemical analyses.

The candidate claims that this work has resulted in the following contributions to knowledge:

1. "Dalmatianite" alteration zones in the Noranda area are the products of the thermal metamorphism of pre-existing chlorite-sericite alteration zones;

2. The rocks of the Noranda area belong to a single volcanic suite which is similar to younger, distinctive suites of potassium-poor volcanic rock which have been found only at the edges of continents and in island arcs; and

3. Elements in the host rocks of the Lake Dufault mine are distributed in a manner which, to the best of the candidate's knowledge, has never been previously described and interpreted and which can be explained most satisfactorily by assuming that the host rocks and ore are contemporaneous products of Precambrian volcanic activity.

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The writer is grateful to W. C. Martin for suggesting this study.

Collecting samples for chemical analysis was accomplished with the help of D. Ouimet and his assistants. The first chemical analyses were produced in the spring of 1963 with the help of R. Beckett and R. Webster. Because of financial support from Falconbridge Nickel Mines Limited and Lake Dufault Mines Limited, the writer was able to spend the summer of 1963 at McGill University, where, assisted by D. Pilbeam and with the advice of J. Jellema, the bulk of the major element analyses and some trace element analyses were completed. By February, 1964, the first report to the companies showed that major element analyses alone would not be useful in finding new ore. As a result of this finding, the companies consented to having the remainder of funds spent on a detailed study of the trace element content in the host rocks of the new discovery in the Norbec section of the property. During the winter of 1963-1964, T. Frizzell and H. Wiggett prepared samples for trace element analyses.

The writer spent the summer of 1964 in the employ of Dr. W. G. Robinson and J. Boldy of the Noranda office of Falconbridge Nickel Mines Limited and gained, through association with these men, much valuable experience in the Noranda area.

During the winter of 1964-1965, R. Bogoch and Mrs. H. Sakrison prepared the bulk of the Norbec samples for trace element analysis.

With more assistance from the two companies and with the help of Mrs. W. Beaton and Miss N. Gill, the writer was able to finish analytical work and begin a compilation of results during the summer of 1965. By the end of August, 1965, about 450 samples were analysed for each of twenty four elements.

Financial aid in the form of the J. Williamson Memorial and the David Stewart Memorial Fellowships was received by the writer during the course of his studies at McGill University.

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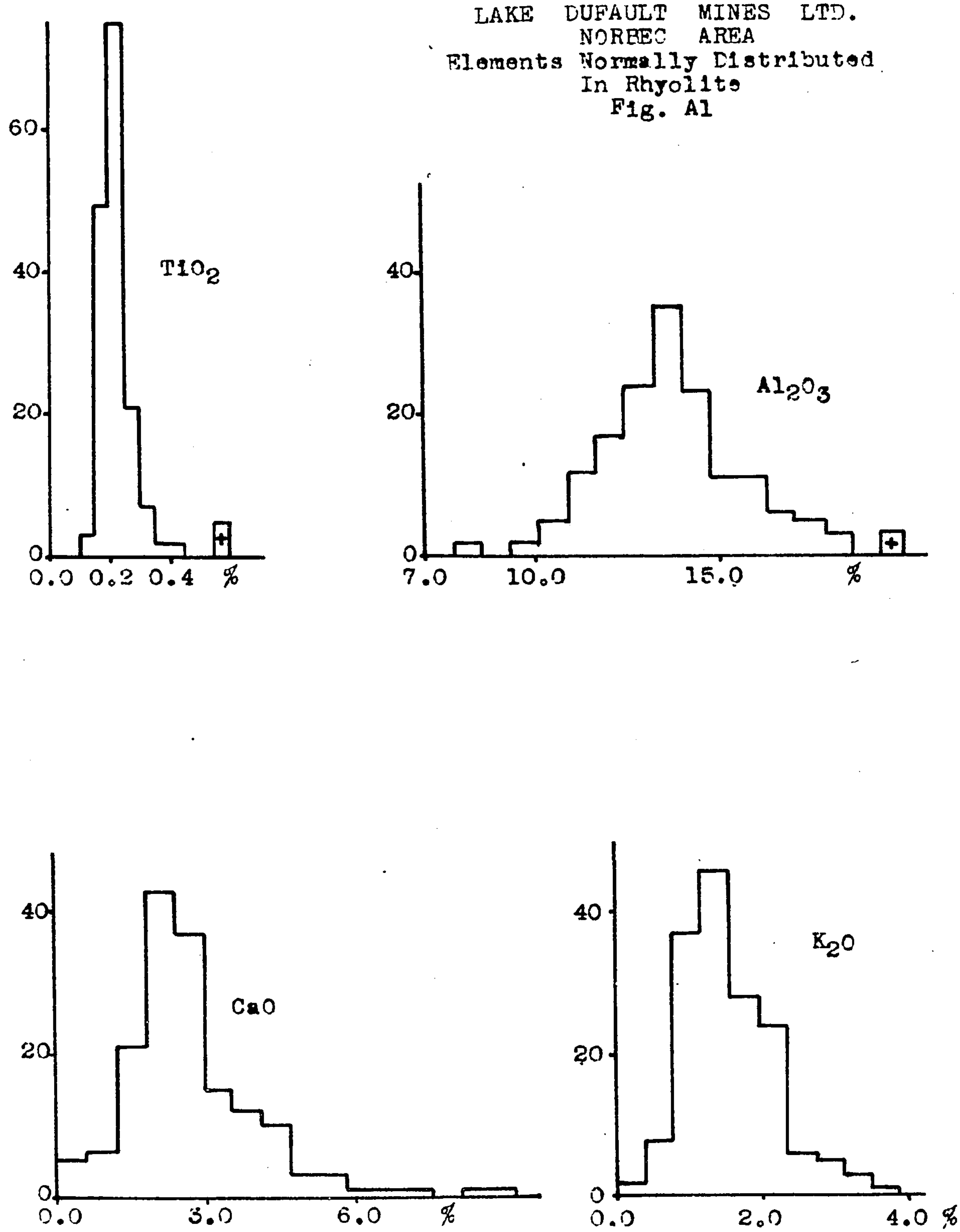
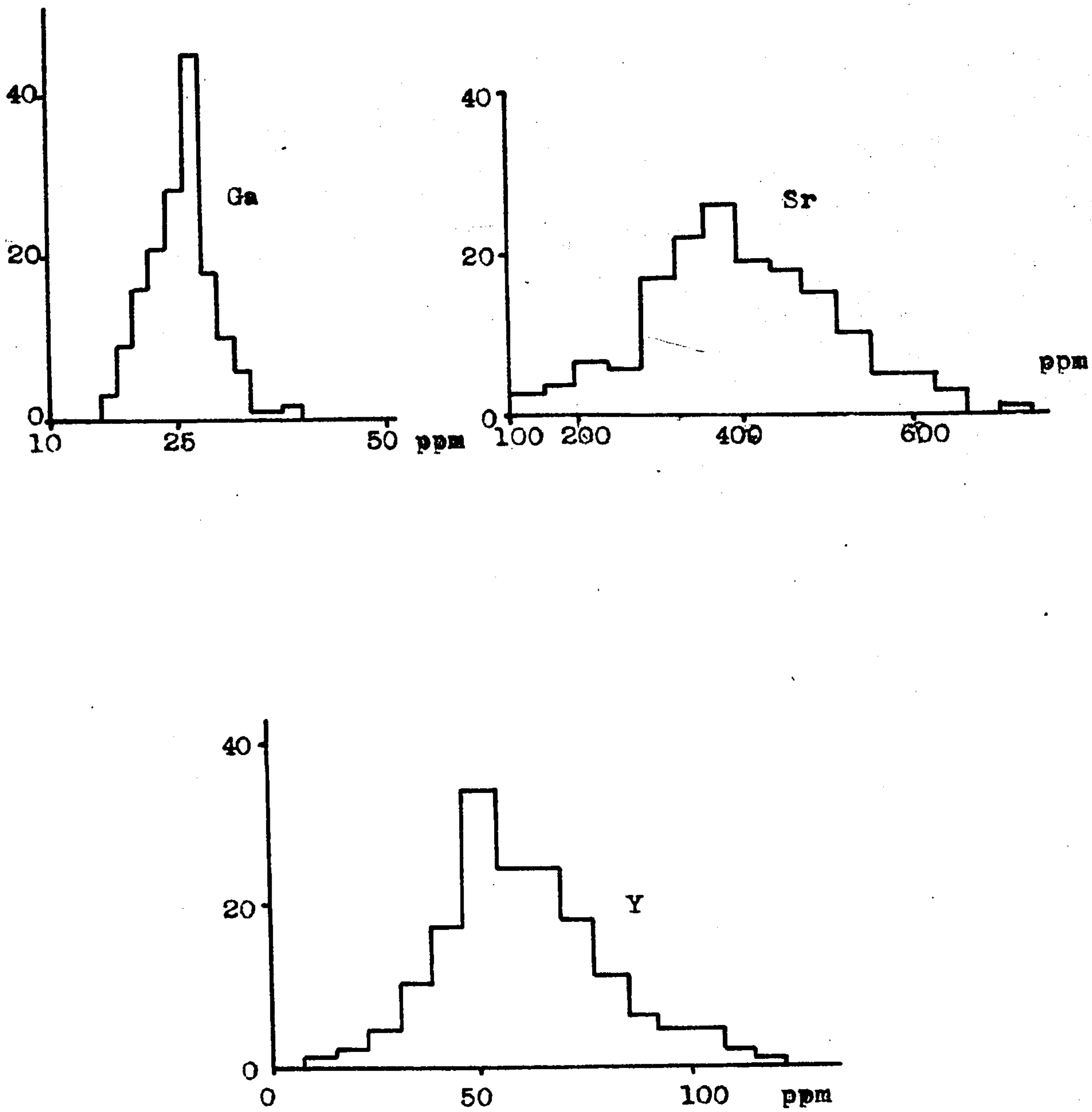
APPENDIX A

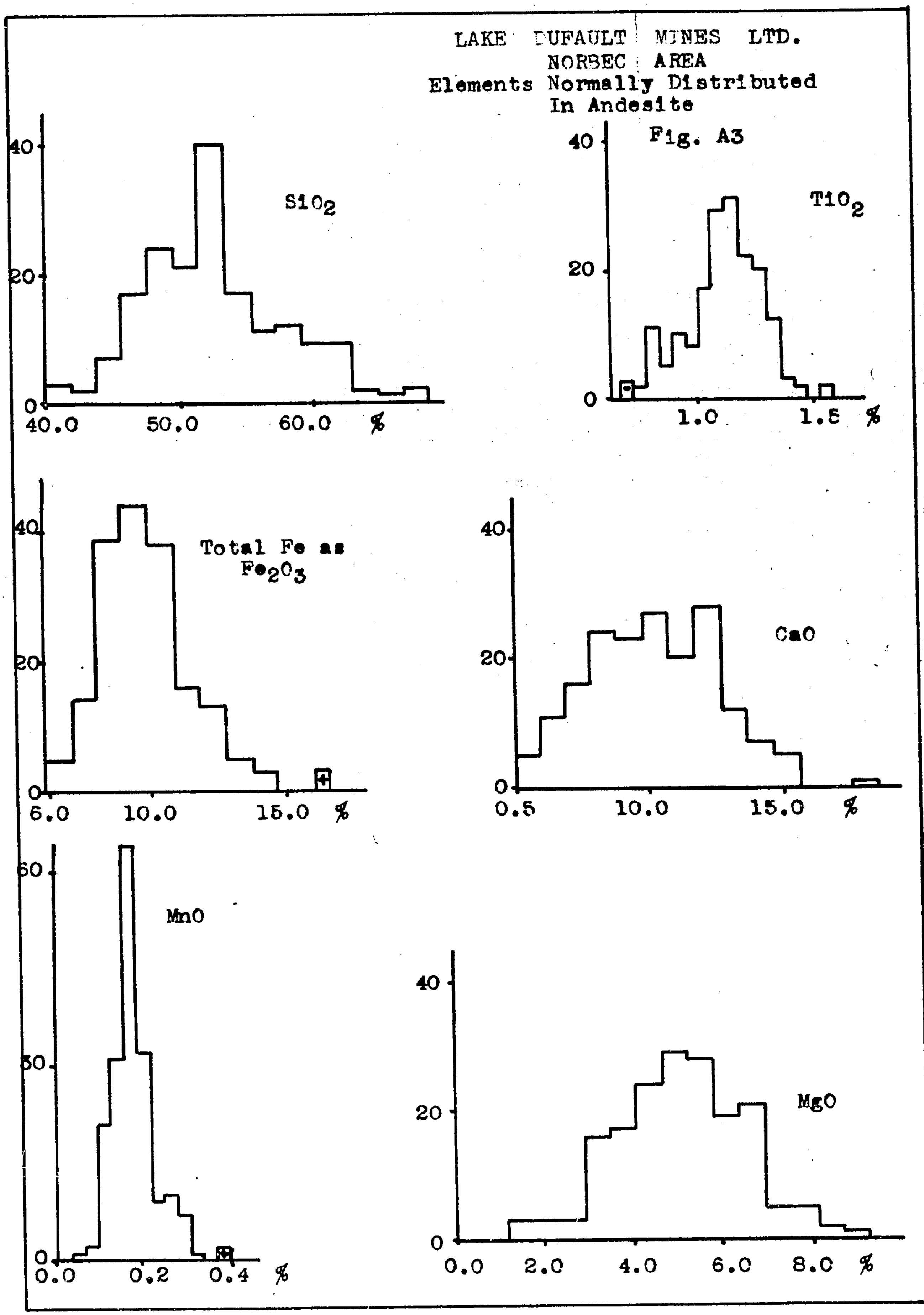
Frequency Distribution Diagrams of the Elements in Rhyolite and Andesite

LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements Normally Distributed
In Rhyolite
Fig. A1

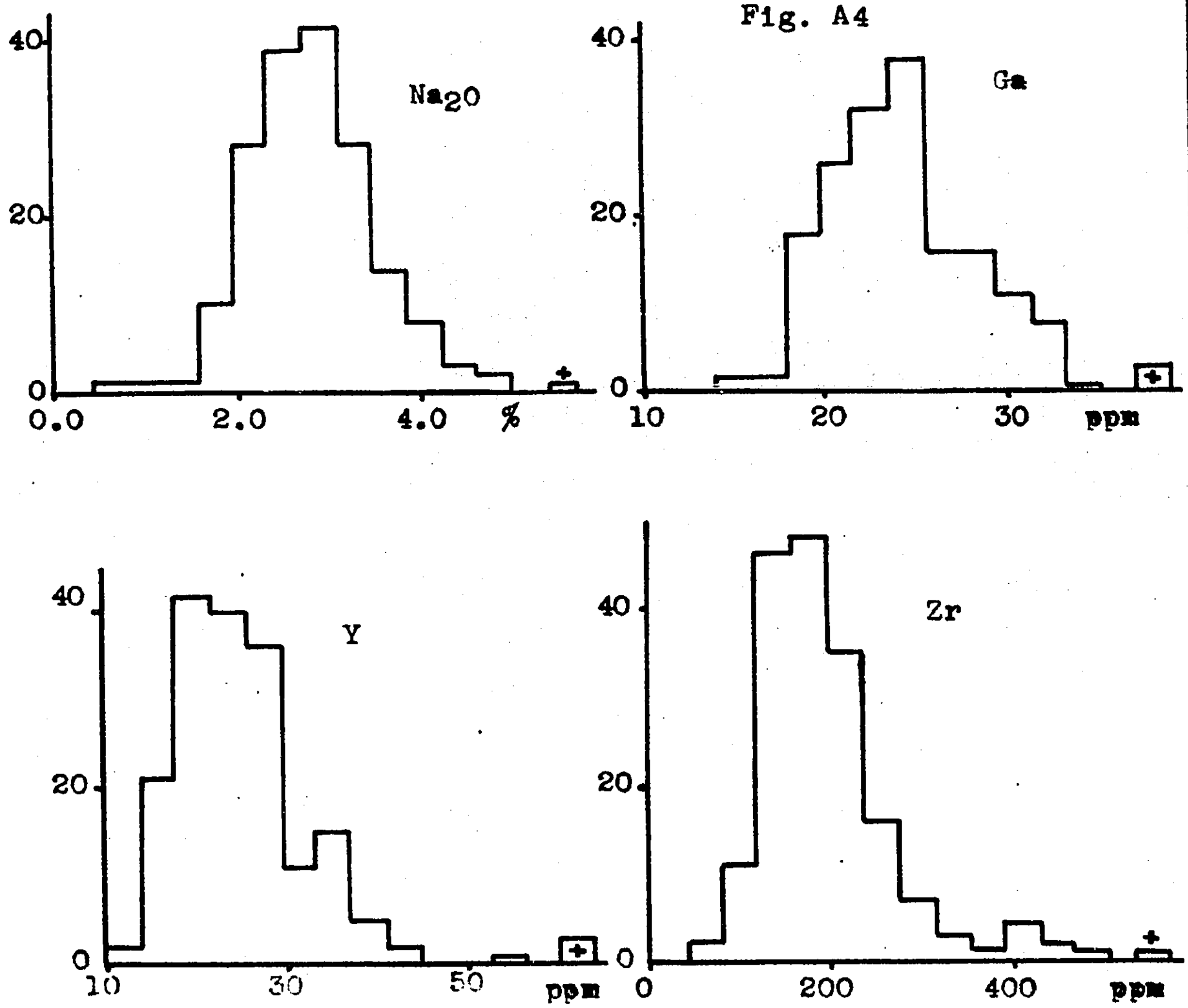


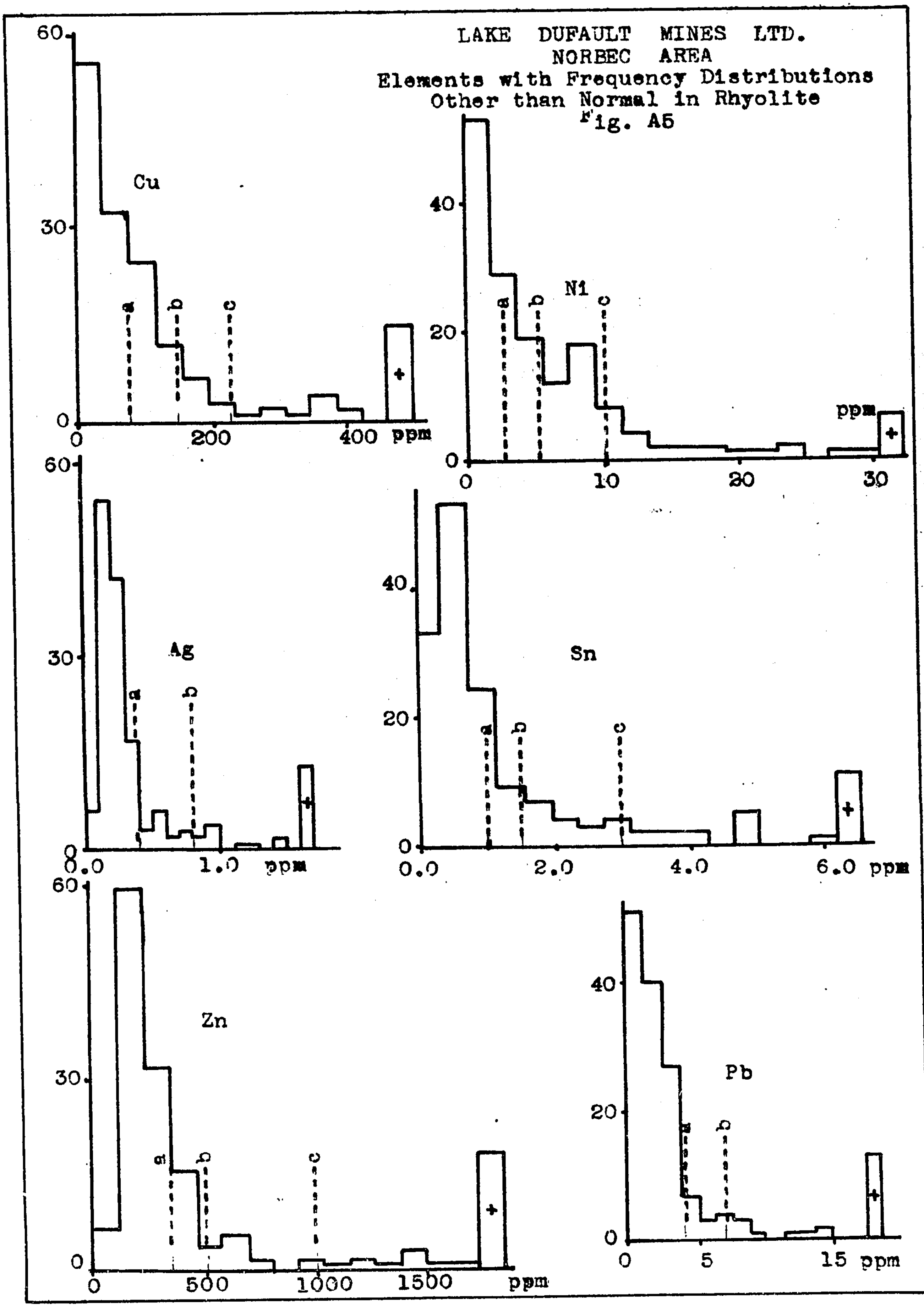
LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements Normally Distributed
In Rhyolite
Fig. A2



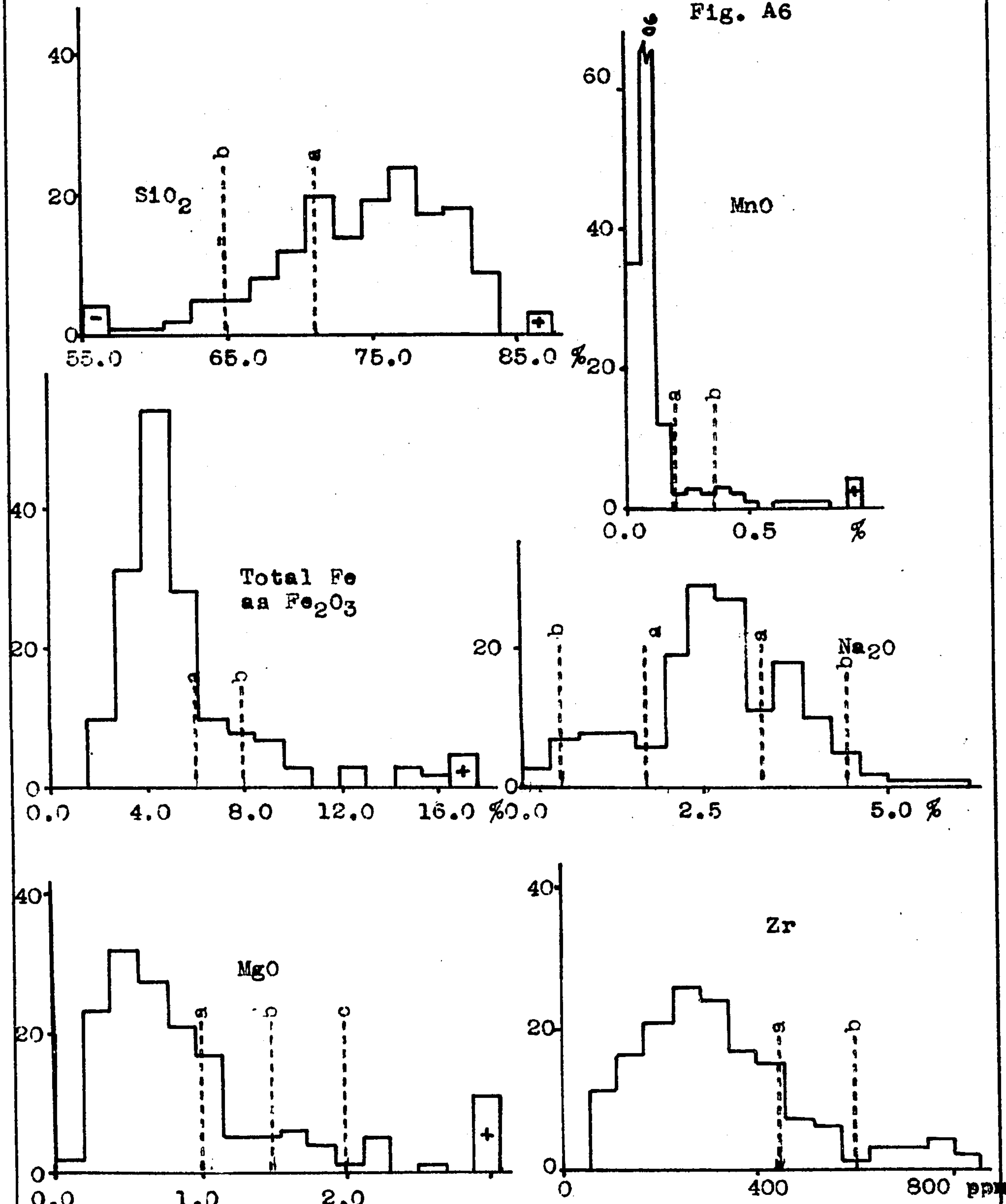

LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements Normally Distributed
In Andesite
Fig. A3
SiO2
40
20
0
40.0
50.0
60.0
%
TiO2
40
20
0
1.0
1.5
%
Total Fe as Fe2O3
40
20
0
6.0
10.0
15.0
%
CaO
40
20
0
0.5
10.0
15.0
%
MnO
60
30
0
0.0
0.2
0.4
%
MgO
40
20
0
0.0
2.0
4.0
6.0
8.0
%

LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements Normally Distributed
In Andesite
Fig. A4

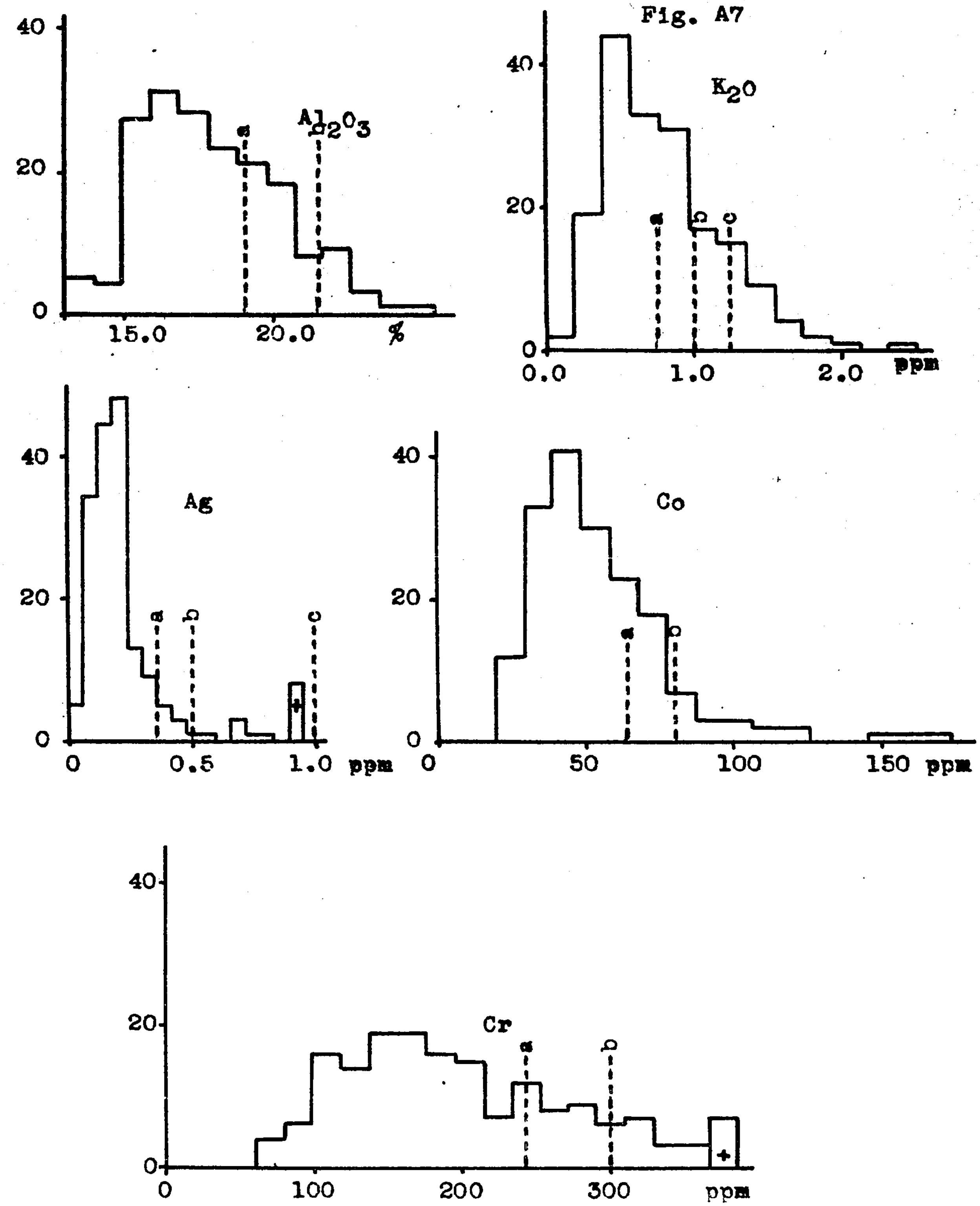



LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements with Frequency Distributions
Other than Normal in Rhyolite
Fig. A5
Cu
Ni
Ag
Sn
Zn
Pb
a
b
c
ppm
60
30
0
200
400
40
20
10
30
0.0
1.0
2.0
4.0
6.0
500
1000
1500
5
15

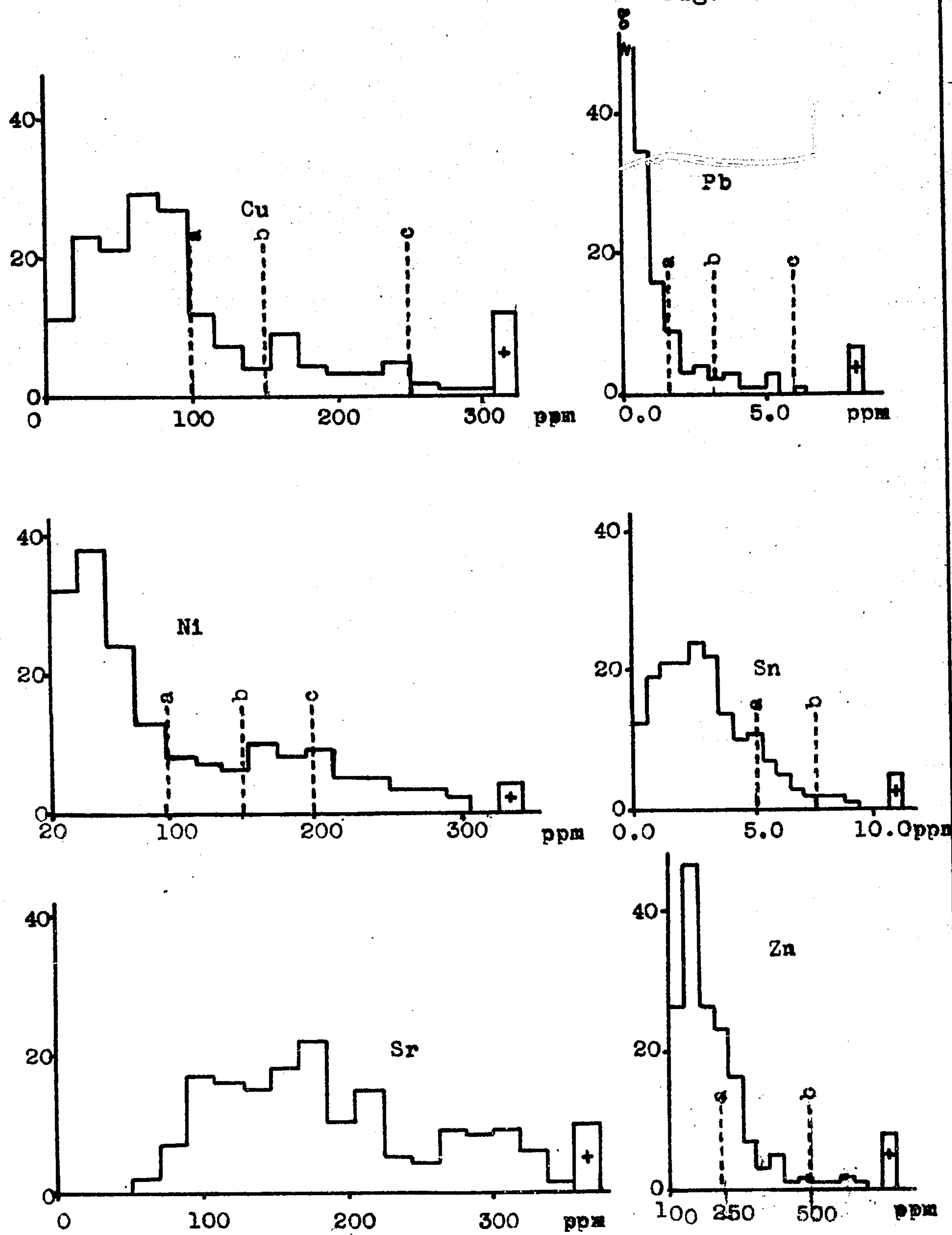
LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements with Frequency Distributions Other than Normal in Rhyolite
Fig. A6



LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements with Frequency Distributions
Other than Normal in Andesite
Fig. A7



LAKE DUFAULT MINES LTD.
NORBEC AREA
Elements with Frequency Distributions
Other than Normal in Andesite
Fig. A8



APPENDIX B

Data Charts of the Elements in Rhyolite and Andesite

Abbreviations Used in Presentation of Results

*$\bar{\bar{x}}$ - grand mean

Mo - mode (most common value)

*$\bar{\sigma}$ - sample standard deviation (weighted average of σ)

FD - type of frequency distribution

a,b,c - limits of anomalous ranges

*ULB - upper background limits (for normal distribution only)

LLB - lower background limits (for normal distribution only)

C_A - relative deviation of replicate analyses

R - C_A/C* total

r - # samples 0 - 50% / # samples 50 - 100% (for tuff samples)

*All samples close to the ore body removed from calculations

Silicon (oxide) (SiO_2) Rhyolite chart 1

$\bar{\bar{x}}$	75.5%
Mo	77.0%
$\bar{\sigma}$	4.1%
FD	Type II (except negatively skewed)
a	71.0%
b	65.0%
C_A	5.0% of $\bar{\bar{x}}$
R	.92

Most of the variation of SiO_2 in rhyolite can be attributed to analytical error, yet two anomalous conditions can be discerned. SiO_2 content is quite naturally low where the rhyolite is mineralized near the ore body. Several drill holes slightly low in SiO_2 are grouped together in the northwest corner of the property. The grouping of these low values is the best evidence that the low SiO_2 values are anomalous.

SiO_2 Andesite chart 2

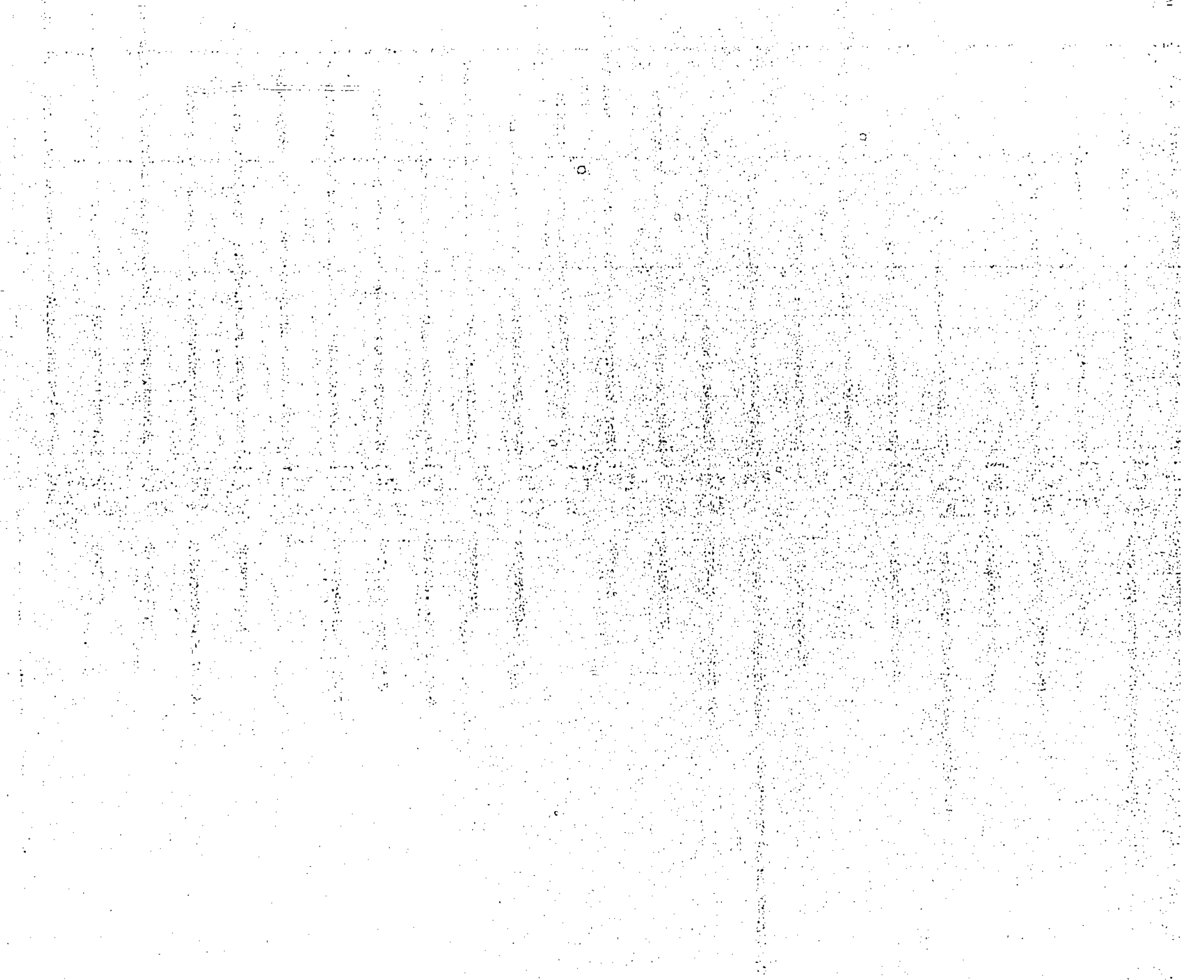
$\bar{\bar{x}}$	52.4%
Mo	52.5%
$\bar{\sigma}$	4.2%
FD	Type I
*ULB	52.4 + 6.4%
LLB	52.4 - 6.4%
C_A	8.6% of $\bar{\bar{x}}$
R	1.06

Diamond drill hole 125 is anomalous because rhyolite was mistakenly logged as andesite. Samples from diamond drill holes 174, 181, 190, 199 and 204 were the only ones which were analysed in one group at one time. Because of this it is highly probable that the high values for SiO_2 in these holes are due to analytical error.

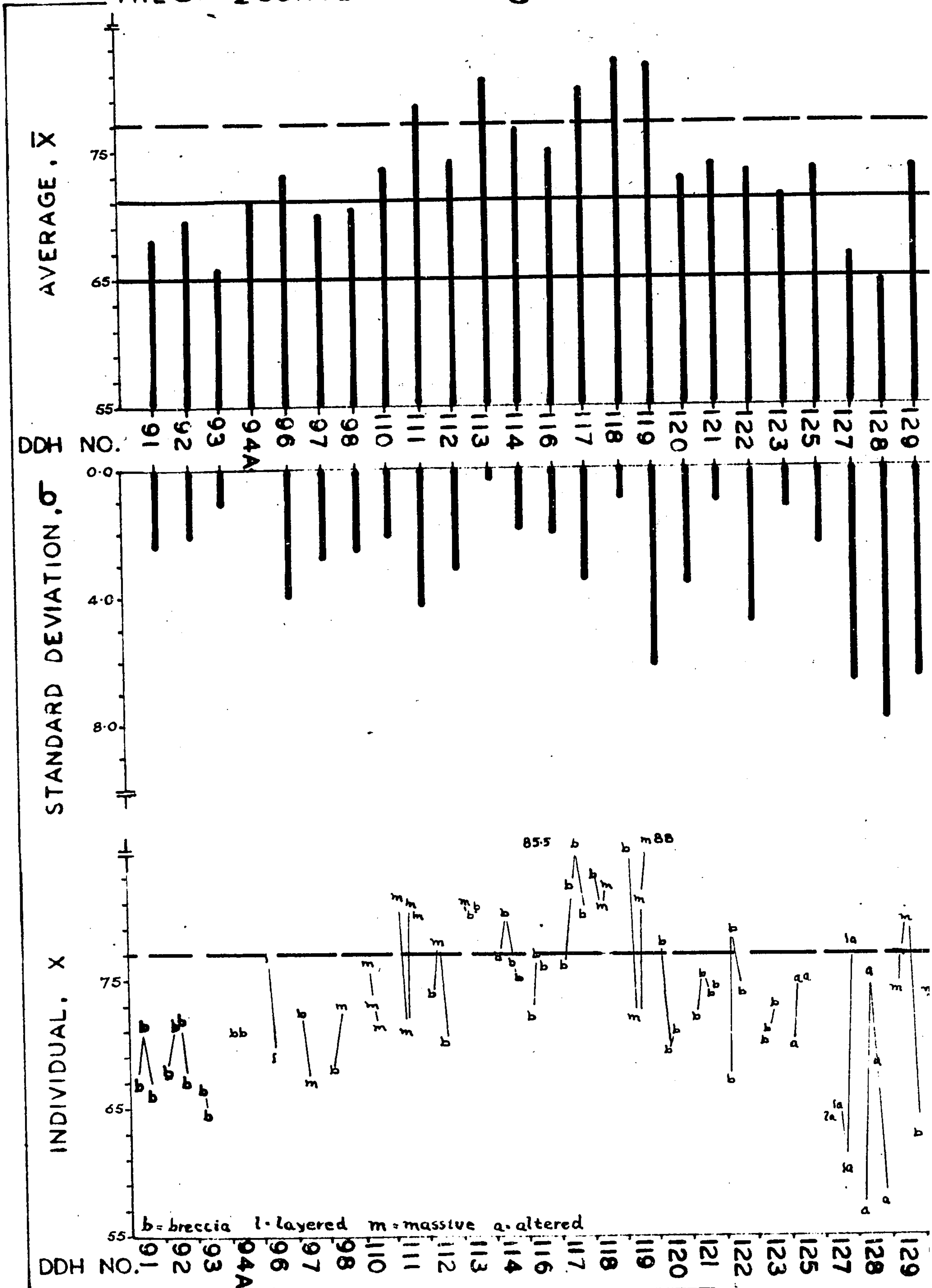
*Background limits vary slightly as a function of N, the number of samples. All values given are for N = 4; see the data charts for effect of changing N.

Chart 1

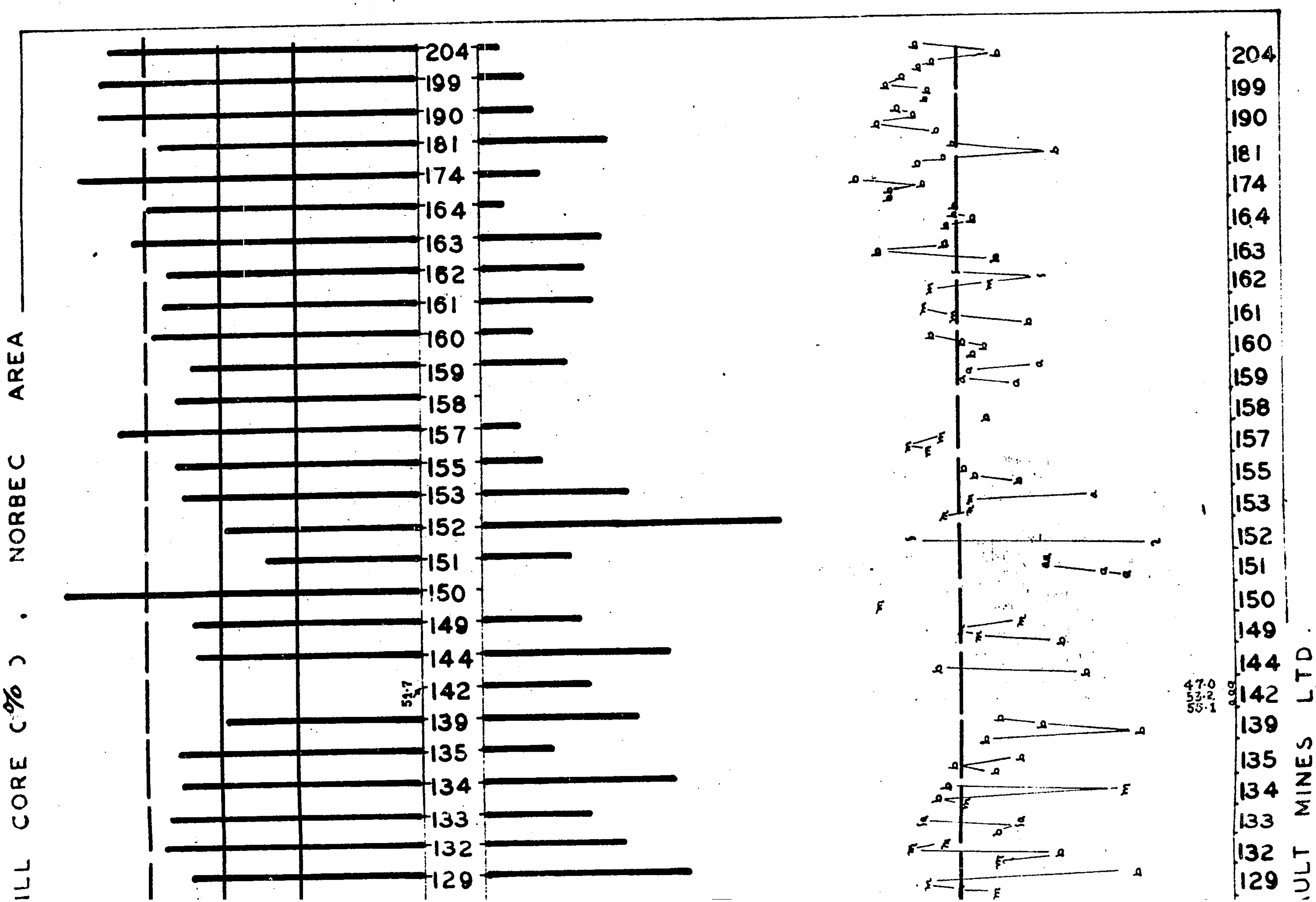
SiO_2 rhyolite



THE SiO_2 CONTENT OF *Rhyolite* IN DIAMOND DRILL



LAKE DUFAUL

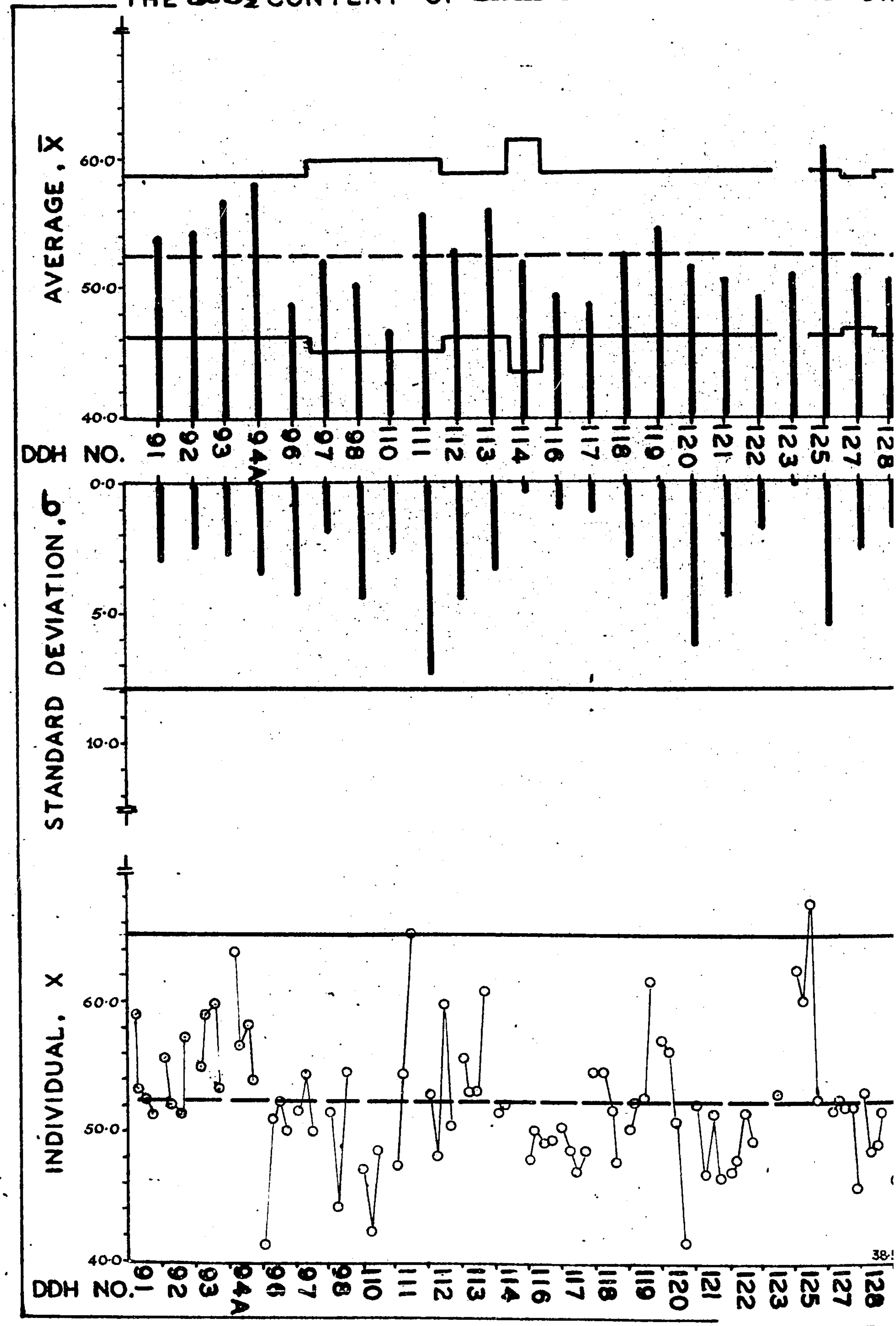


ILL CORE (%)
NORBEC AREA
ULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
53.7
47.0
53.2
55.1

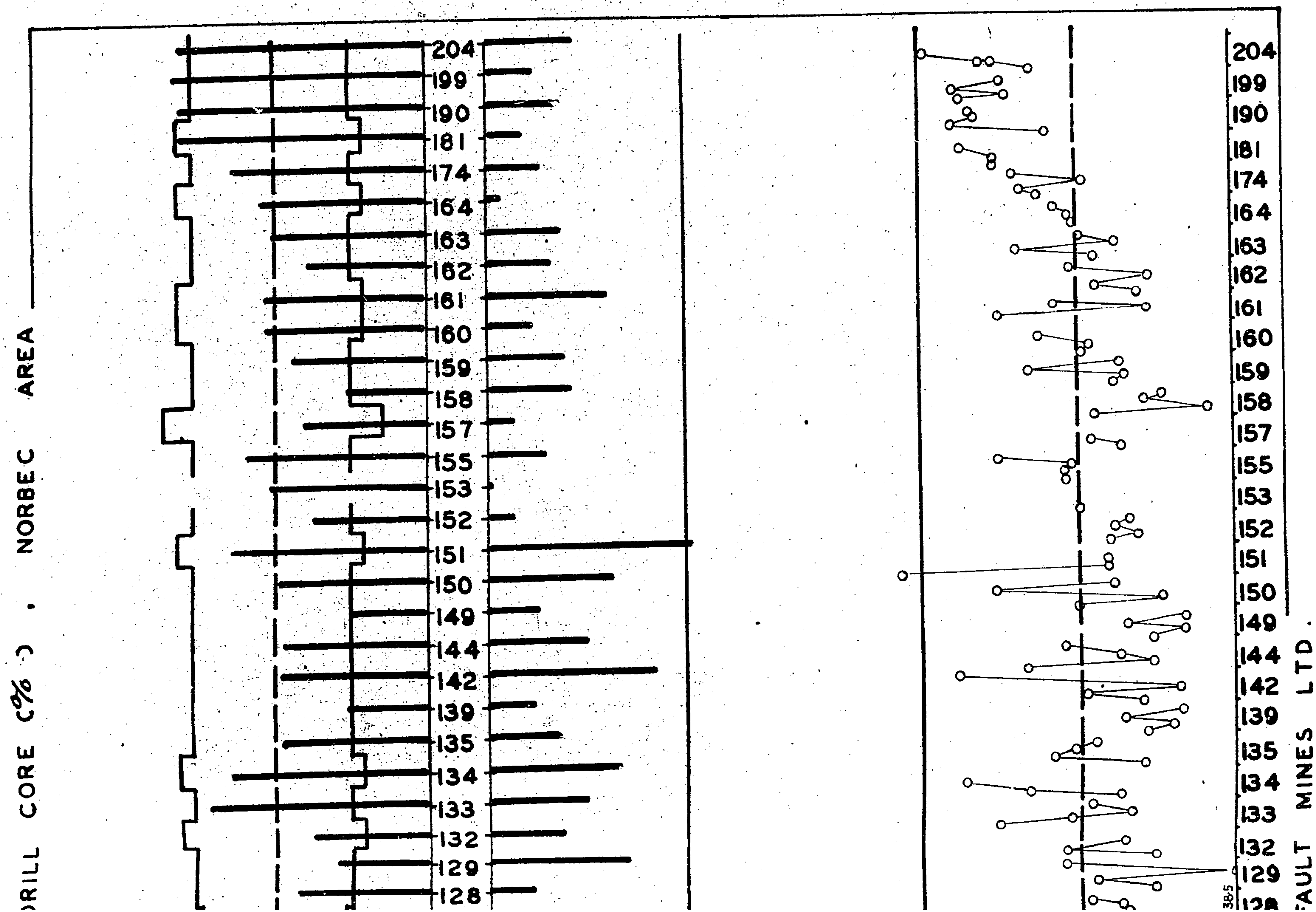
Chart 2

SiO_2 andesite

THE SiO_2 CONTENT OF *Andesite* IN DIAMOND DR



LAKE DUFA



DRILL CORE (%) . NORBEC AREA
FAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
38.5

Titanium (oxide) (TiO_2) Rhyolite chart 3

$\bar{\bar{x}}$	0.323%
Mo	0.23%
$\bar{\sigma}$	0.1%
FD	Type I
ULB	0.32 + 0.16%
LLB	0.32 - 0.16%
C_A	9.1% of $\bar{\bar{x}}$
R	0.48

Samples from hole 125 have an extra high TiO_2 content because they are actually andesite. Other anomalous samples were taken from holes 134, 139 and 153 near the ore body. Hole 96 in the Northwest Norbec section cut rhyolite with a high content of TiO_2.

TiO_2 Andesite chart 4

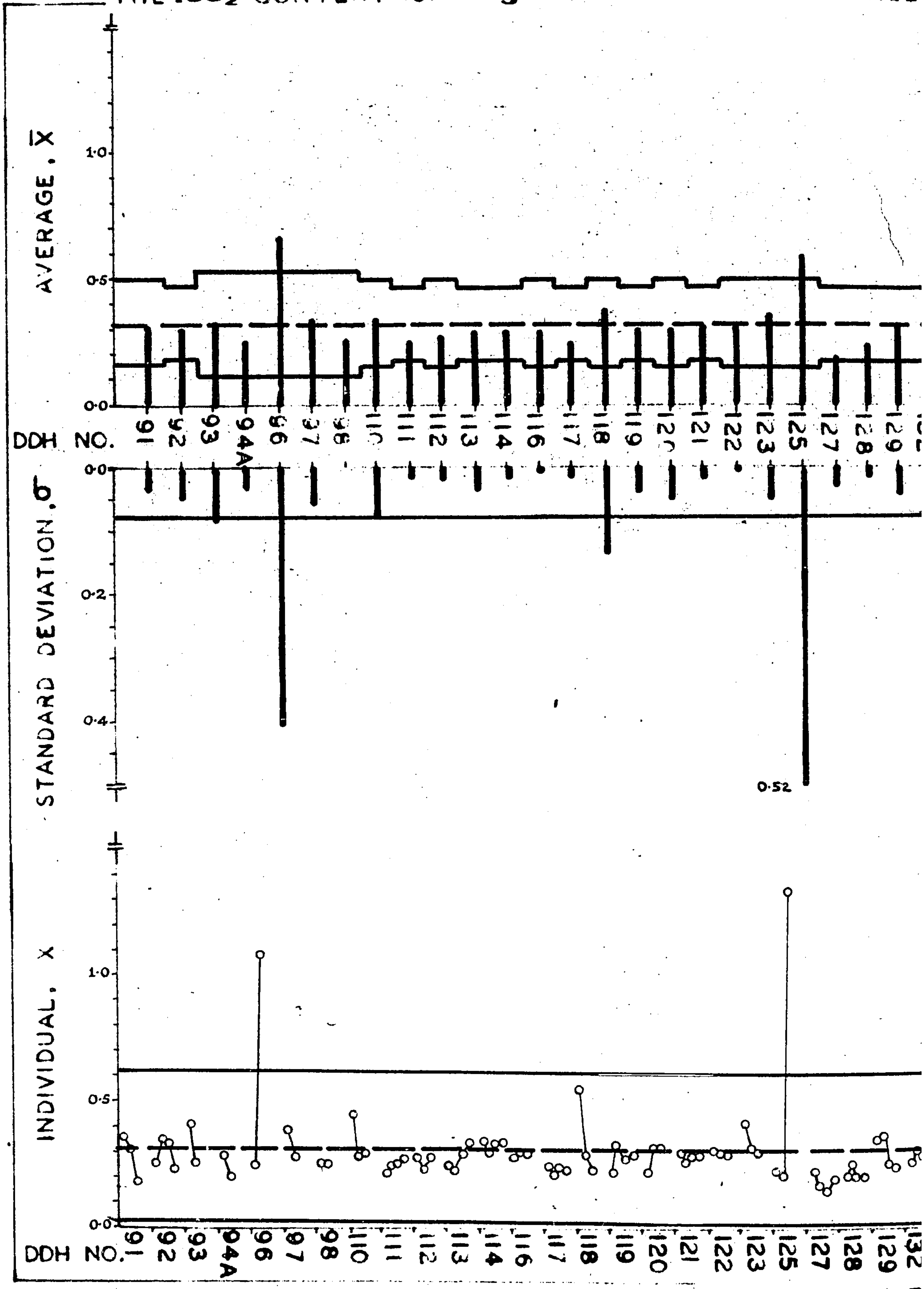
$\bar{\bar{x}}$	1.20%
Mo	1.11%
$\bar{\sigma}$	.159%
FD	Type I
ULB	1.20 + .24%
LLB	1.20 - .24%
C_A	5.9% of $\bar{\bar{x}}$
R	.45

Sections of andesite cut by four holes in the northwest corner of the property are abnormally low in TiO_2. Two samples from diamond drill hole 125 are actually rhyolite, not andesite. Andesite cut by diamond drill hole 161 is low in TiO_2. Diamond drill holes 190 and 199 are abnormally high, possibly because of analytical error.

Chart 3

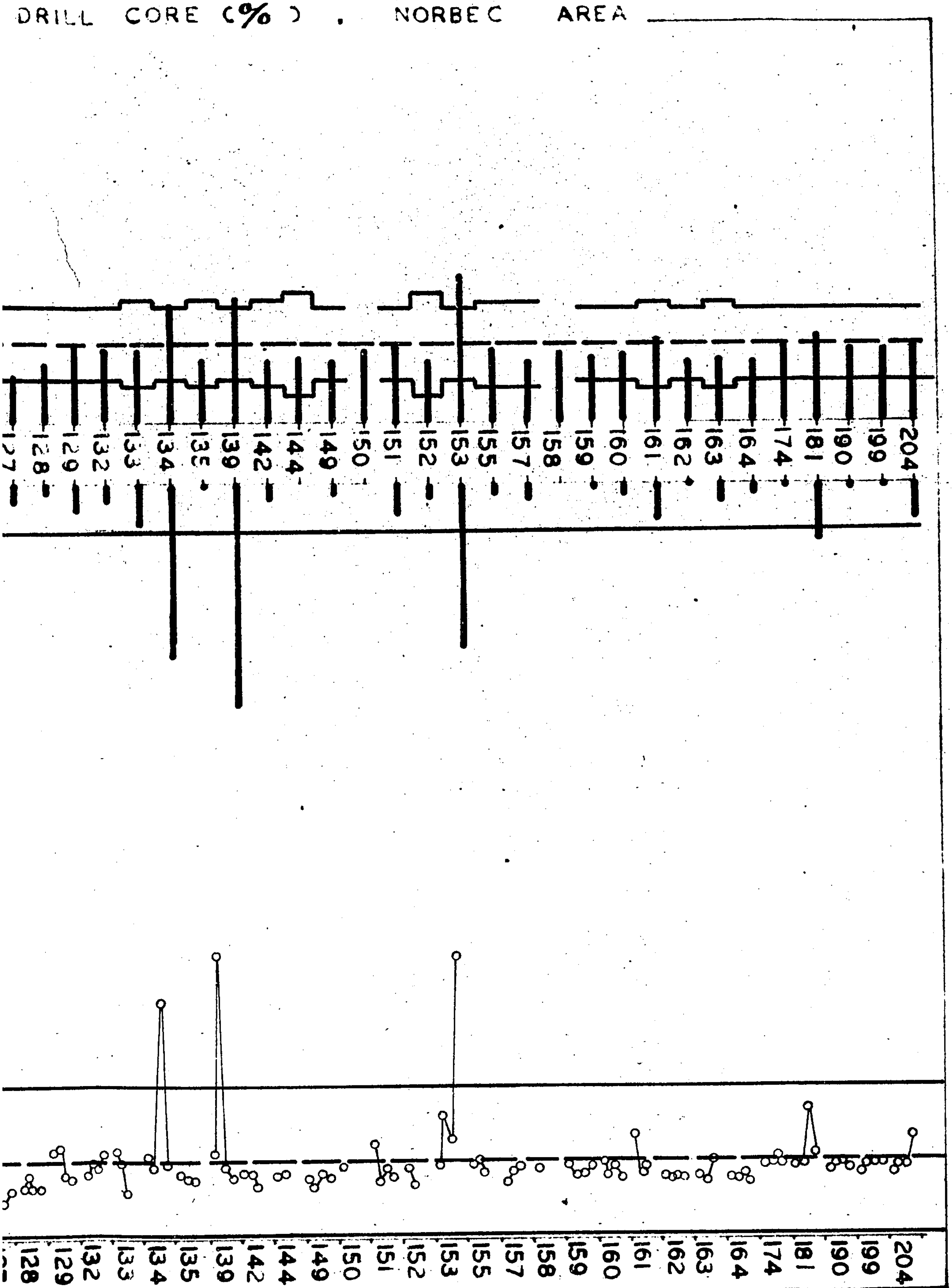
TiO_2 rhyolite

THE TiO_2 CONTENT OF *Rhyolite* IN DIAMOND DRILL



LAKE DUFAULT

DRILL CORE (%) . NORBEC AREA

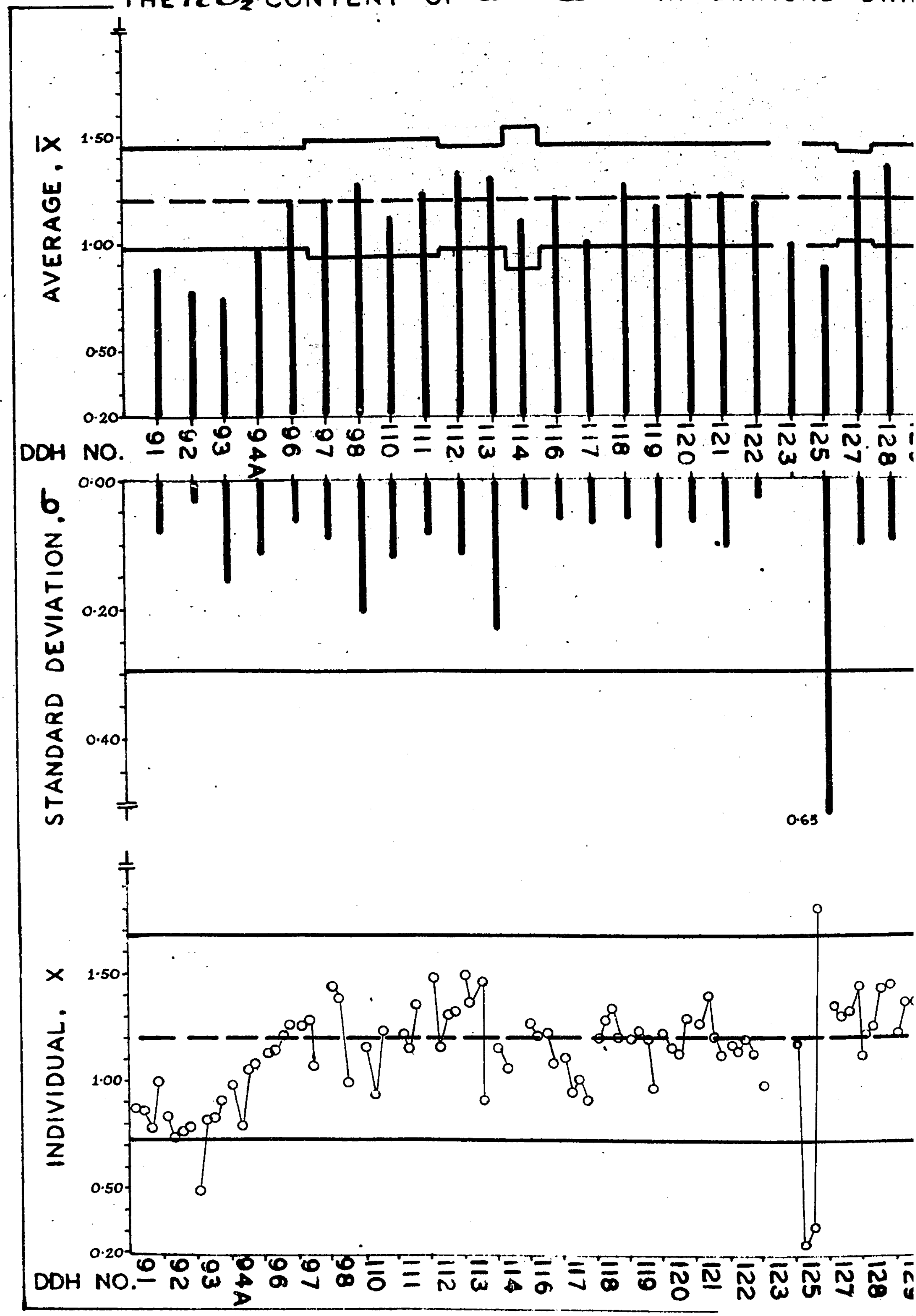


UFAULT MINES LTD.

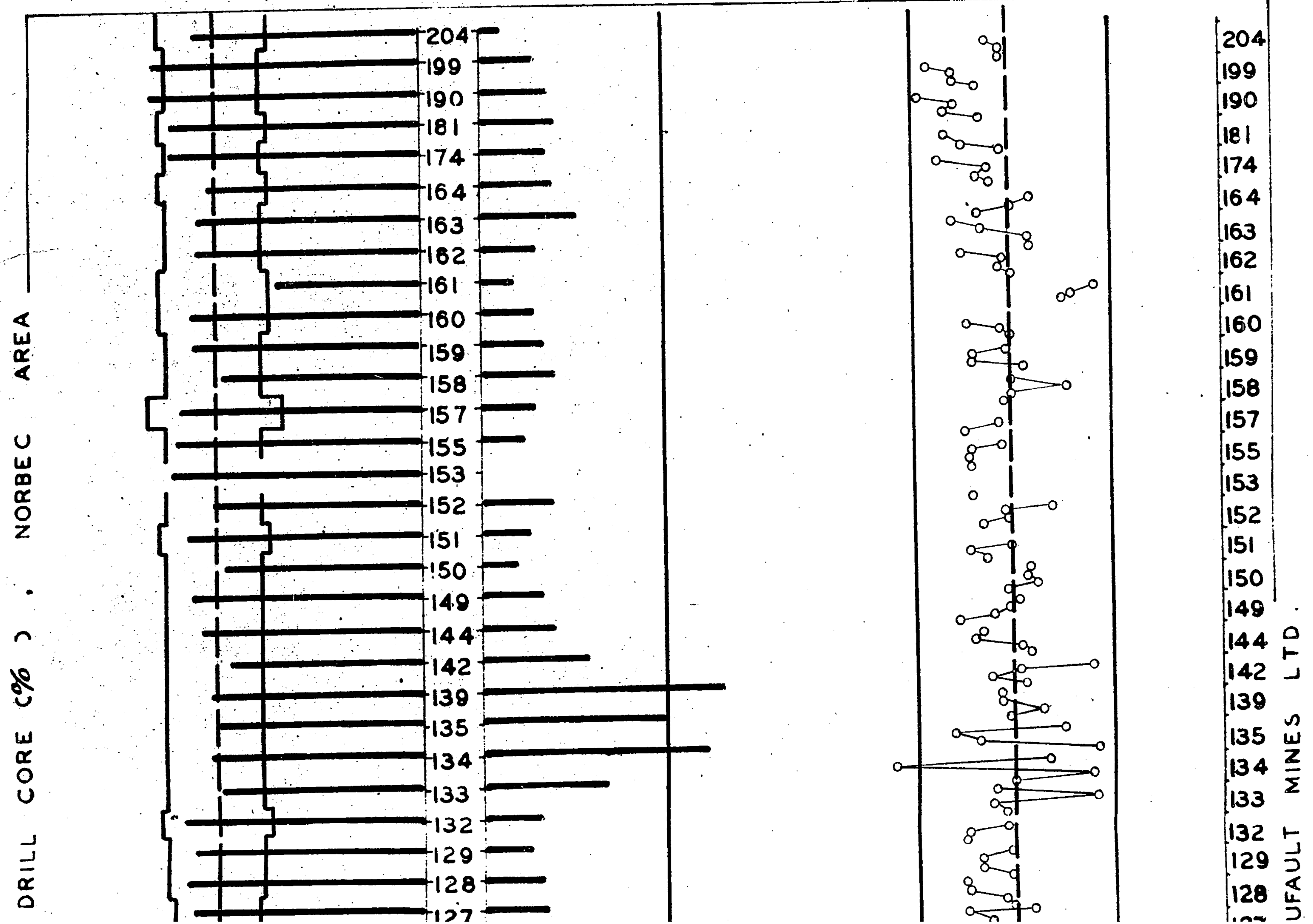
Chart 4

TiO_2 andesite

THE TiO_2 CONTENT OF *Andesite* IN DIAMOND DRI



LAKE DUFAU



DRILL CORE (%) . NORBEC AREA
UFAULT MINES LTD
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128

Aluminum (oxide) (Al_2O_3) Rhyolite chart 5

$\bar{x}$	14.2%
Mo	13.6%
$\bar{\sigma}$	1.6%
FD	Type I
ULB	14.2 + 2.4%
LLB	14.2 - 2.4%
C_A	14.2% of $\bar{x}$
R	1.35

Near the ore body, mineralized rhyolite cut by holes 127, 128 and 142 is diluted with respect to Al_2O_3 as it was with SiO_2. Holes 181 and 204 cut rhyolite containing greater than normal amounts of Al_2O_3.

Al_2O_3 Andesite chart 6

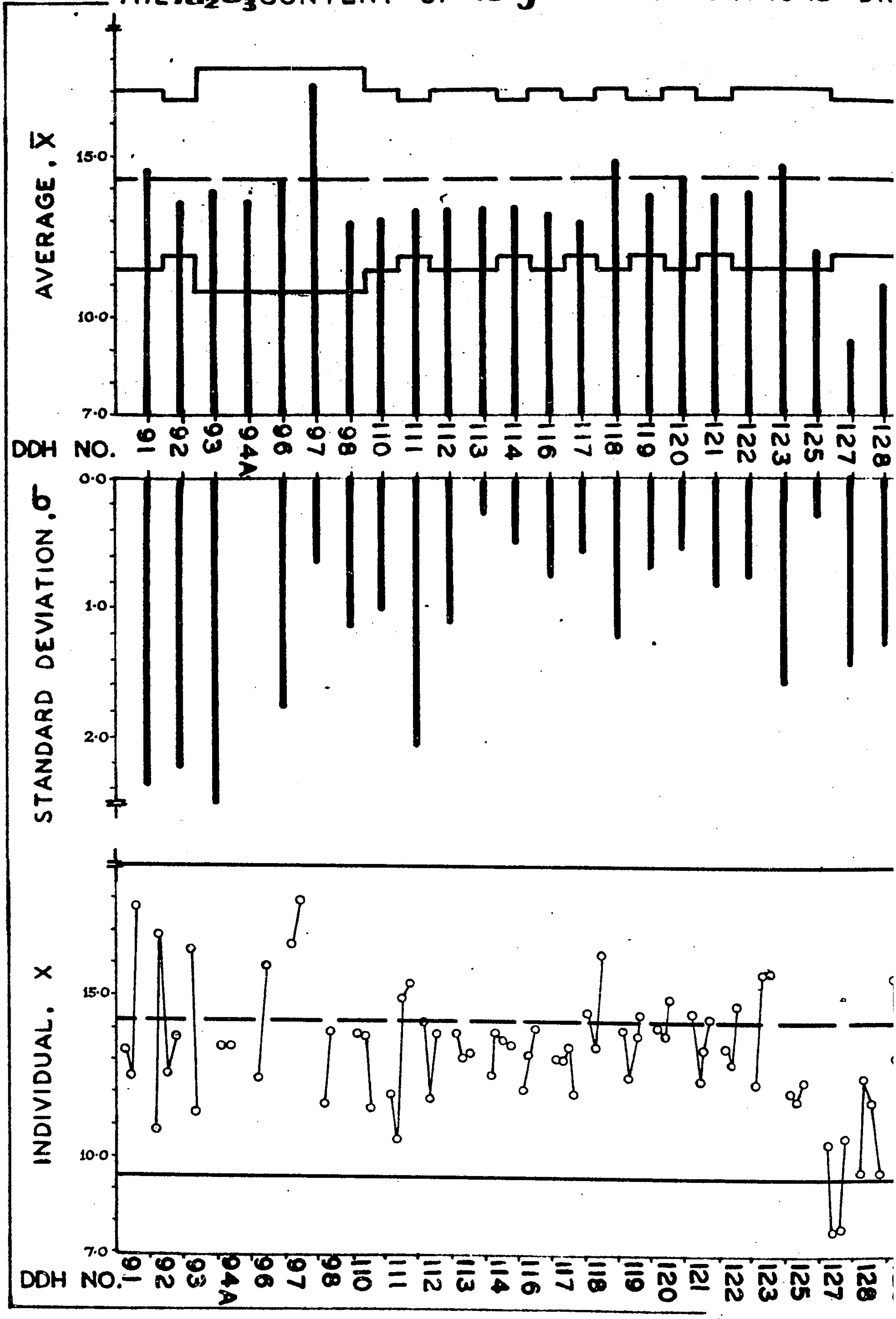
$\bar{\bar{x}}$	18.3%
Mo	16.4%
$\bar{\sigma}$	1.8%
FD	Type II
a	19.0%
b	21.5%
C_A	7.7% of $\bar{x}$
R	.79

Anomalous sections of Al_2O_3 are scattered and apparently are not related to the presence of ore.

Chart 5

Al_2O_3 rhyolite

THE Al_2O_3 CONTENT OF *Rhyolite* IN DIAMOND DR



LAKE DUFA

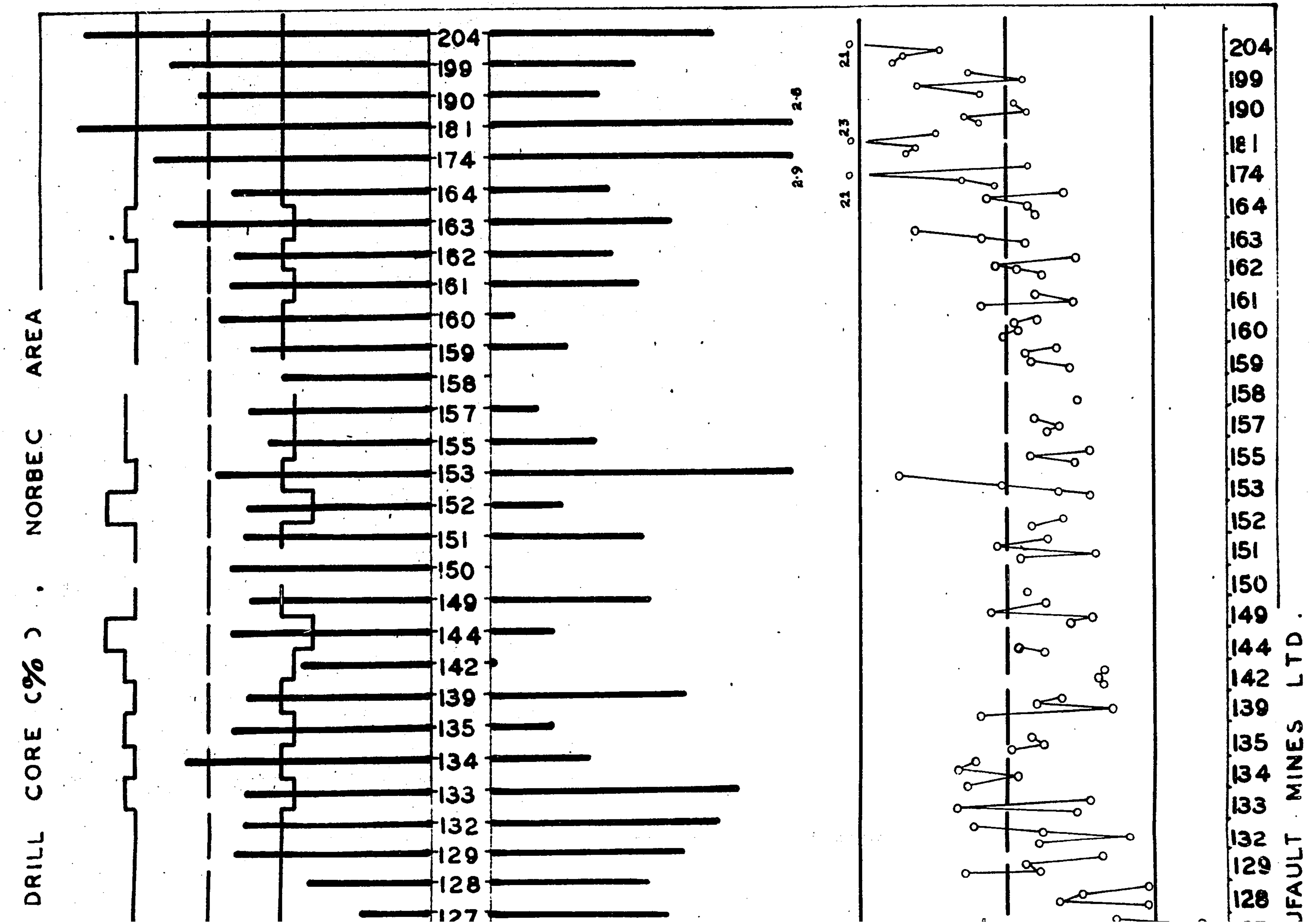
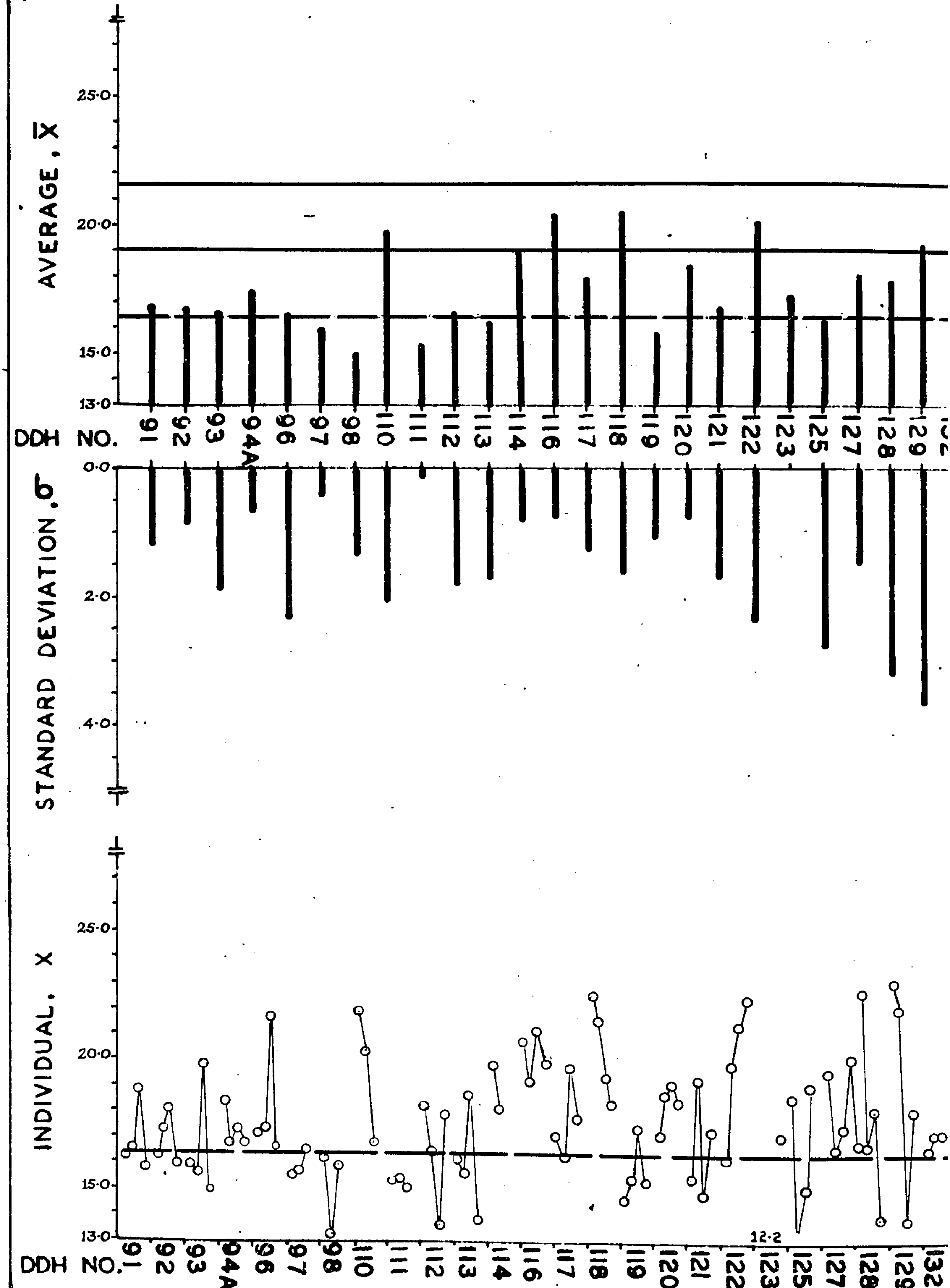

DRILL CORE (%) . NORBEC AREA
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
2·8
2·9
21
23
21
UFAULT MINES LTD.

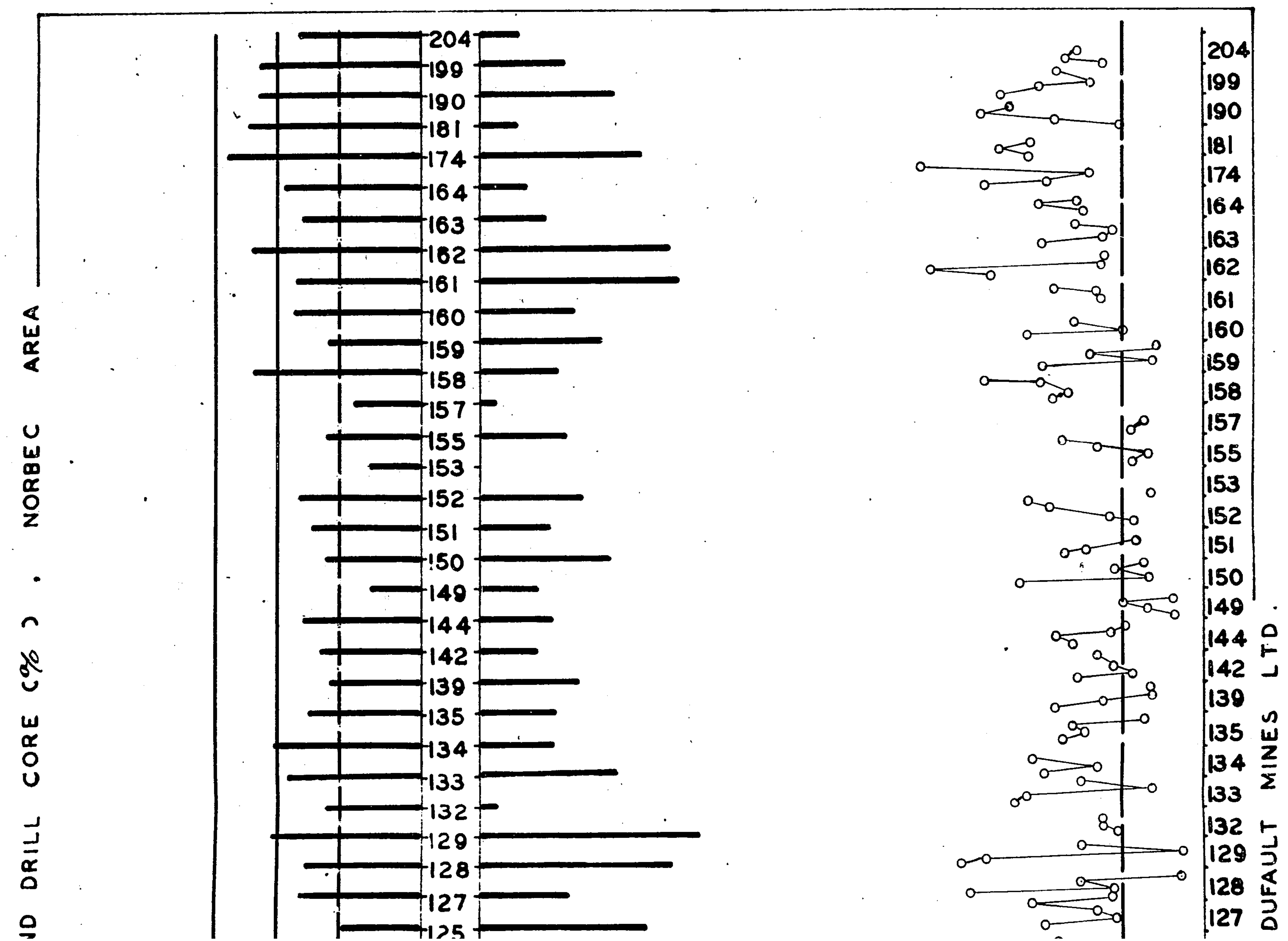
Chart 6

Al_2O_3 andesite

THE Al_2O_3 CONTENT OF *Andesite* IN DIAMOND DRILL



LAKE DUFAULT



ND DRILL CORE (%) . NORBEC AREA
DUFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
125

Iron (oxide) Total Fe as Fe_2O_3 Rhyolite chart 7

$\bar{\bar{x}}$	4.9%
Mo	4.5%
$\bar{\sigma}$	1.3%
FD	Type II
a	6.0%
b	8.0%
C_A	2.3% of $\bar{x}$
R	.09

Only one drill hole away from the immediate vicinity of the ore body cuts rhyolite abnormally high in Fe (97). Of the anomalous holes near the ore body only 162, 129 and 153 do <u>not</u> cut rhyolite which is obviously mineralized.

Total Fe as Fe_2O_3 Andesite chart 8

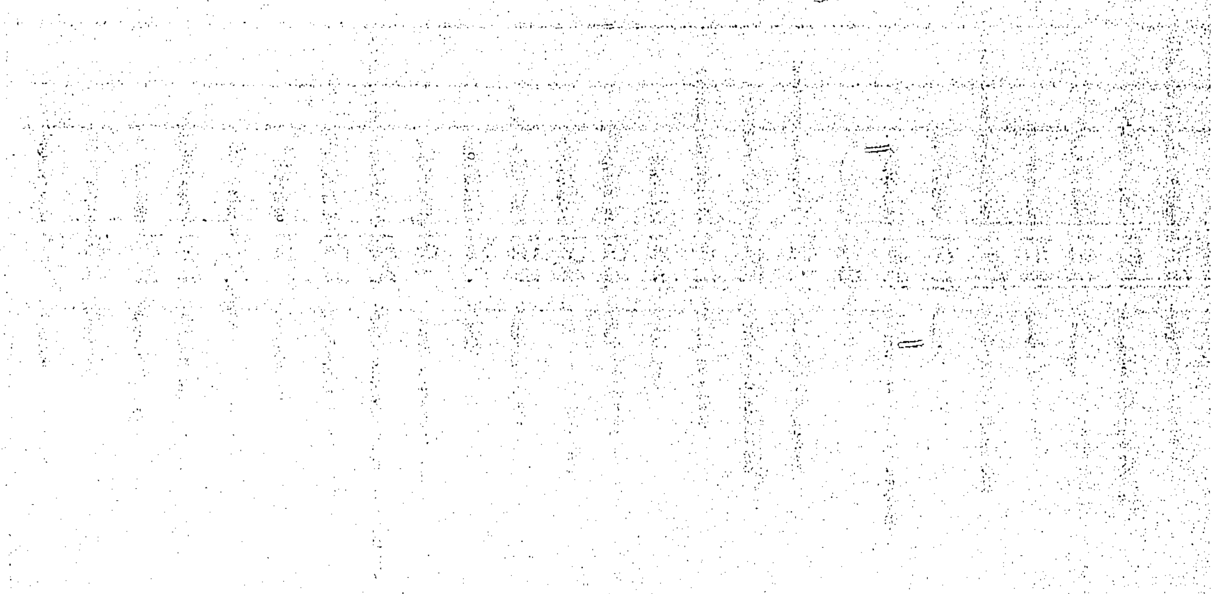
$\bar{\bar{x}}$	9.3%
Mo	9.4%
$\bar{\sigma}$	1.4%
FD	Type I
ULB	9.3 + 2.1%
LLB	9.3 - 2.1%
C_A	3.0% of $\bar{x}$
R	.20

Andesite cut by drill hole 92 contains an unusually low amount of Fe. Hole 125 cuts andesite with an unusually high Fe content. One sample of andesite from diamond drill hole 150 contained much more Fe than usual.

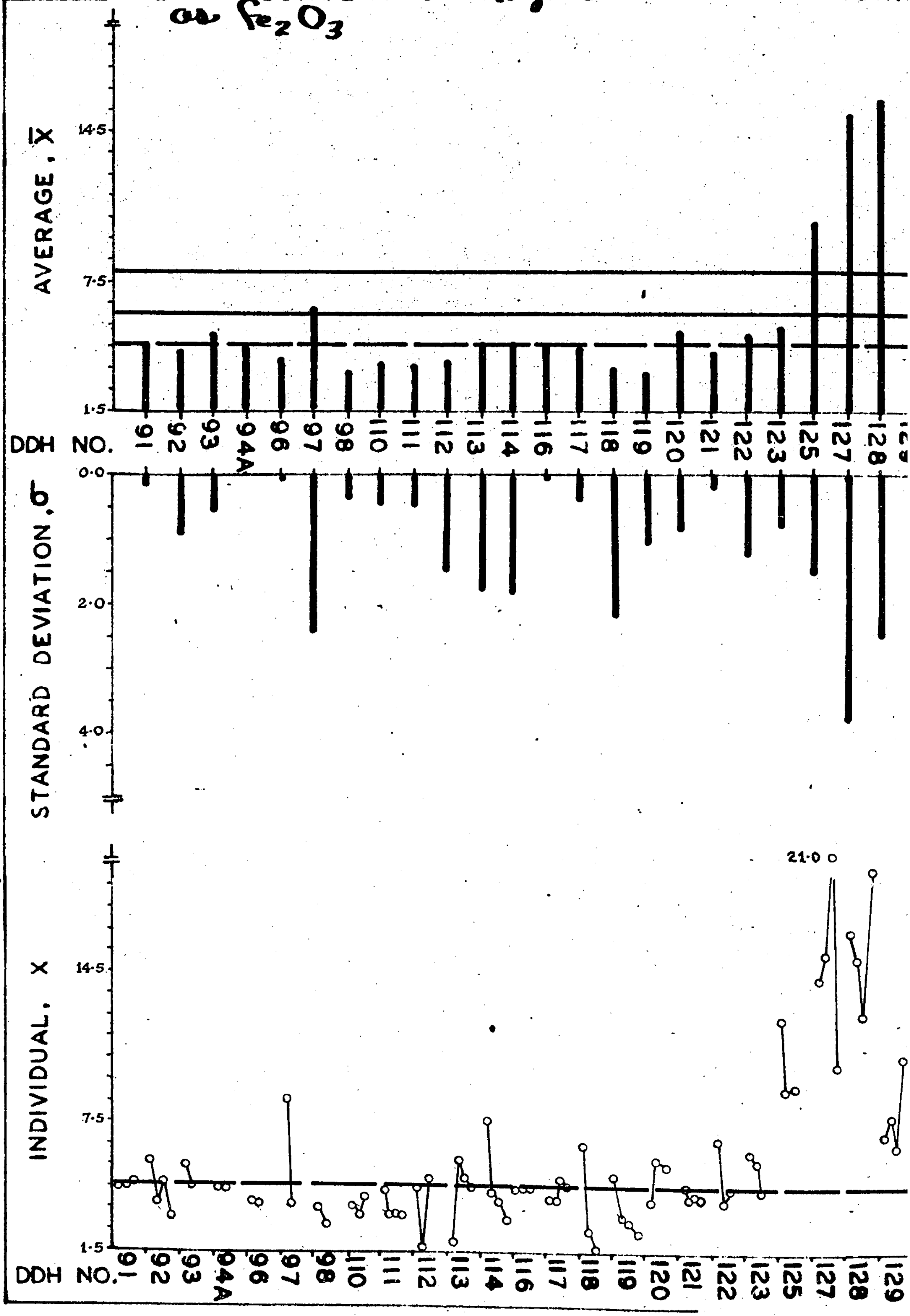
Chart 7

total Fe as Fe_2O_3

rhyolite

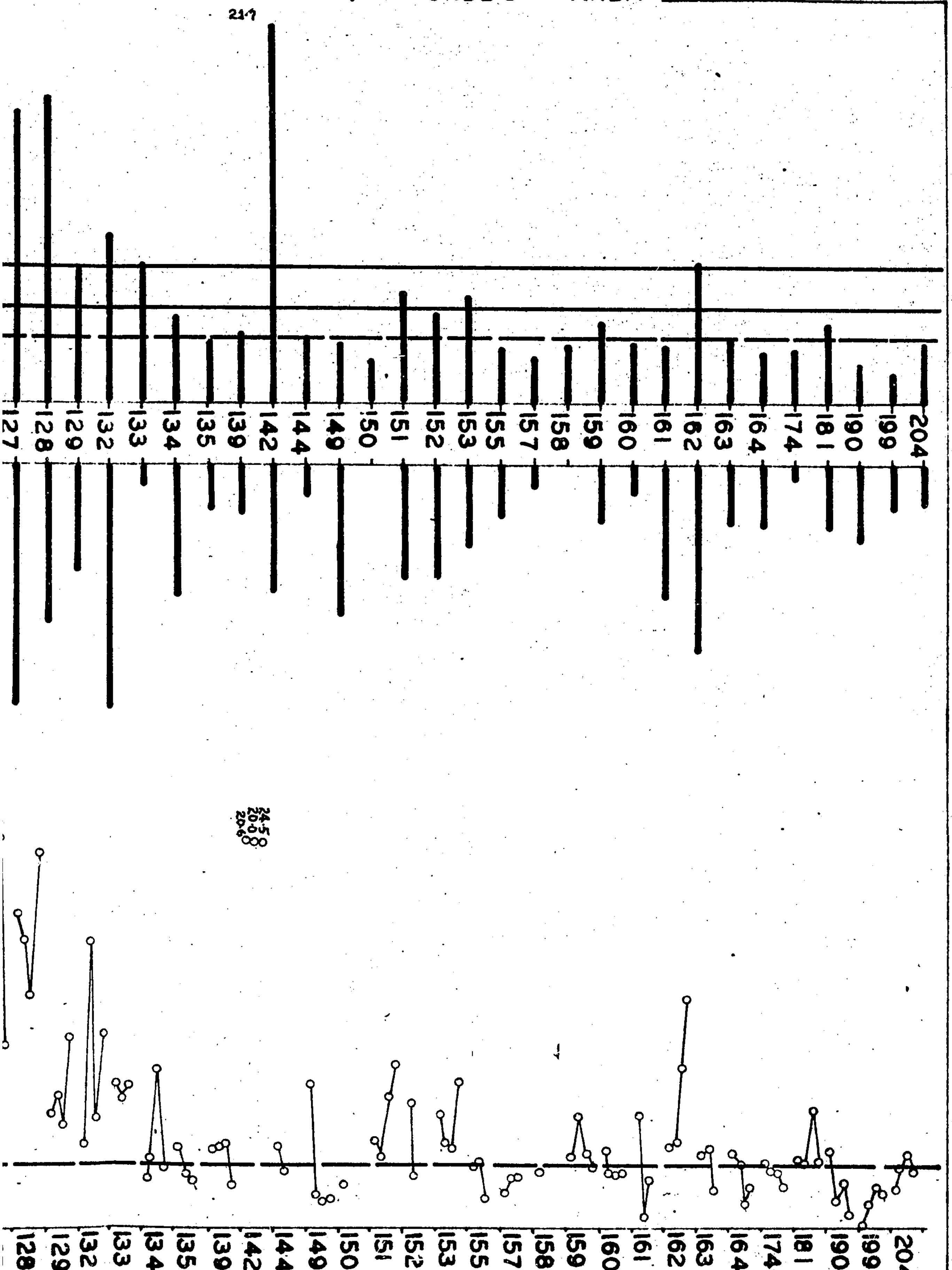


THE Fe CONTENT OF Rhyolite IN DIAMOND DRI
as Fe_2O_3



LAKE DUFAUL

DRILL CORE (%) . NORBEC AREA

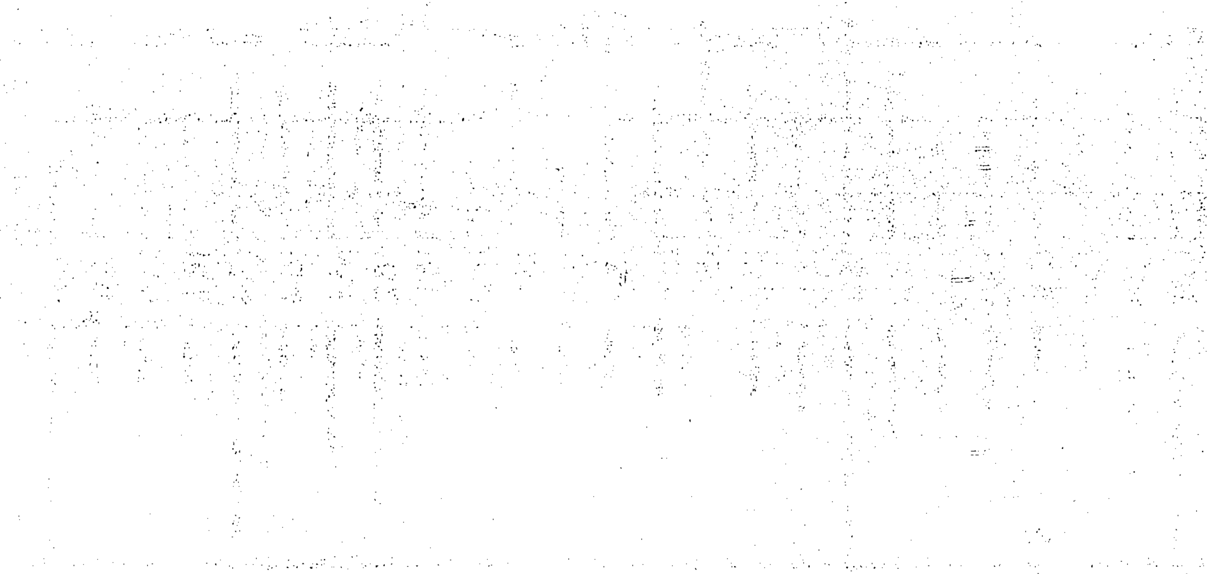


JFAULT MINES LTD.

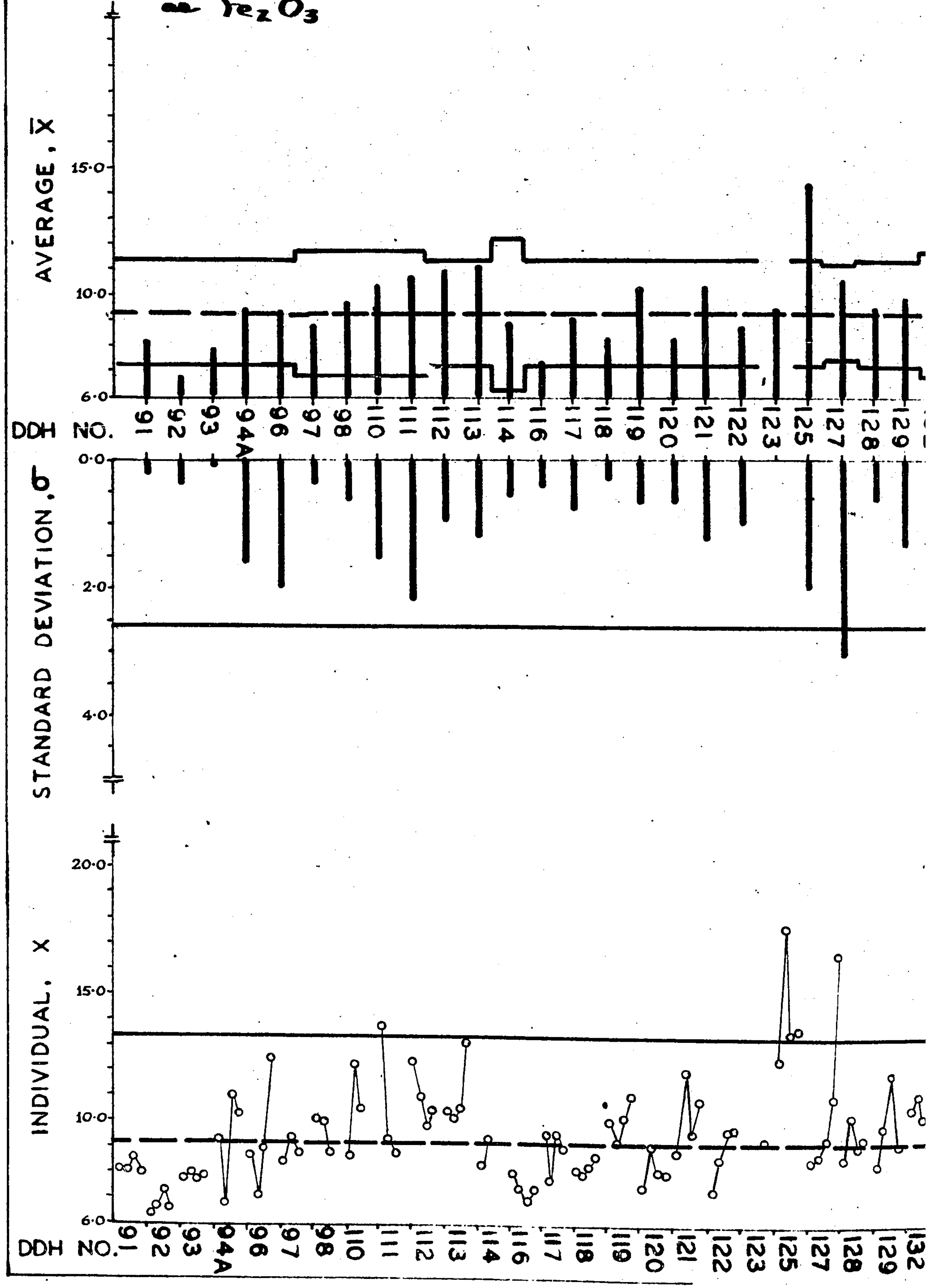
Chart 8

total Fe as Fe_2O_3

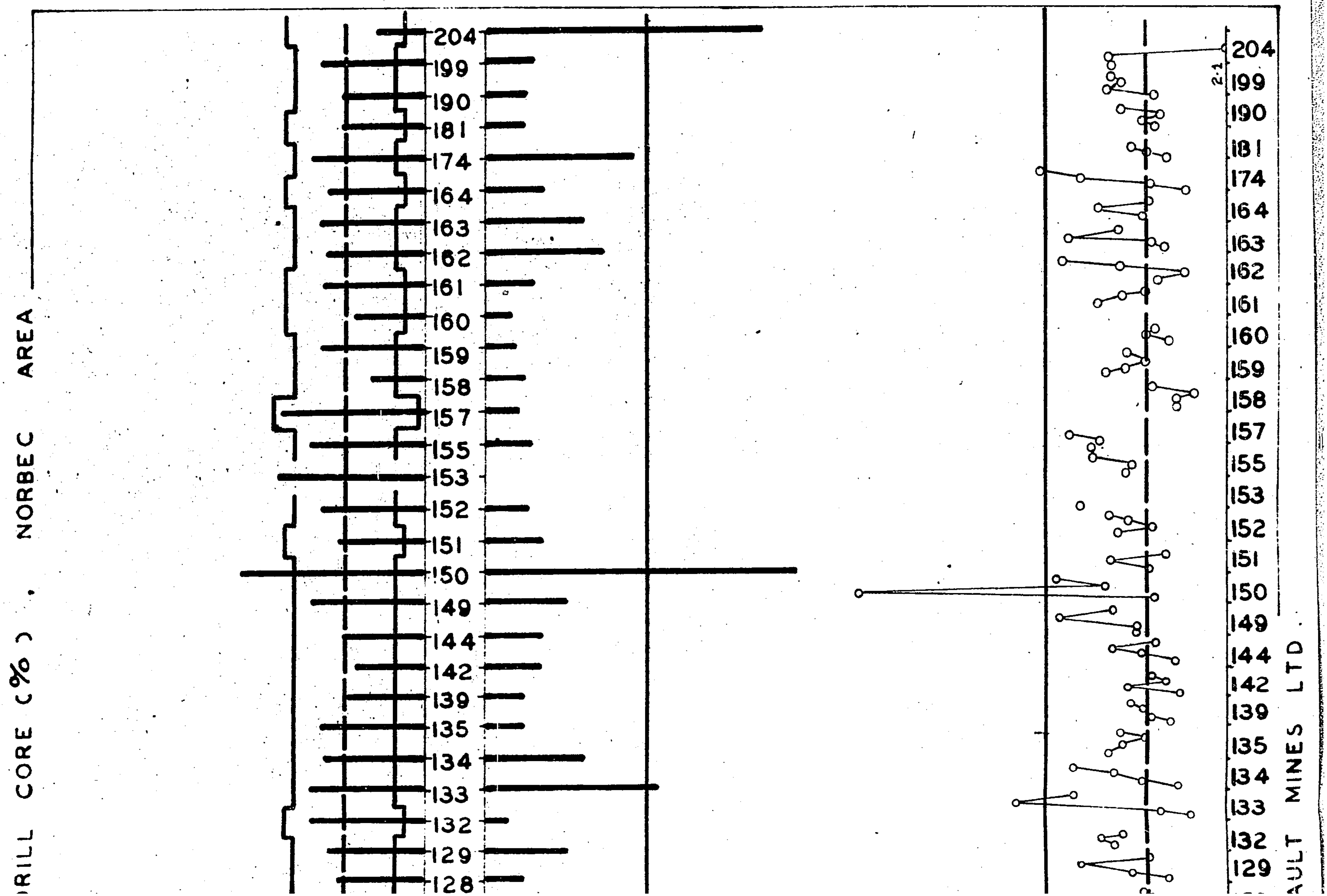
andesite



THE Fe CONTENT OF Andesite IN DIAMOND DRILL
as Fe_2O_3



LAKE DUFAULT



CORE (%)
NORBEC AREA
MINES LTD
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
2·1

Manganese (oxide) (MnO) Rhyolite chart 9

$\bar{\bar{x}}$	0.156%
Mo	0.10%
$\bar{\sigma}$	0.095%
FD	Type IV
a	.2%
b	.35%
C_A	3.0% of $\bar{\bar{x}}$
R	.050

Away from the ore body only holes 92 and 113 cut rhyolite containing abnormally high amounts of MnO. Other than those holes cutting mineralized rhyolite only numbers 139, 162 and 129 are anomalous.

MnO Andesite chart 10

$\bar{\bar{x}}$	0.19%
Mo	0.16%
$\bar{\sigma}$	.035%
FD	Type I
ULB	0.19 + .05%
LLB	0.19 - .05%
C_A	5.6% of $\bar{\bar{x}}$
R	.31

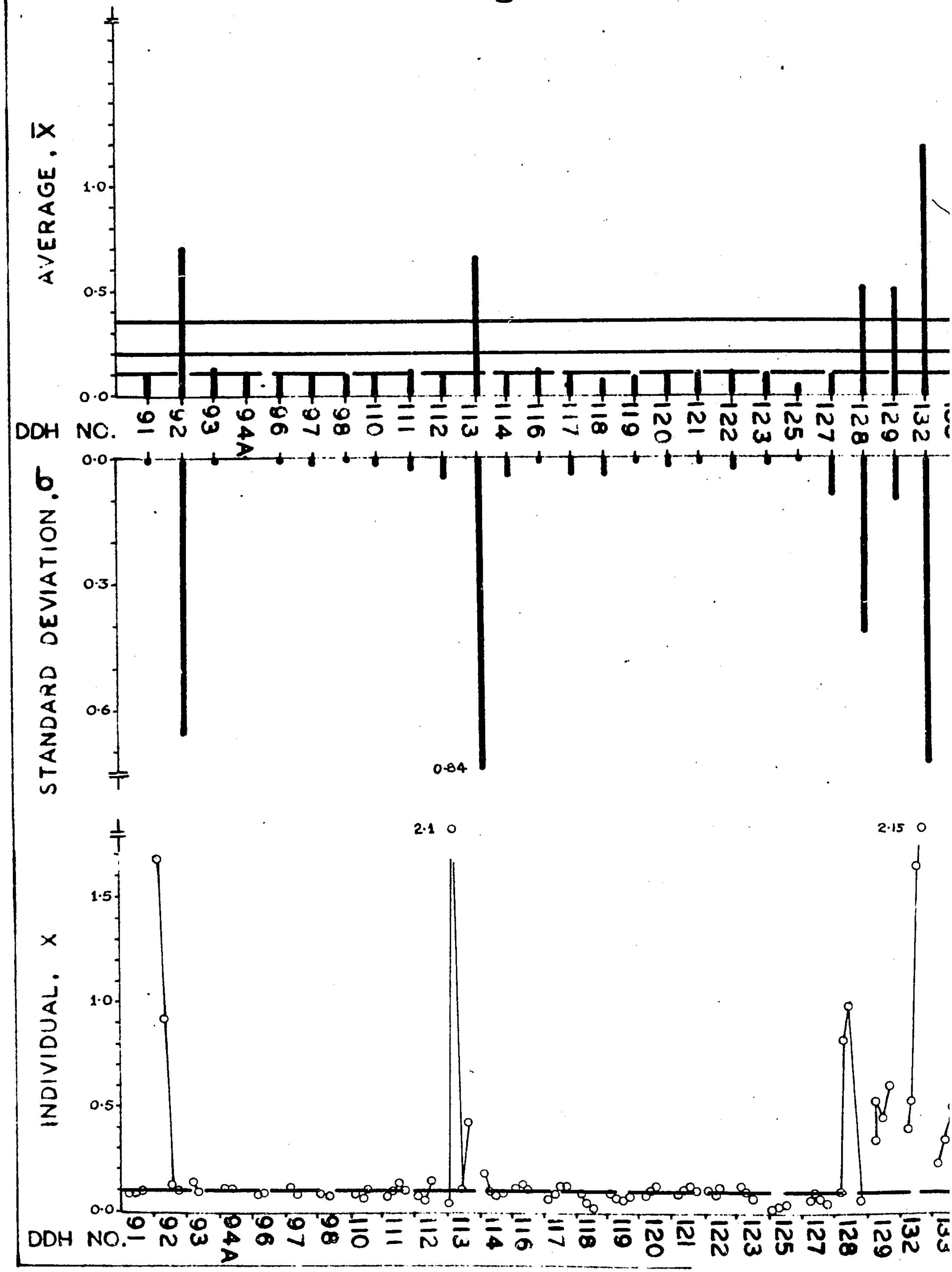
Over the ore body, andesite cut by holes 125, 127, 129, 132 and 149 contains unusually high amounts of MnO.

Off to the side of the ore body only hole 164 is anomalous. Far away from the ore body hole 150 cuts andesite containing an extra amount of MnO. The high value for hole 153 is from an individual sample.

Chart 9

MnO rhyolite

THE MnO CONTENT OF Rhyolite IN DIAMOND DRILL (



LAKE DUFAULT

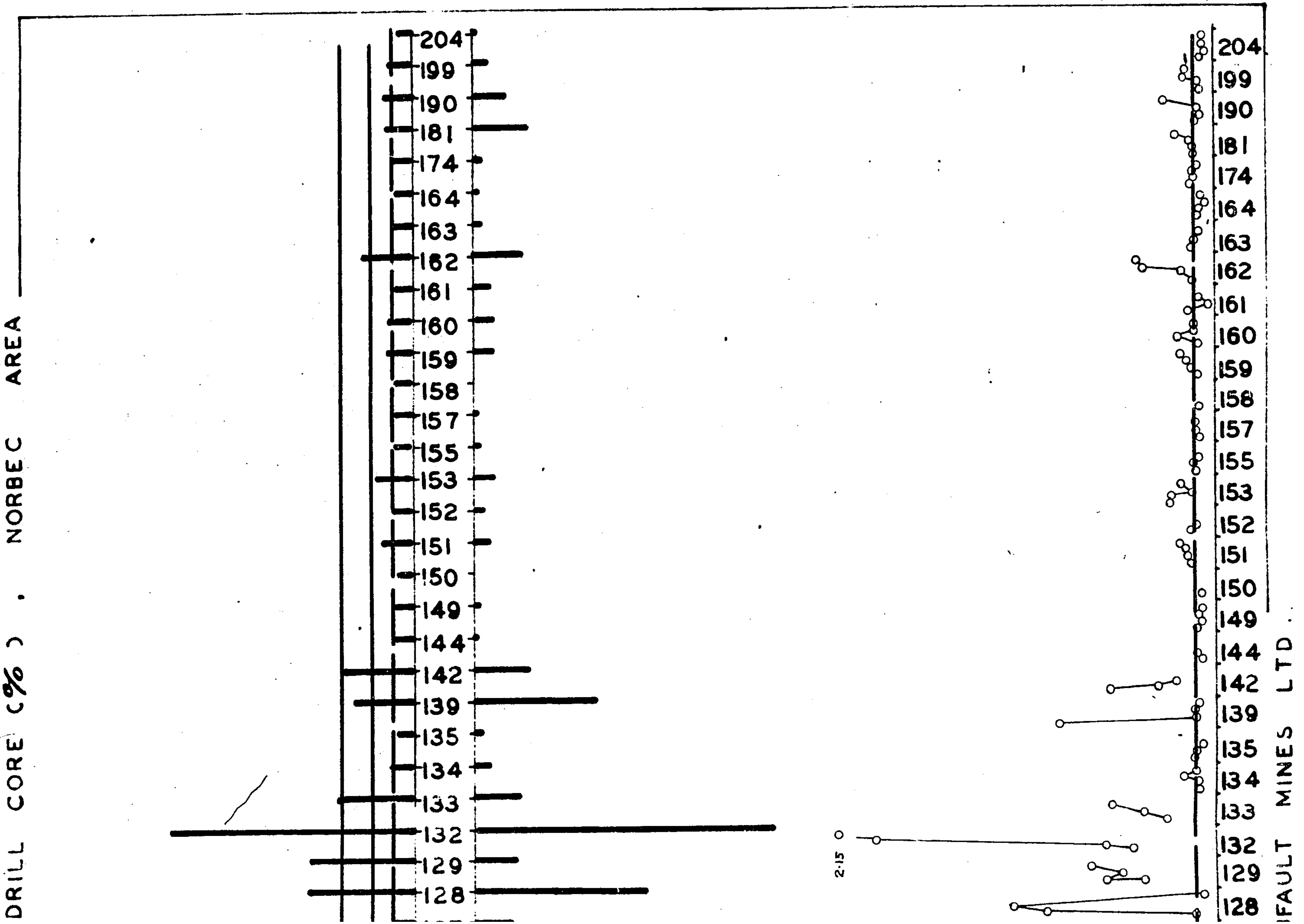
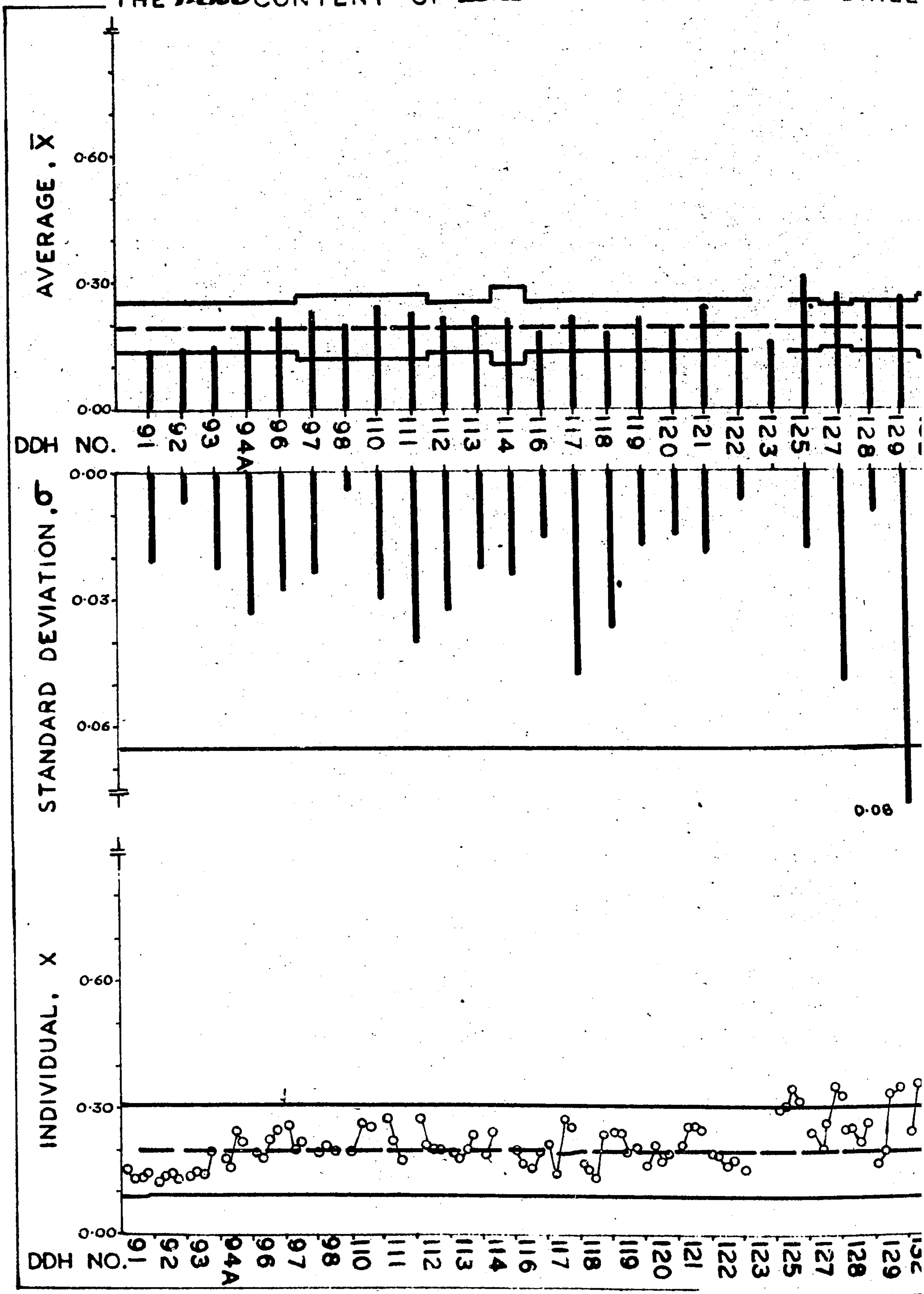

DRILL CORE (%) . NORBEC AREA
FAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
2·15

Chart 10

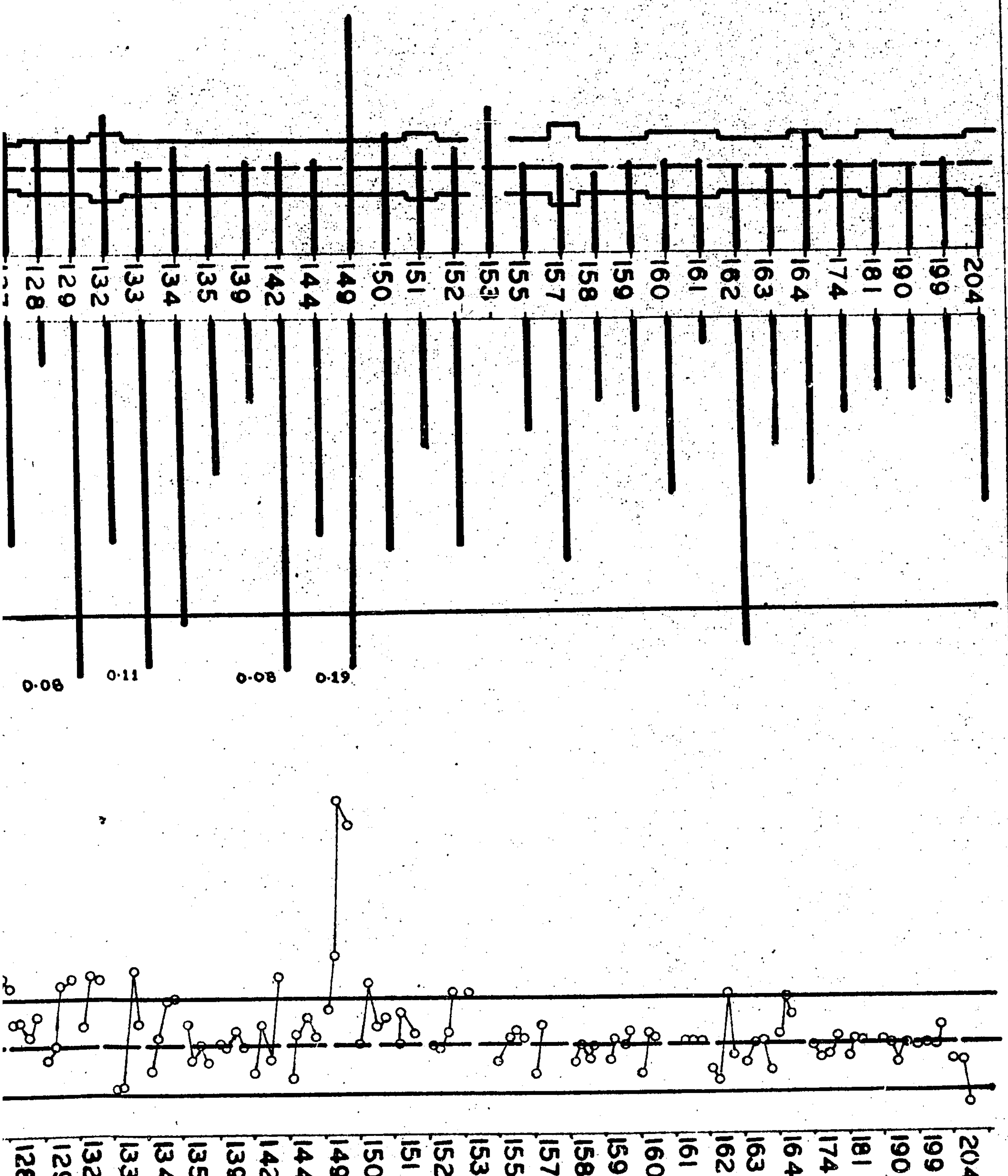
MnO andesite

THE MnO CONTENT OF *Andesite* IN DIAMOND DRILL



LAKE DUFAULT

DRILL CORE (%) . NORBEC AREA



JFAULT MINES LTD.

Calcium (oxide) (CaO) Rhyolite chart 11

$\bar{\bar{x}}$ 2.6%
Mo 2.5%
$\bar{\sigma}$ .78%
FD Type I
ULB 2.6 + 1.2%
LLB 2.6 - 1.2%
C_A 4.0% of $\bar{\bar{x}}$
R .13

Of the mineralized rhyolite below the ore body, that cut by holes 125 and 127 is unusually low in CaO while that cut by 132 and 133 is high in CaO (142 is on the upper limit line). Rhyolite cut by hole 129 below the ore body is high in CaO. Close to the ore body hole 162 cut rhyolite with a CaO content high enough to be on the border of anomalous. In the general vicinity of ore, holes 181 and 190 cut rhyolite which contains unusually large amounts of CaO.

CaO Andesite chart 12

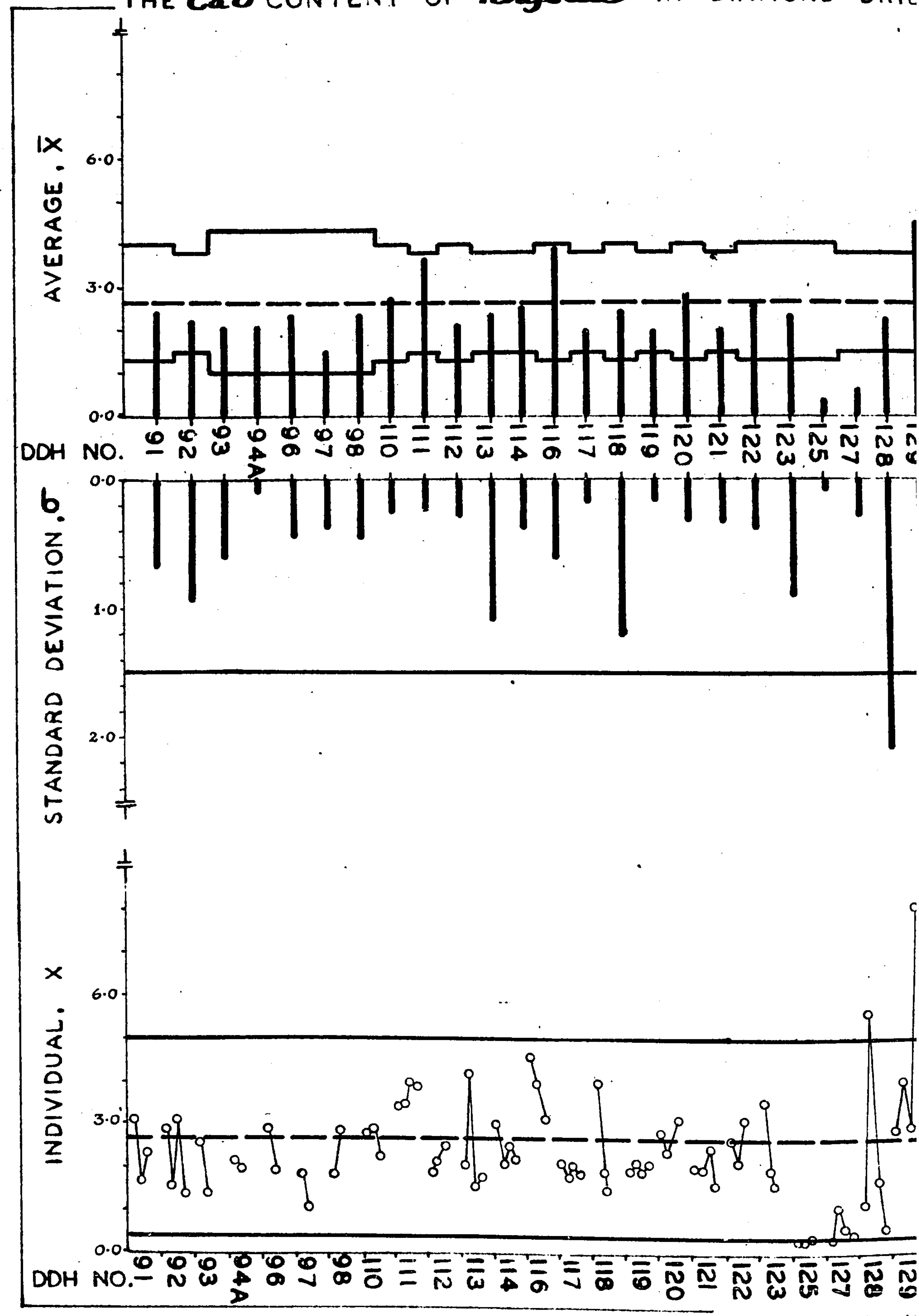
$\bar{\bar{x}}$ 8.9%
Mo 10.3%
$\bar{\sigma}$ 1.3%
FD Type I
ULB 8.9 + 2.0%
LLB 8.9 - 2.0%
C_A 2.9% of $\bar{\bar{x}}$
R .19

A few holes over and away from the ore body cut andesite with an unusually high content of CaO.

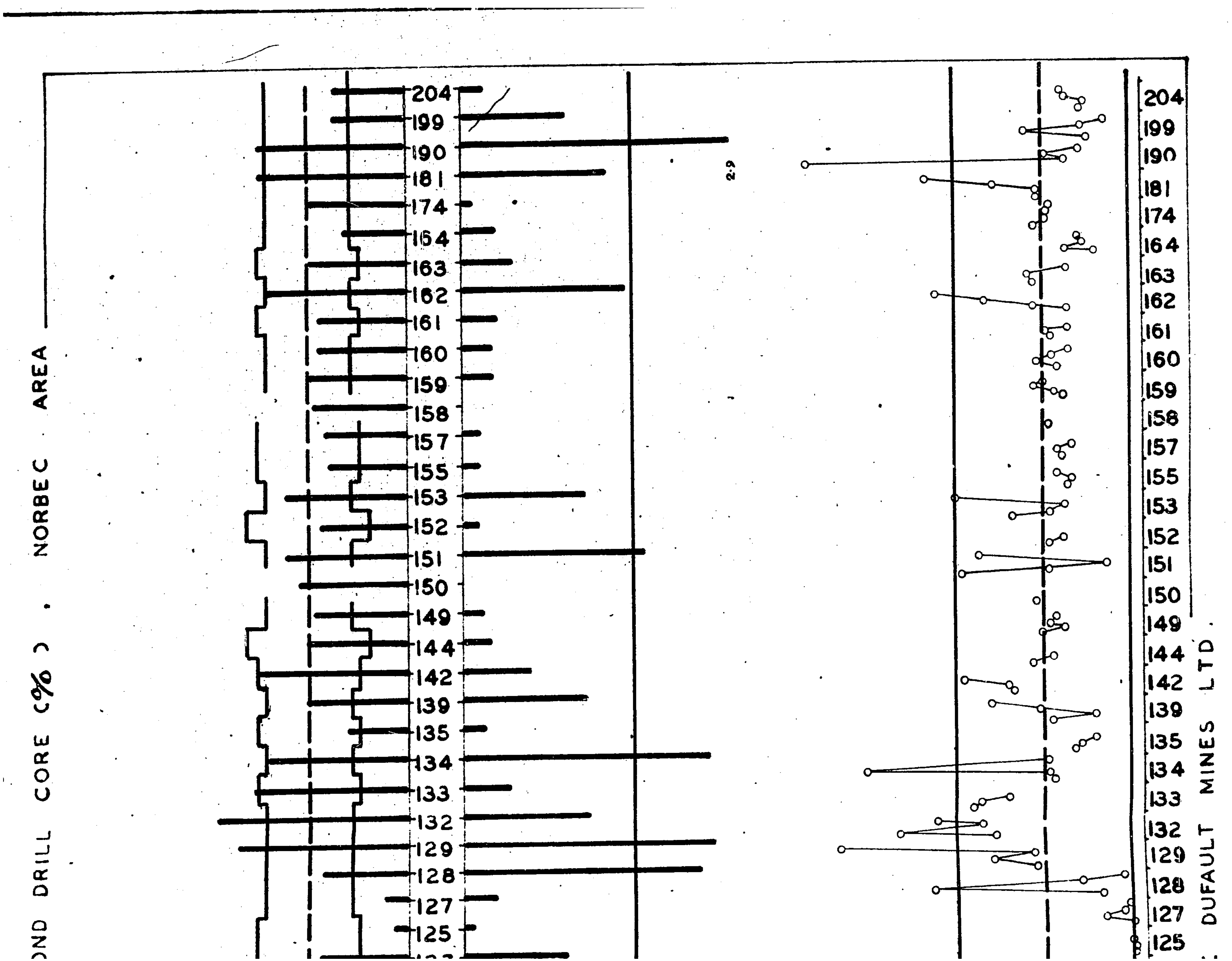
Chart 11

CaO rhyolite

THE CaO CONTENT OF *Rhyolite* IN DIAMOND DRIL



LAKE DUFAUI

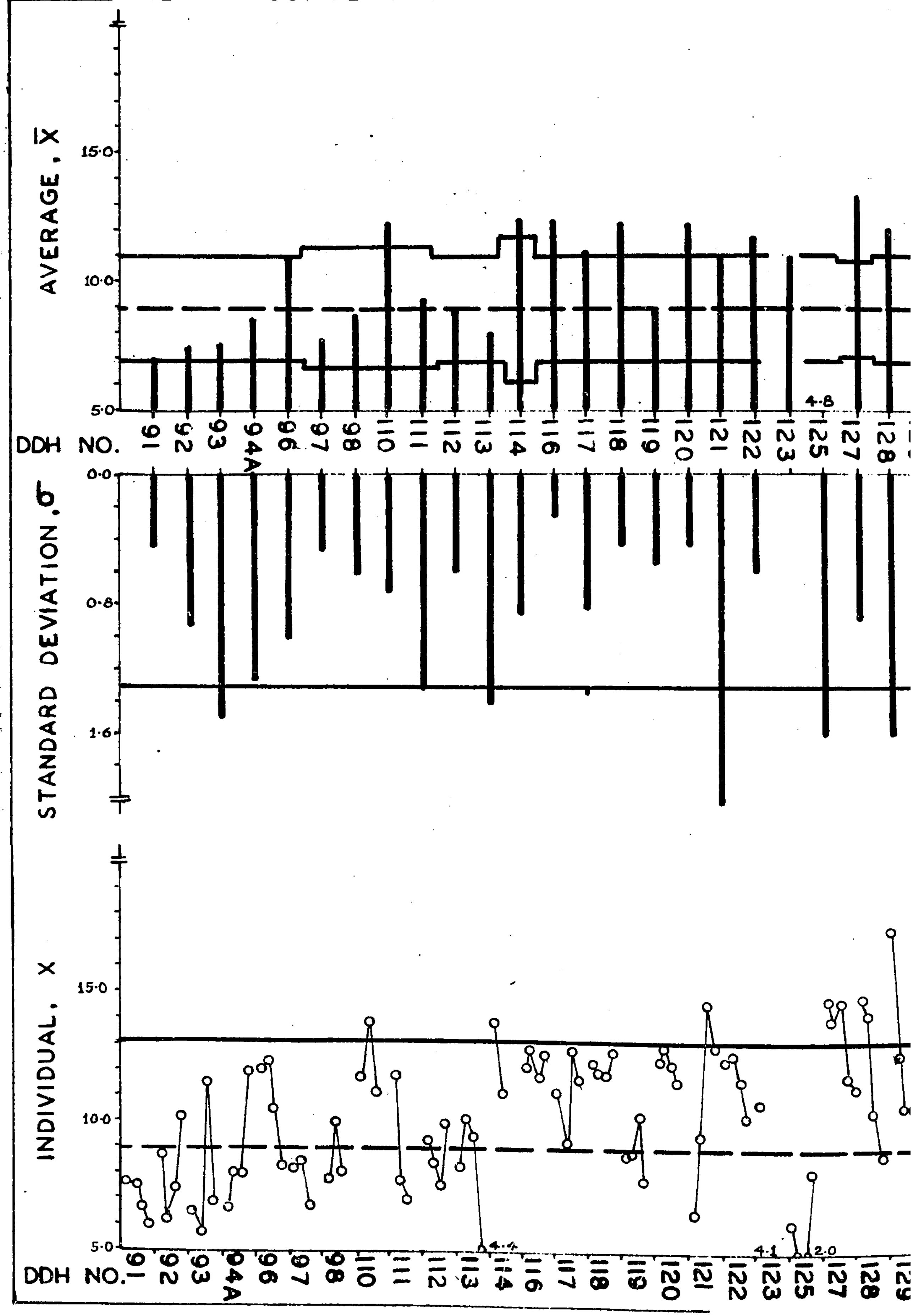


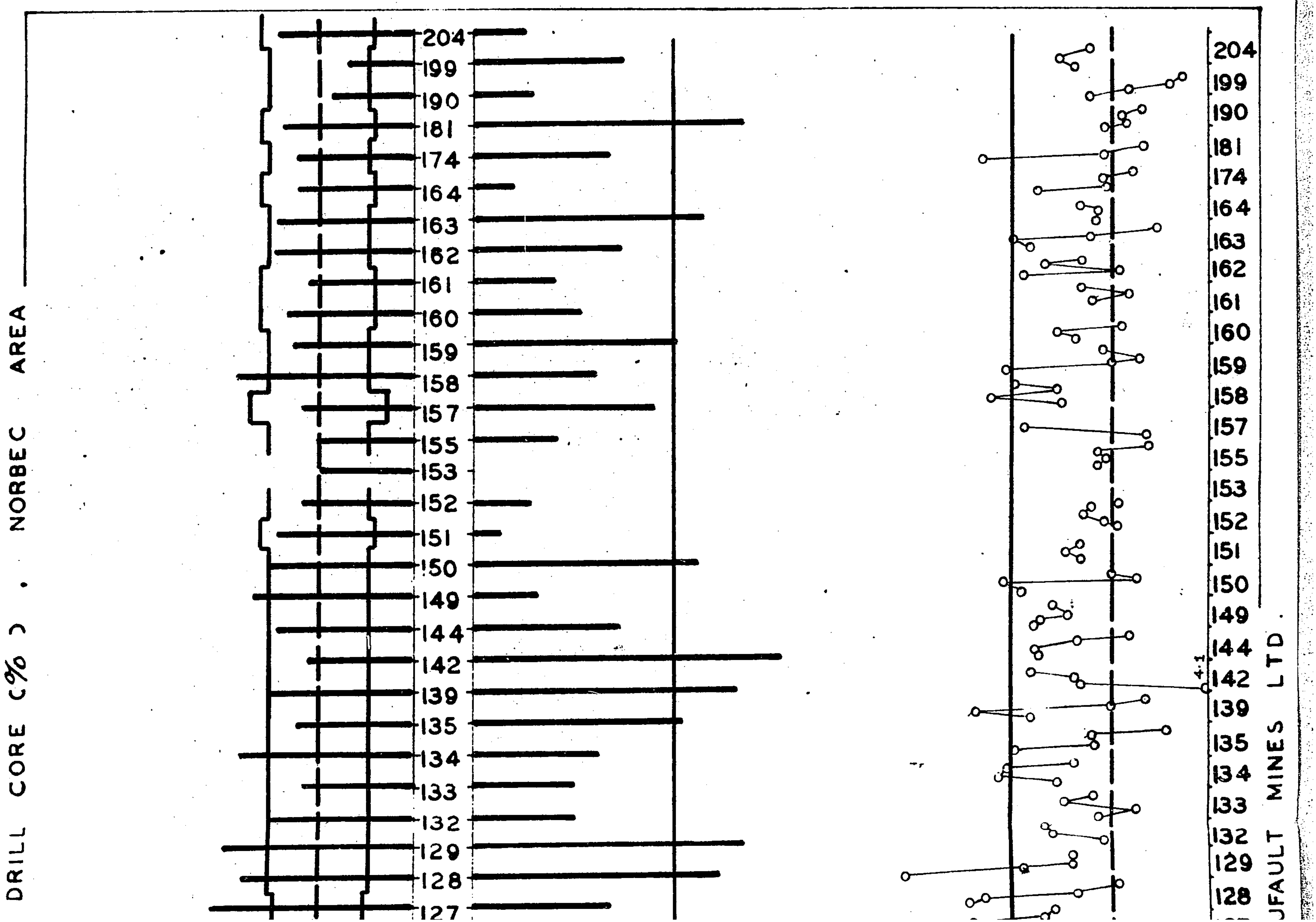
OND DRILL CORE (%) . NORBEC AREA
DUFAULT MINES LTD
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
125
2.9

Chart 12

CaO andesite

THE CaO CONTENT OF Andesite IN DIAMOND DRI





DRILL CORE (%) . NORBEC AREA
204
199
190
181
174
164
163
162
161
160
159
158
157
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150
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142
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135
134
133
132
129
128
127
4.1
FAULT MINES LTD.

Potassium (oxide) (K_2O) Rhyolite chart 13

$\bar{\bar{x}}$	1.54%
Mo	1.3%
$\bar{\sigma}$	.50%
FD	Type I
ULB	1.54 + .78%
LLB	1.54 - .78%
C_A	6.6% of $\bar{\bar{x}}$
R	.20

Diamond drill hole 118 cuts rhyolite with an unusually low K_2O content. Hole 199 cuts a section of rhyolite containing abnormally large amounts of K_2O.

K_2O Andesite chart 14

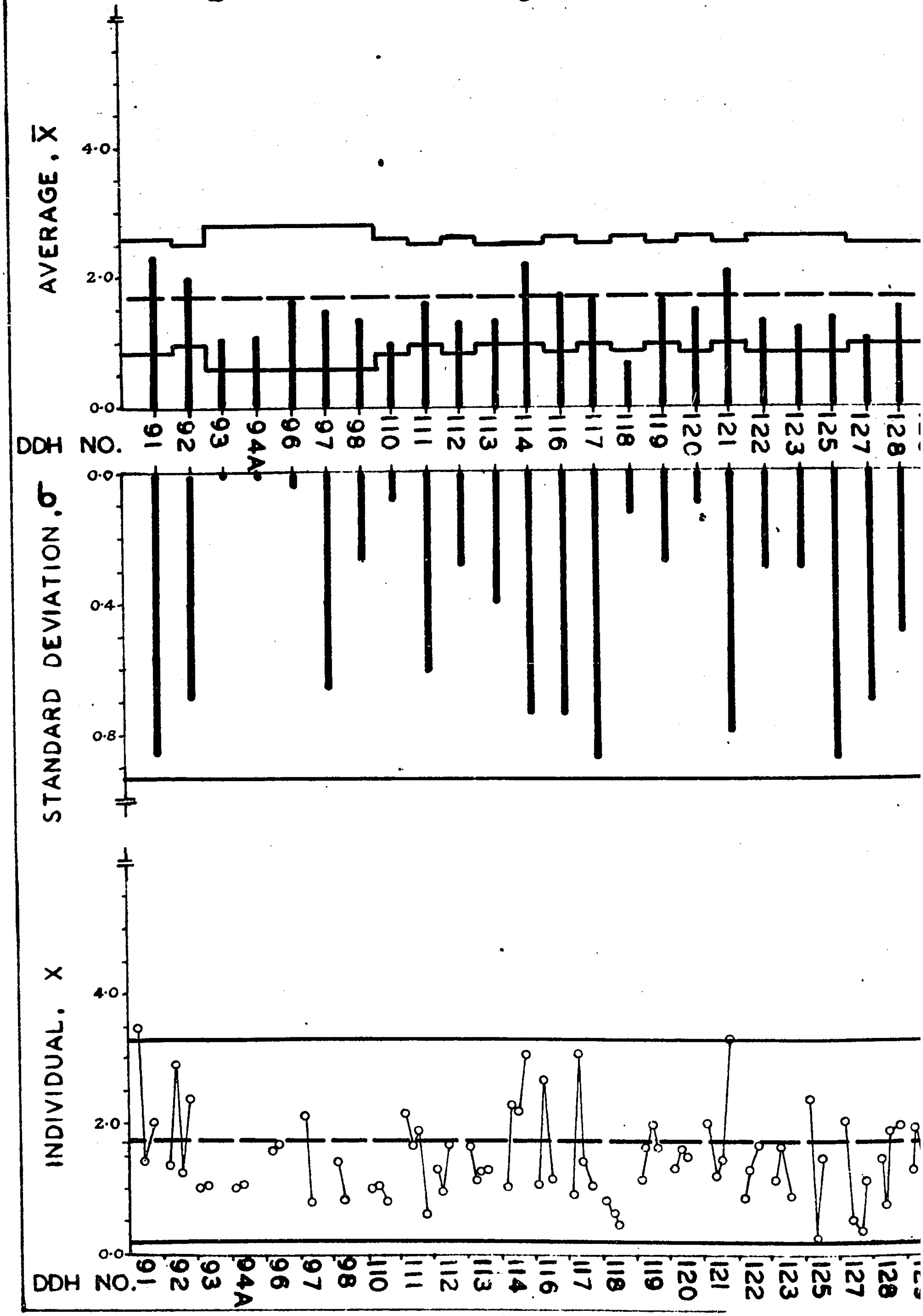
$\bar{\bar{x}}$	1.11%
Mo	0.5%
$\bar{\sigma}$	0.36%
FD	Type II
a	0.75%
b	1.00%
c	1.25%
C_A	14.0% of $\bar{\bar{x}}$
R	.46

Most of the drill holes show an average K_2O content which is slightly high compared with all andesite samples. This is the case because the samples of andesite closest to the main contact often exhibit high contents of K_2O.

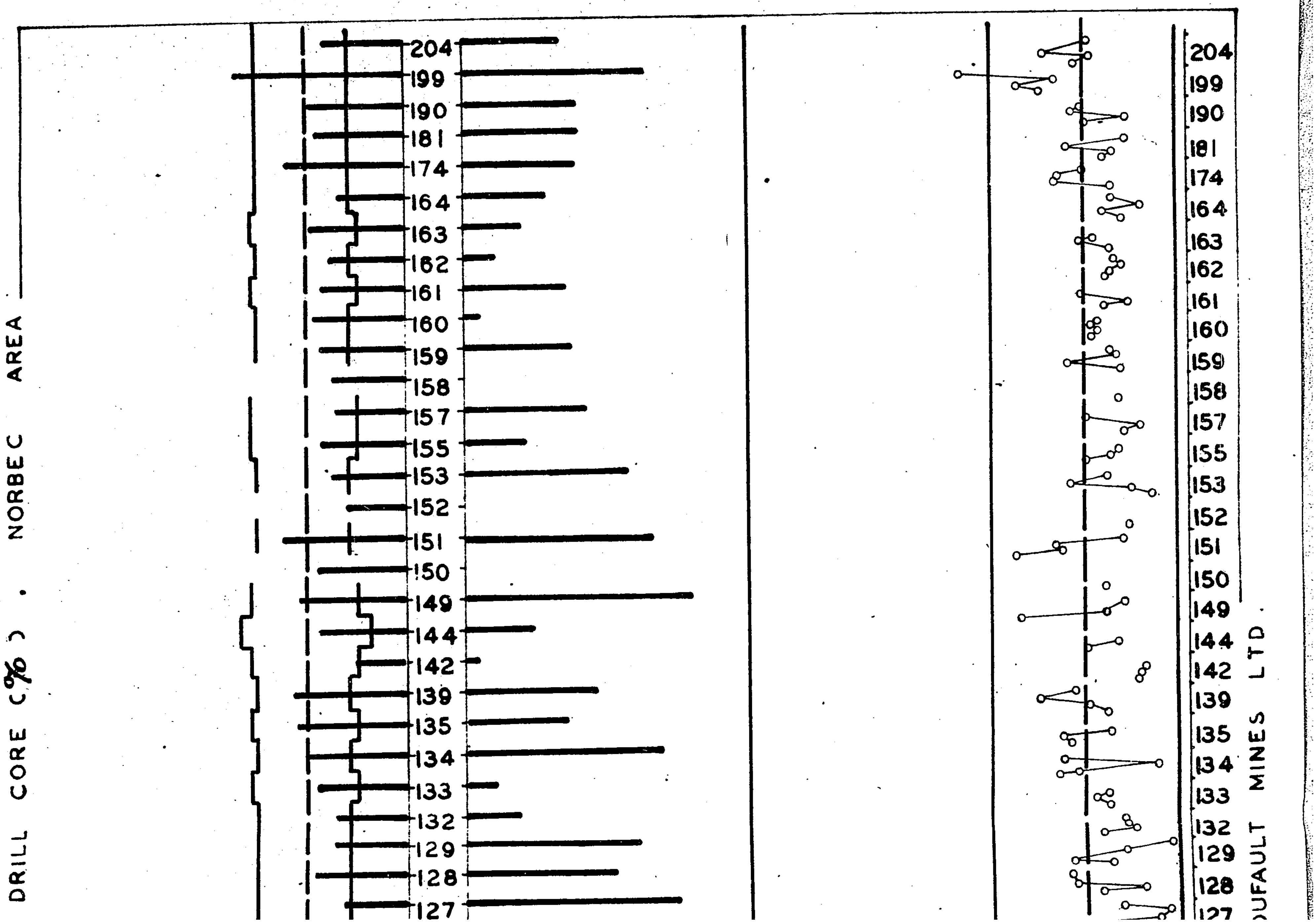
Chart 13

K_2O rhyolite

THE K_2O CONTENT OF *Rhyolite* IN DIAMOND DRI



LAKE DUFAL

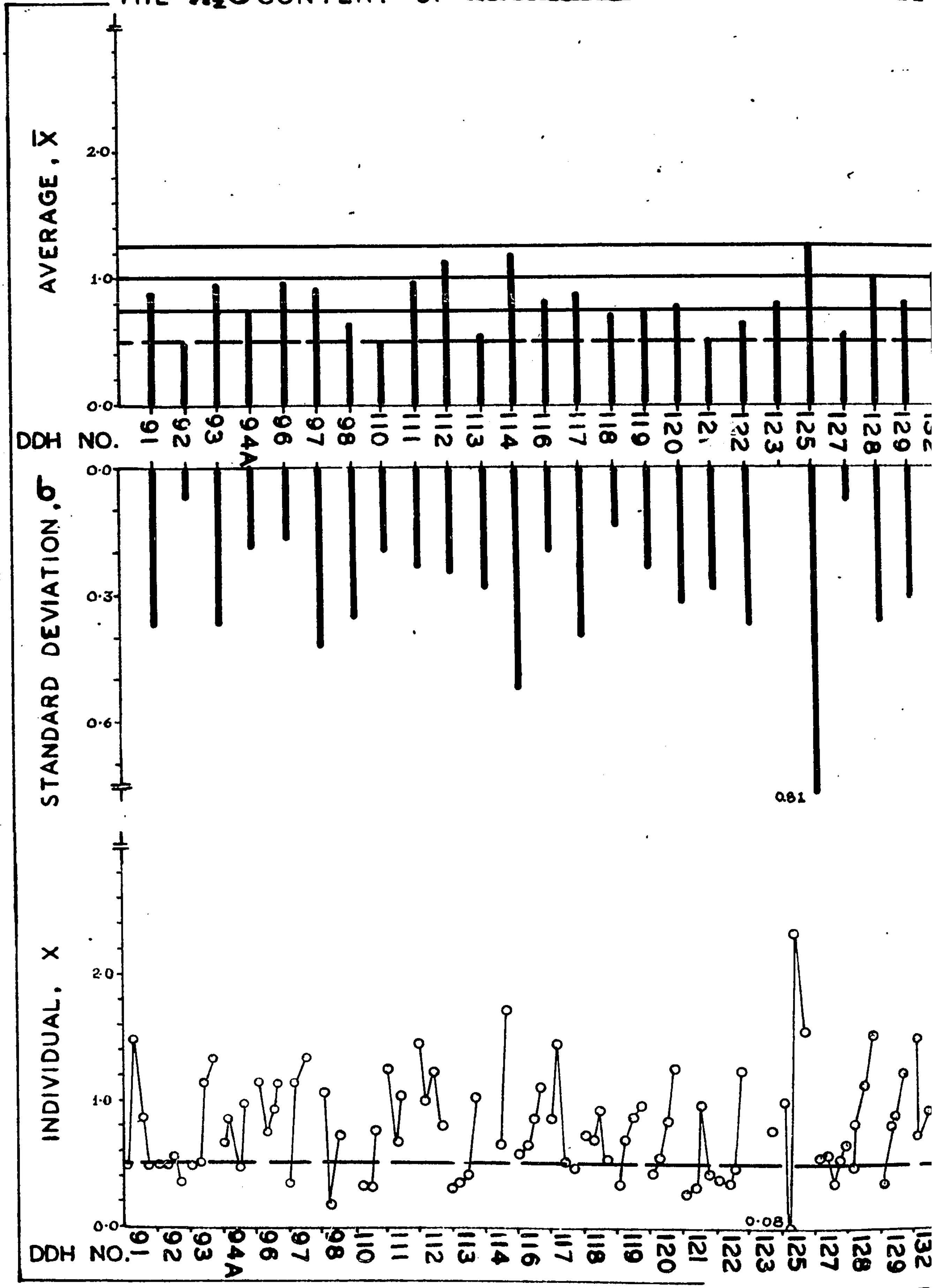


DRILL CORE (%) . NORBEC AREA
UFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127

Chart 14

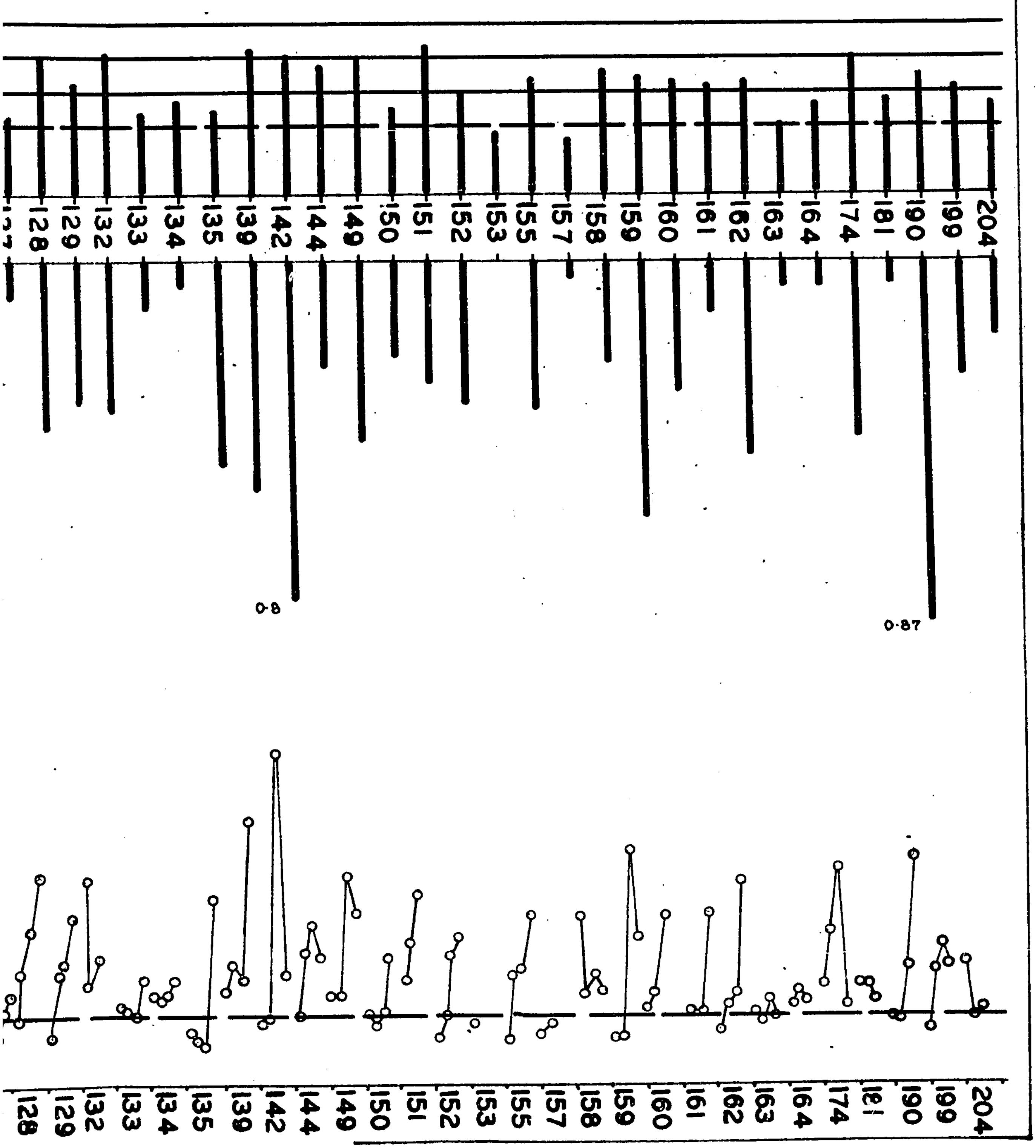
K_2O andesite

THE K_2O CONTENT OF *Andesite* IN DIAMOND DRILL



LAKE DUFAULT

DRILL CORE (%) . NORBEC AREA



JFAULT MINES LTD.

Magnesium (oxide) (MgO) Rhyolite chart 15

$\bar{\bar{x}}$	1.06%
Mo	.50%
$\bar{\sigma}$	.88%
FD	Type II
a	1.0%
b	1.5%
c	2.0%
C_A	9.4% of $\bar{x}$
R	.11

Sections of rhyolite containing unusually high amounts of MgO occur mainly near the ore body and in the northwest portion of the Norbec area.

MgO Andesite chart 16

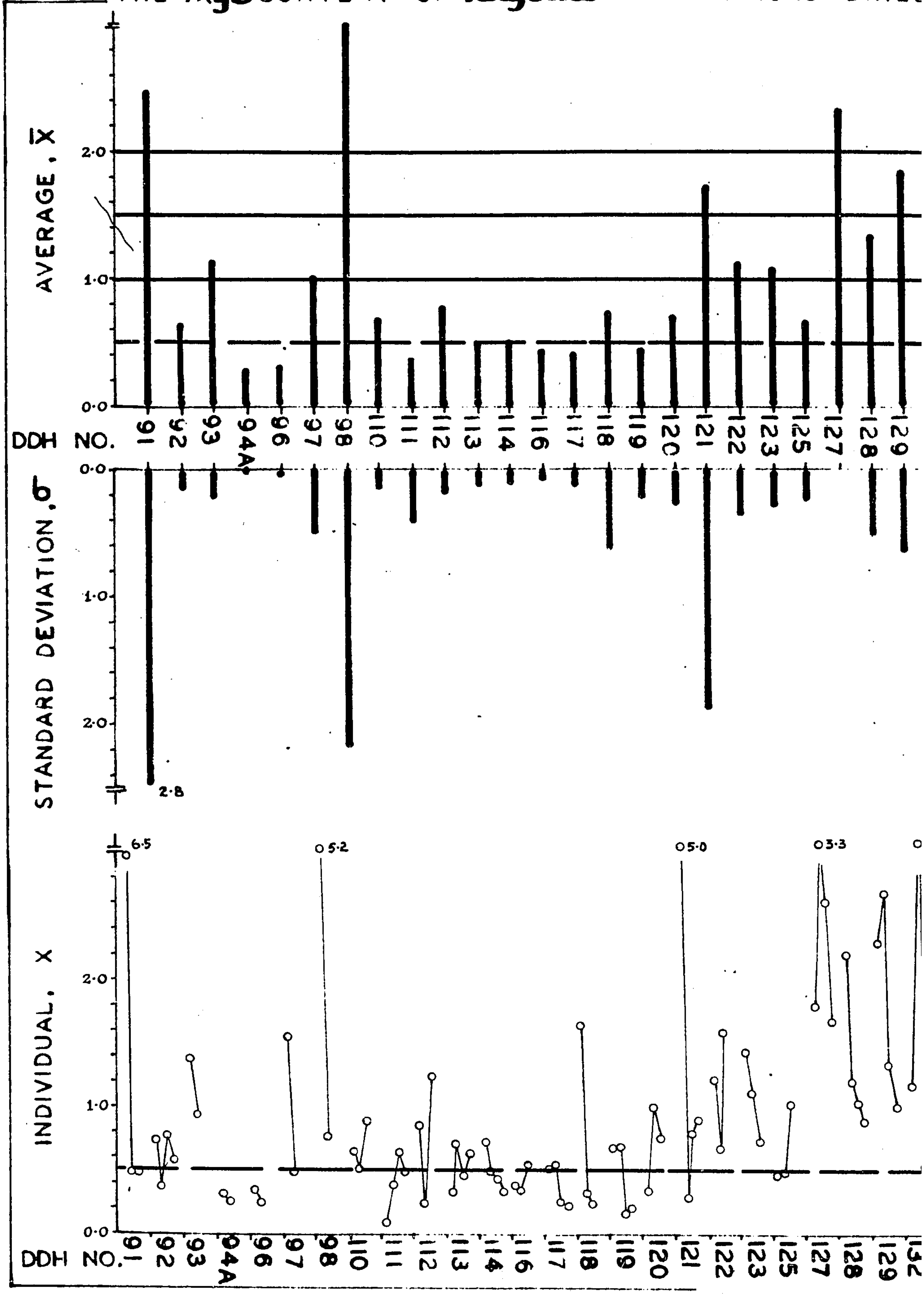
$\bar{\bar{x}}$	4.9%
Mo	5.2%
$\bar{\sigma}$	.98%
FD	Type I
ULB	4.9 + 1.5%
LLB	4.9 - 1.5%
C_A	11.1%
R	.55

Holes cutting andesite of an unusually high MgO content are 132, 163 and 204, all in the vicinity of the ore body. Andesite of unusually low MgO content was cut by holes 96, 120 and 158, all far away from known ore.

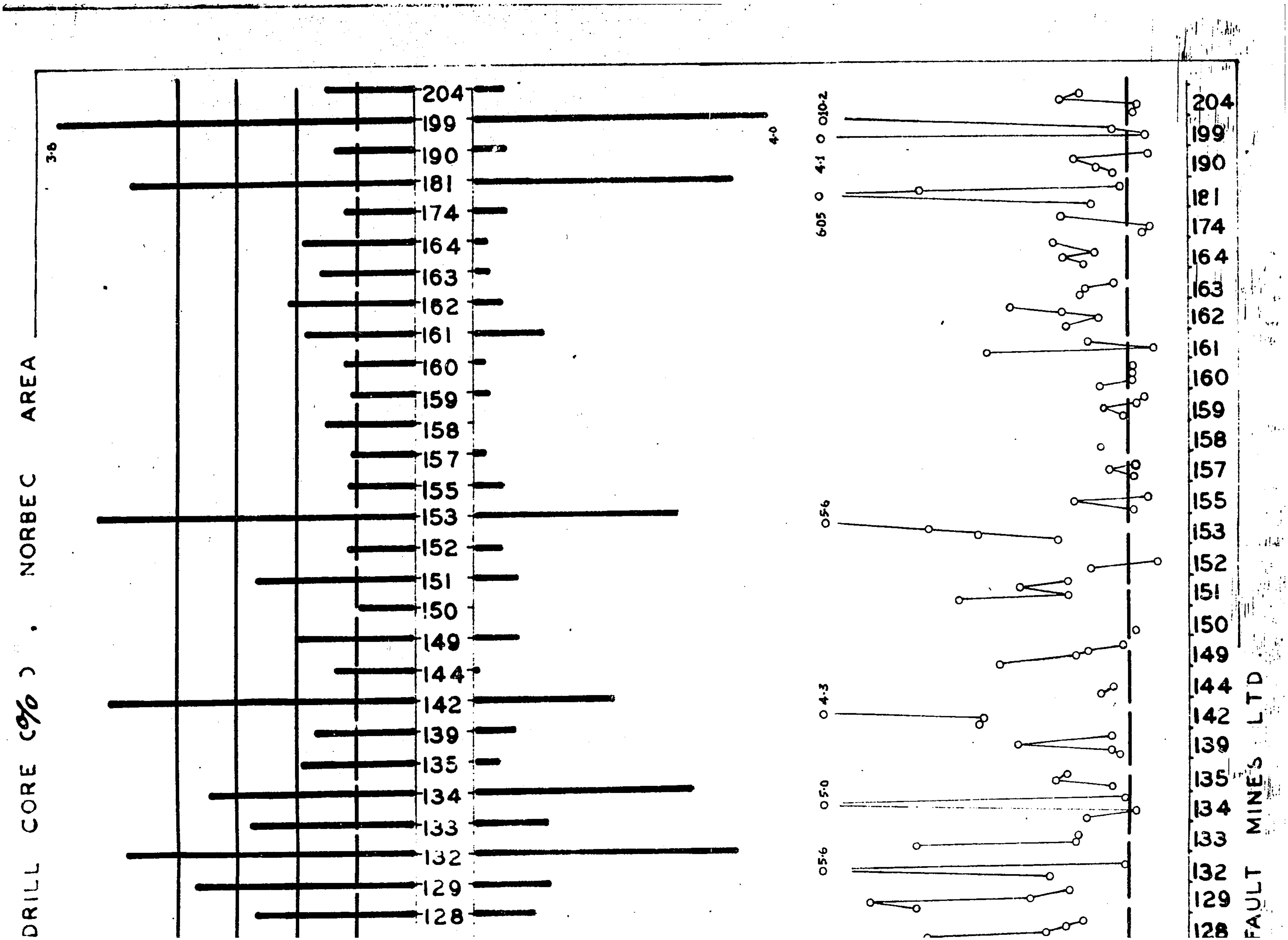
Chart 15

MgO rhyolite

THE MgO CONTENT OF Rhyolite IN DIAMOND DRILL



LAKE DUFAULT



DRILL CORE (%) . NORBEC AREA
FAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
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152
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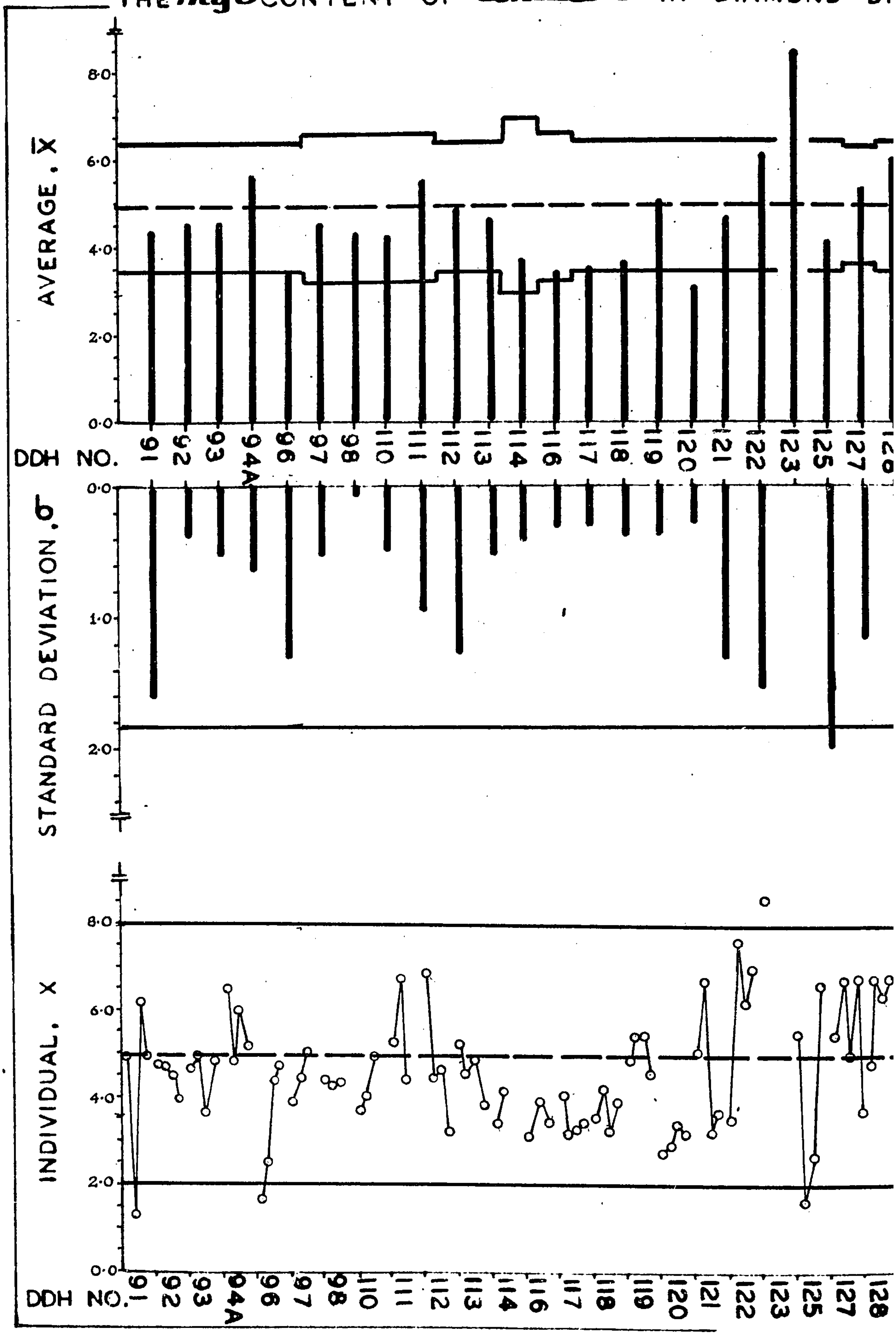
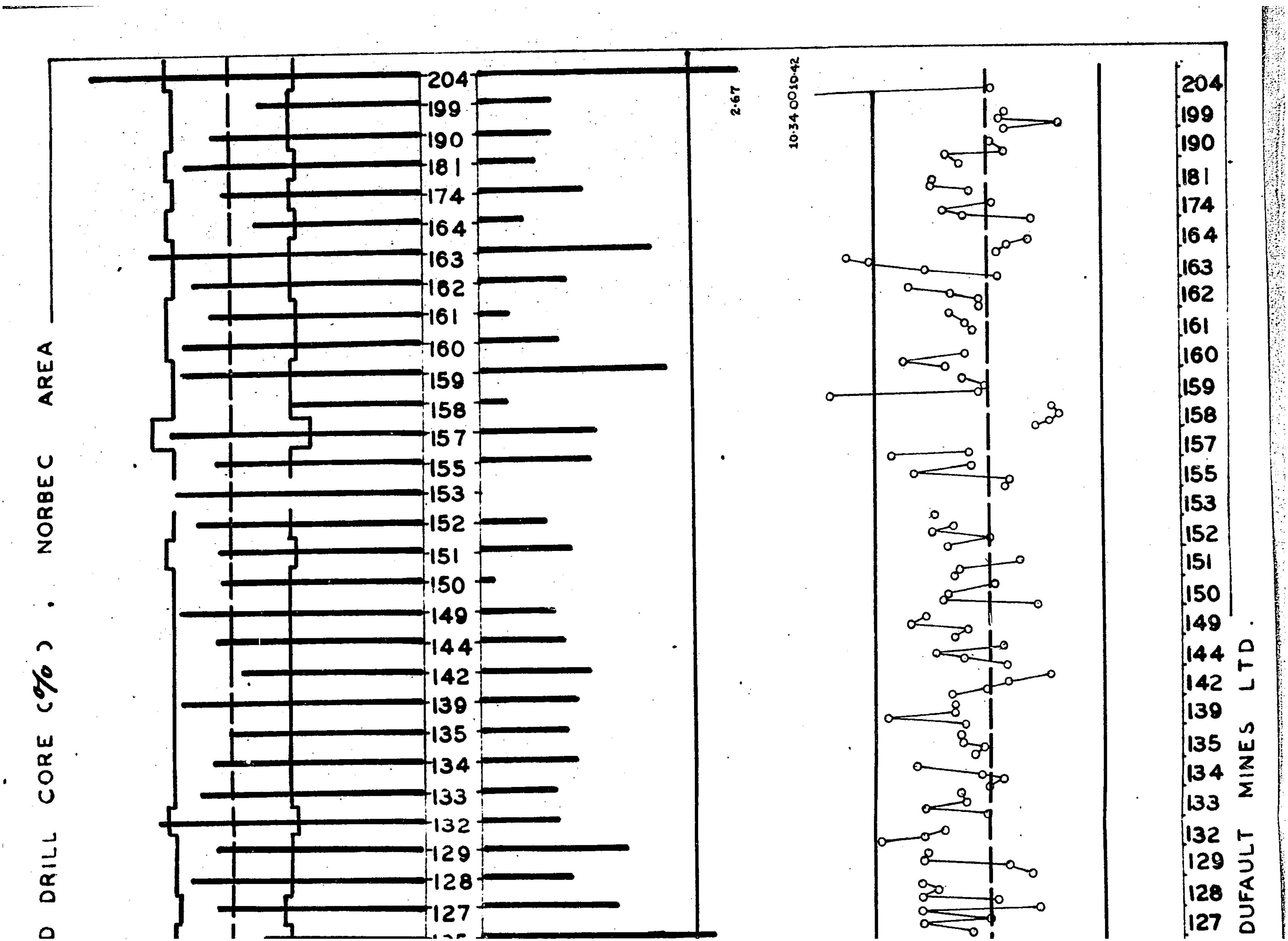
150
149
144
142
139
135
134
133
132
129
128
3·8
4·0
10·2
4·1
6·05
5·6
4·3
5·0
5·6

THE *MgO* CONTENT OF *Andesite* IN DIAMOND DR



LAKE DUFA


D DRILL CORE (%) . NORBEC AREA
DUFAULT MINES LTD.
204
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174
164
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135
134
133
132
129
128
127
2·67
10·34 0010·42

Sodium (oxide) (Na_2O) Rhyolite chart 17

$\bar{\bar{x}}$	3.13%
Mo	2.70%
$\bar{\sigma}$	0.73%
FD	Type III
a	3.3%
b	4.4%
-a	1.7%
-b	0.5%
C_A	20.9% of $\bar{x}$
R	0.90

Mineralized rhyolite near known ore contains unusually low amounts of Na_2O. Rhyolite containing amounts of Na_2O slightly greater than usual is cut by several drill holes in the Norbec area.

Na_2O Andesite chart 18

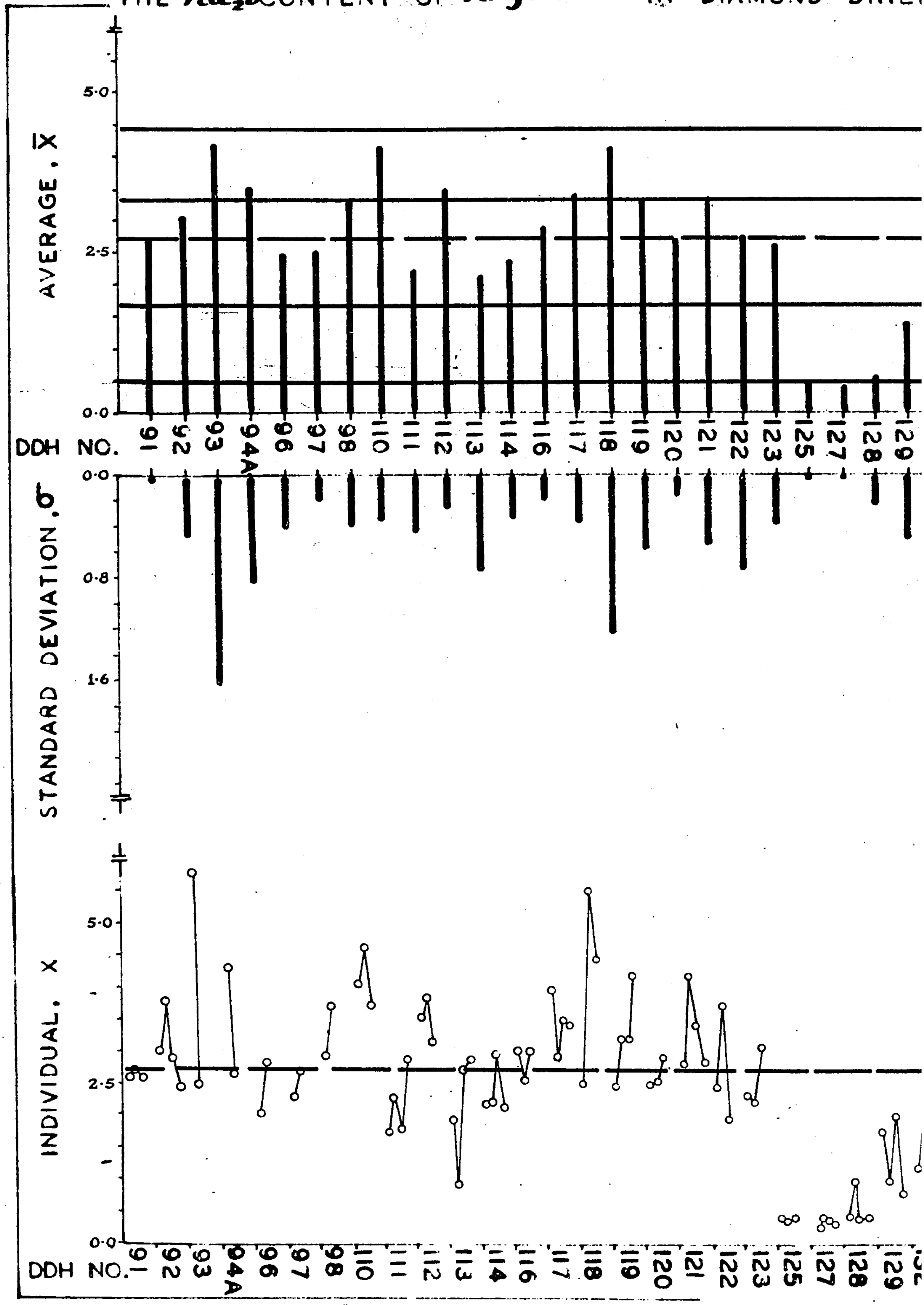
$\bar{\bar{x}}$	2.84%
Mo	2.9%
$\bar{\sigma}$	.57%
FD	Type I
ULB	2.84 + .85%
LLB	2.84 - .85%
R	.55

Only hole 97 cuts andesite which contains an unusually large amount of Na_2O.

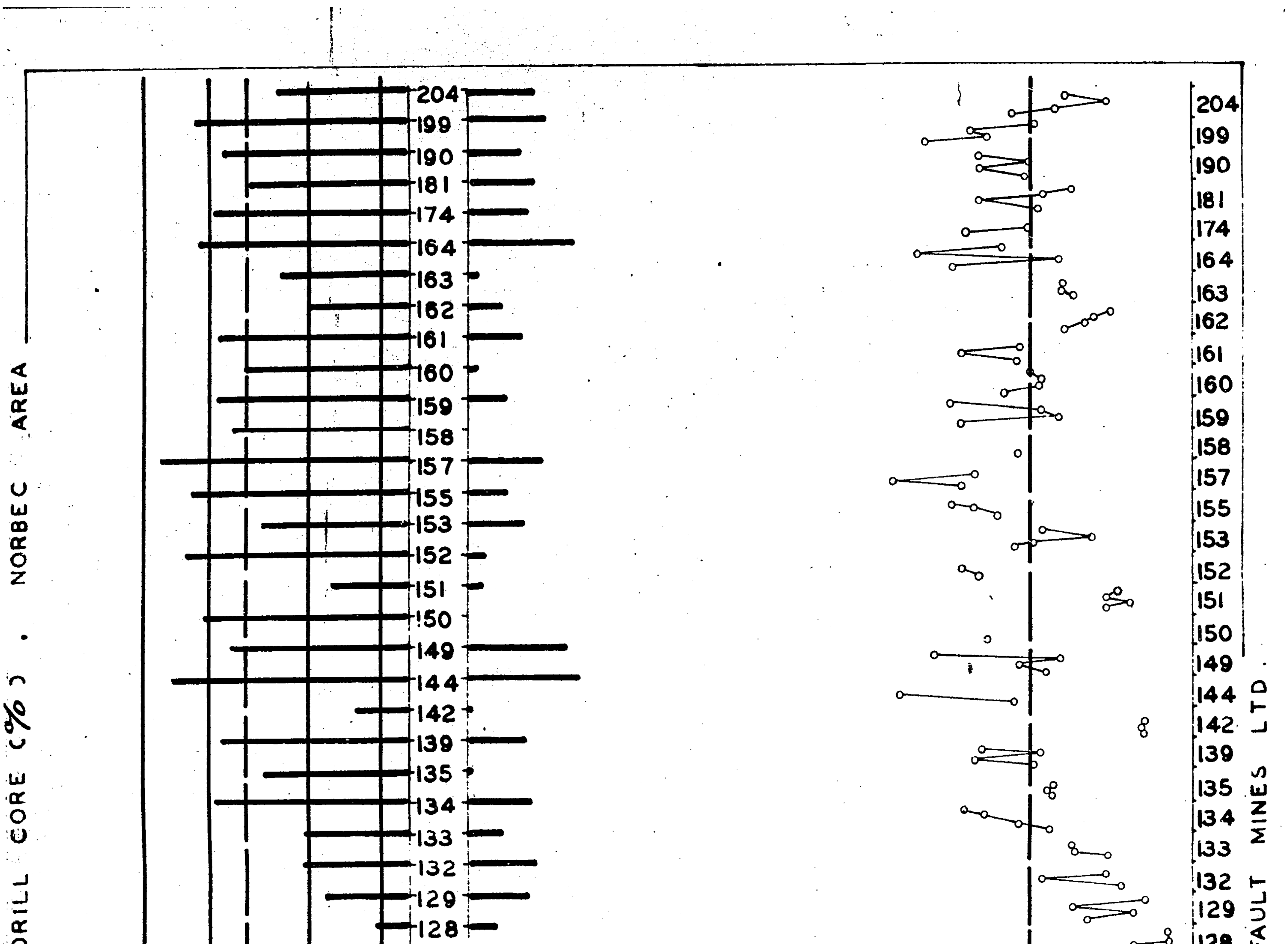
Chart 17

Na_2O rhyolite

THE Na_2O CONTENT OF *Rhyolite* IN DIAMOND DRILL



LAKE DUFAULT



RILL CORE (%) . NORBEC AREA
AULT MINES LTD.
204
199
190
181
174
164
163
162
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152
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150
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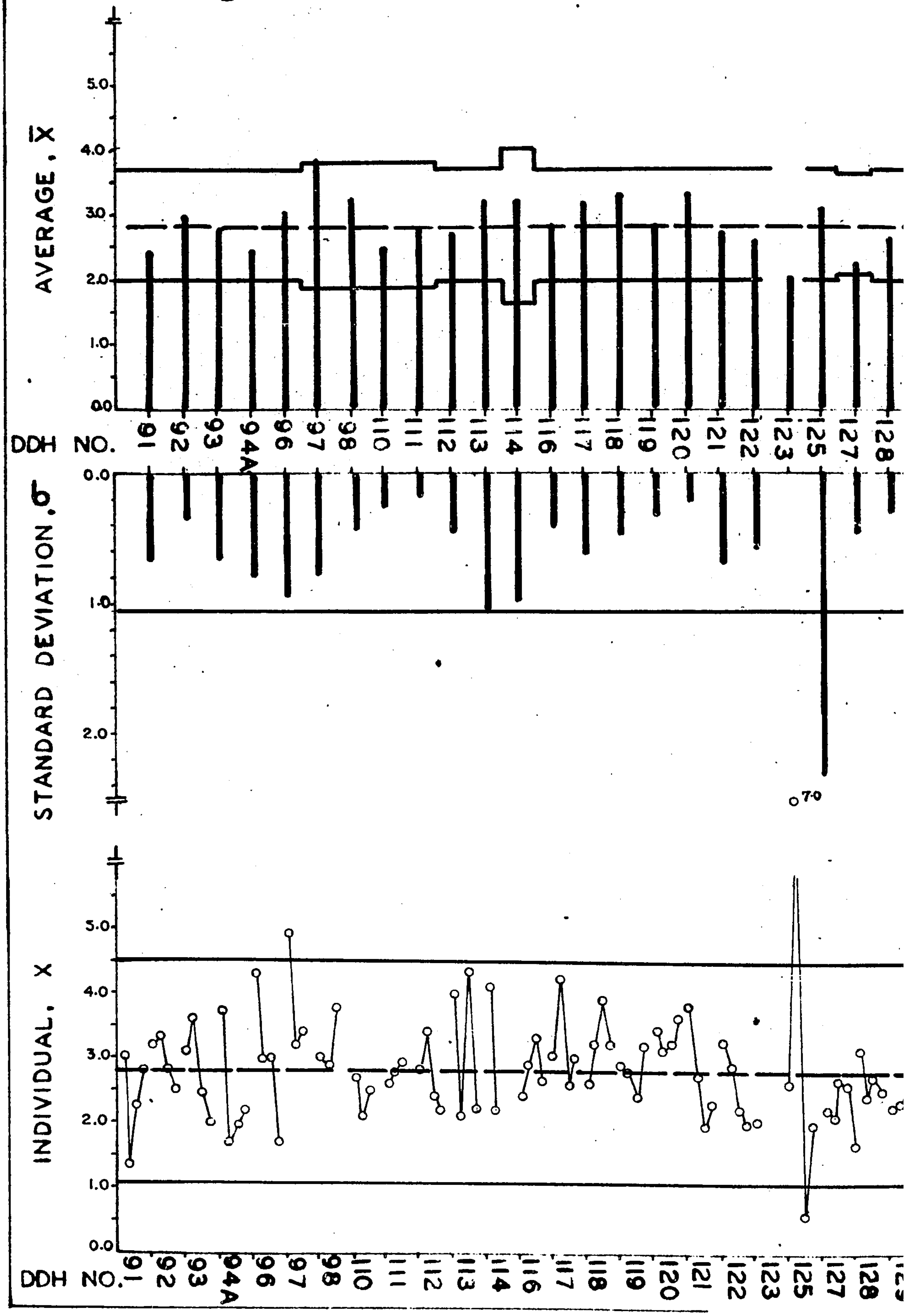
135
134
133
132
129
128

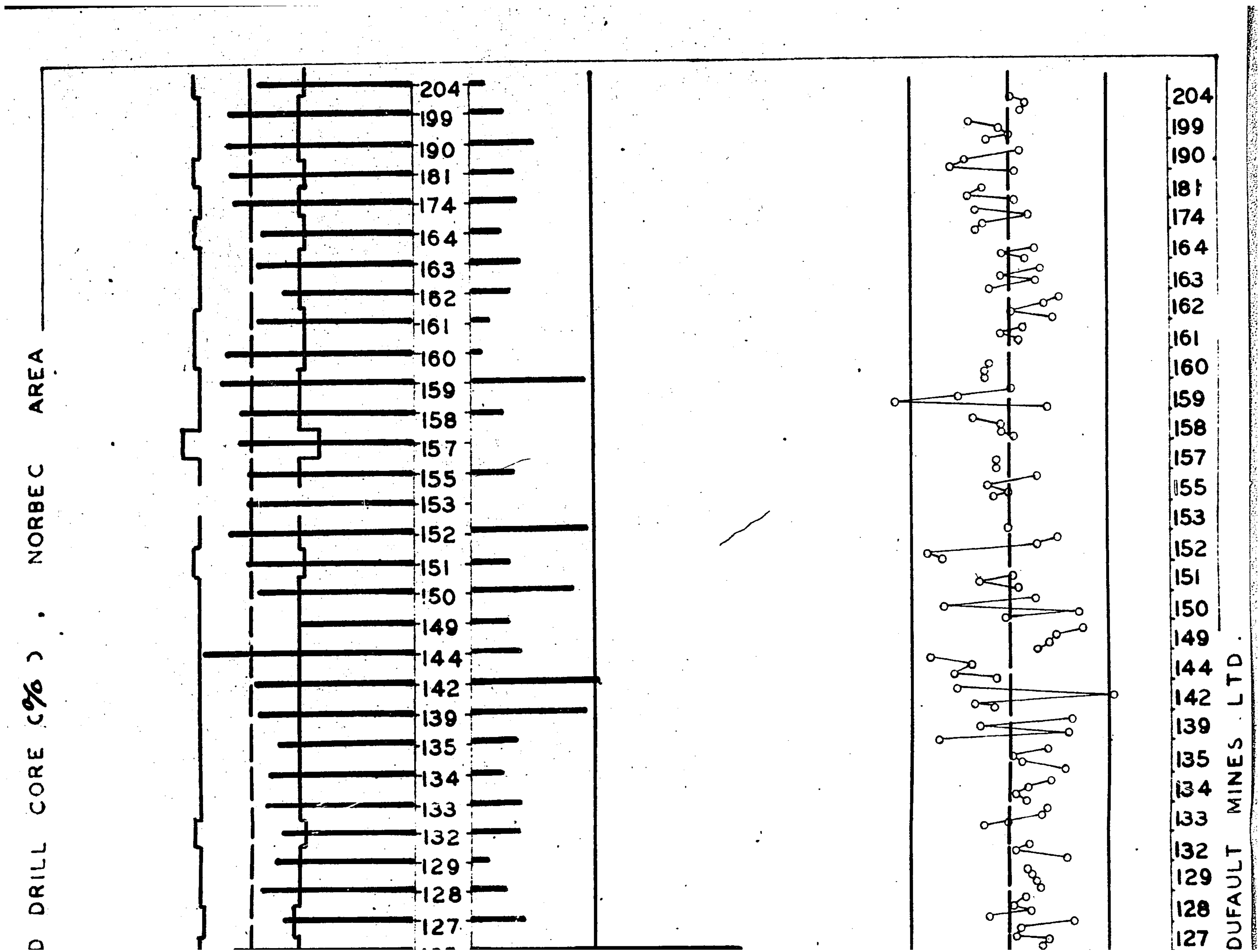
Chart 18

Na_2O andesite

THE Na_2O CONTENT OF *Andesite* IN DIAMOND DR



LAKE DUFAU


D DRILL CORE (%) NORBEC AREA
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
DUFAULT MINES LTD.

Silver (Ag) Rhyolite chart 19

$\bar{\bar{x}}$	.38ppm
Mo	.17ppm
$\bar{\sigma}$	.23ppm
FD	Type II
a	.4ppm
b	.8ppm
C_A	24.8% of $\bar{\bar{x}}$
R	.42

Only two drill holes away from the ore body cut rhyolite with an extra high content of Ag (97, 116). All holes at the ore body and to the south except 133, 135 and 174 cut rhyolite containing 0.4ppm Ag or more.

Ag Andesite chart 20

$\bar{\bar{x}}$	.24ppm
Mo	.18ppm
$\bar{\sigma}$	.10ppm
FD	Type II
a	.35ppm
b	.50ppm
c	1.00ppm
C_A	53.7% of $\bar{\bar{x}}$
R	1.1

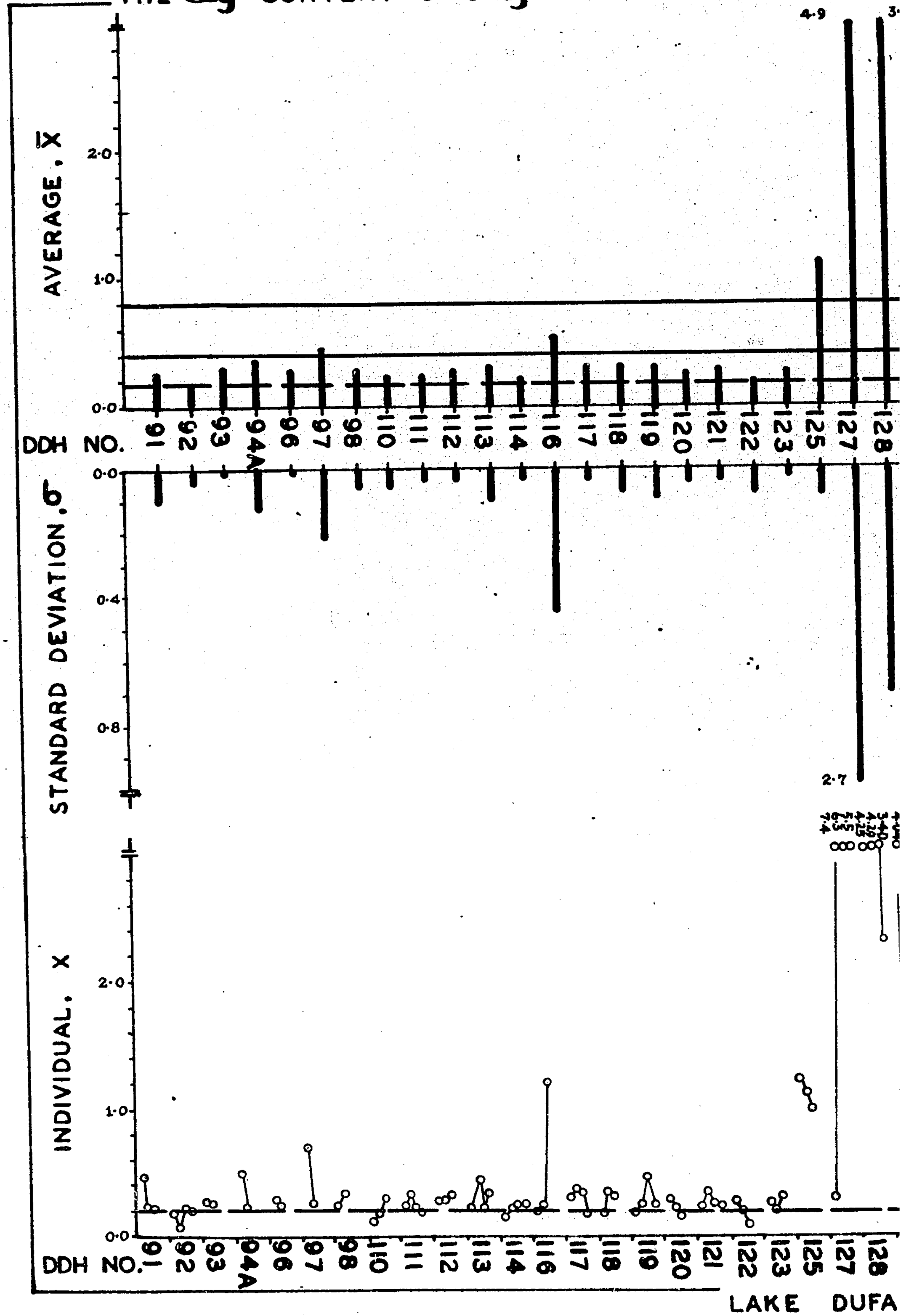
Only one hole far away from the ore body (150) cuts andesite high in Ag.

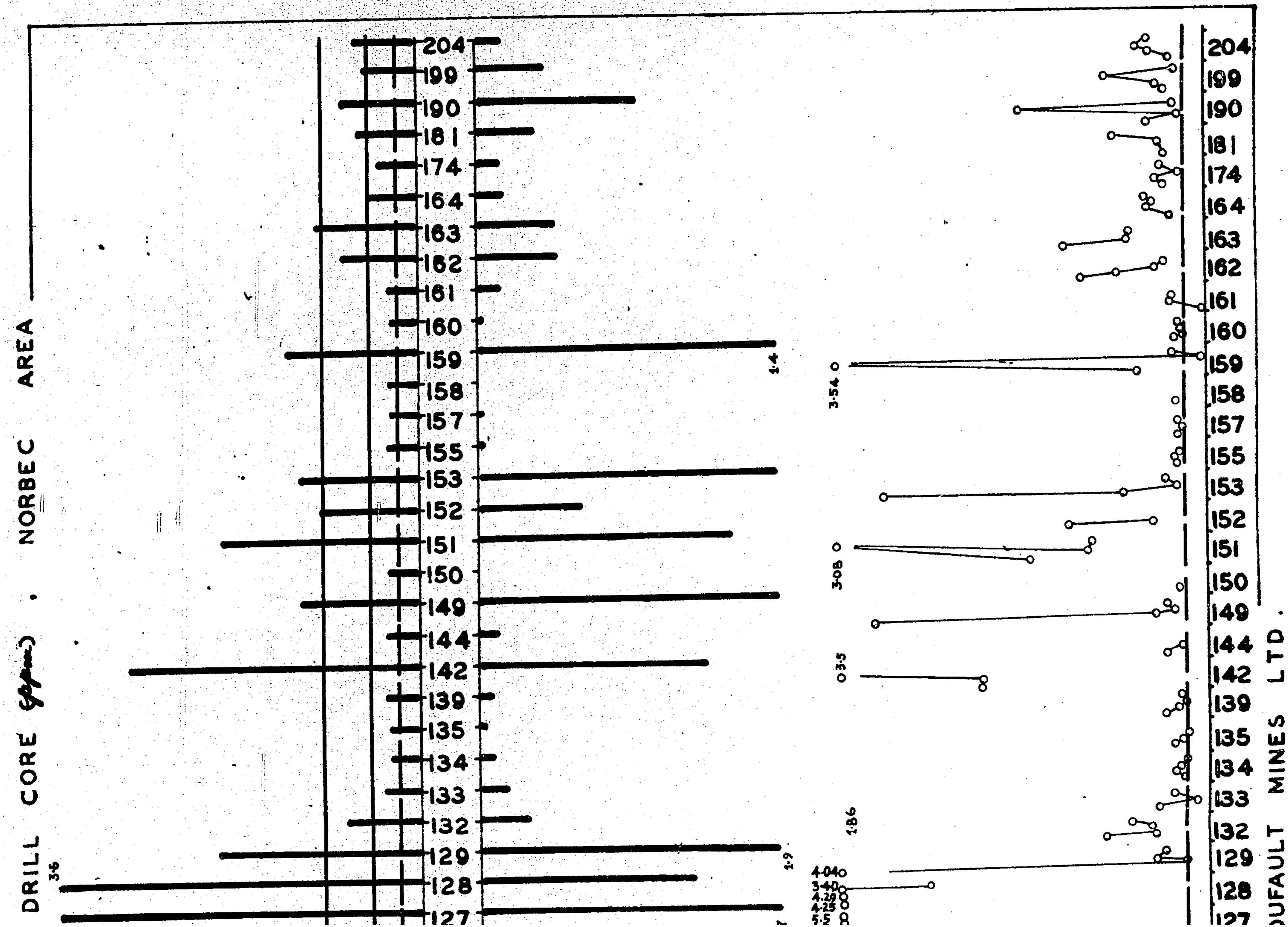
All holes over the ore body except numbers 133 and 128 contain abnormally large amounts of Ag. Here, some andesite samples taken from holes 125 and 129 contain over 2ppm Ag. All other anomalous holes close to the ore body are located to the south.

Chart 19

Ag rhyolite

THE Ag CONTENT OF Rhyolite IN DIAMOND DRI




DRILL CORE (Gypsum) . NORBEC AREA
DUFAULT MINES LTD.
204
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174
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163
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161
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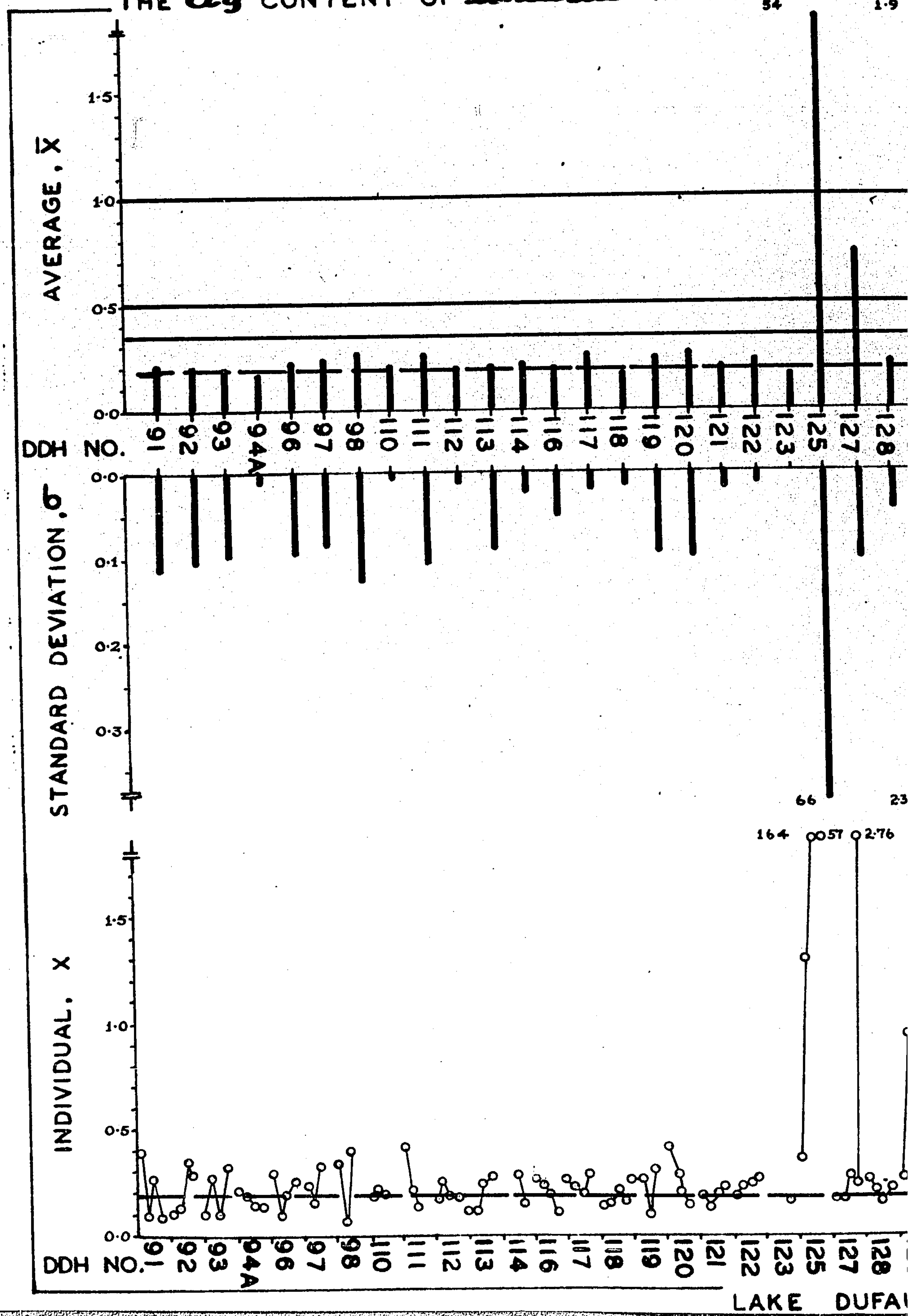
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
1·4
3·54
3·08
3·5
1·86
1·9
3·6
4·04
3·40
4·29
4·25
5·5

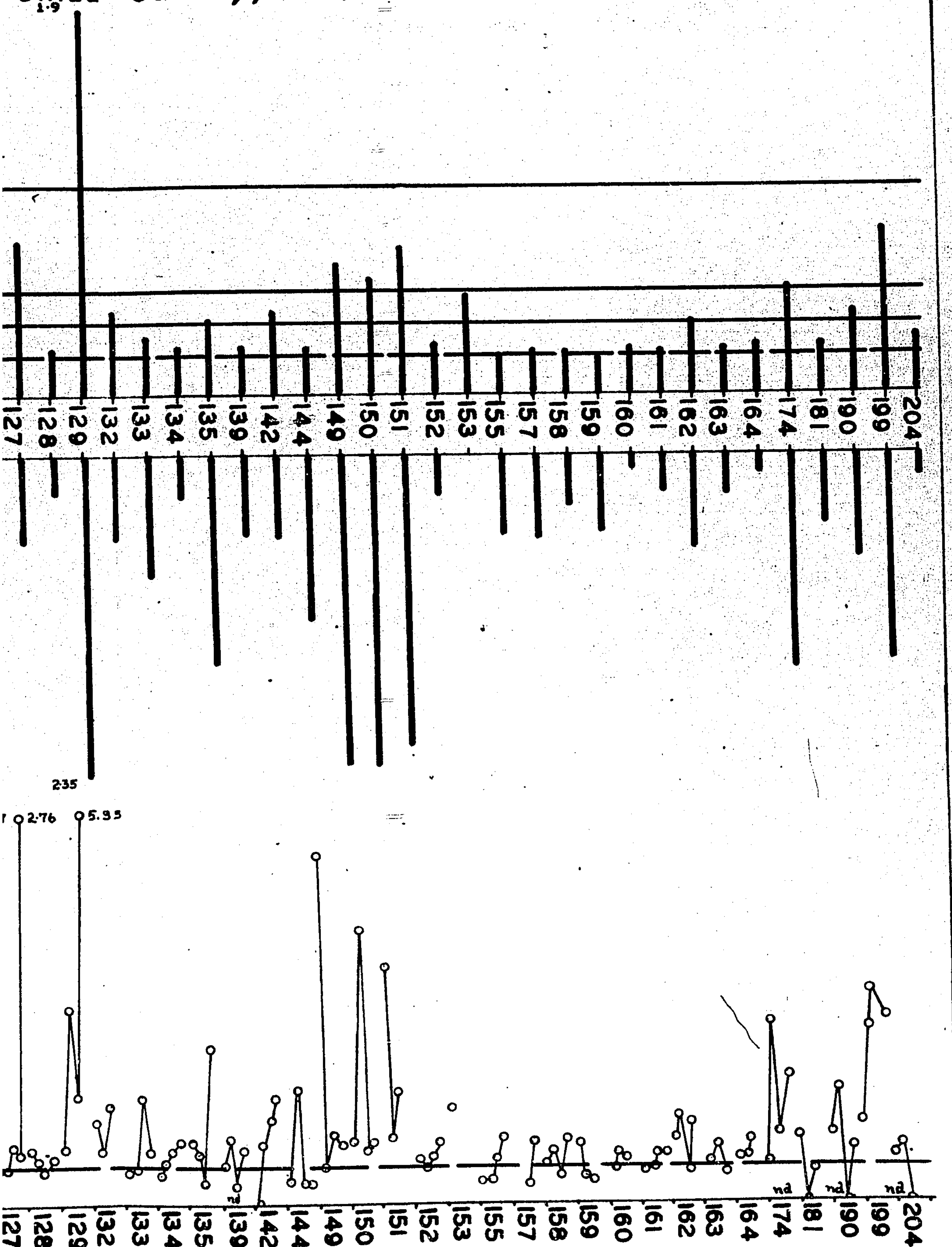
Chart 20

Ag andesite

THE Ag CONTENT OF Andesite IN DIAMOND DRI



DRILL CORE (alpine) . NORBEC AREA



DUFAULT MINES LTD.

Cobalt (Co) Rhyolite chart 21

C_A 20.9% of $\bar{x}$
(Detection limits approximately 1 ppm)

Most of the rhyolite samples contain less than detectable (nd: not detectable) amounts of Co. Those which do contain detectable amounts are anomalous and generally occur next to the main contact and near the ore body.

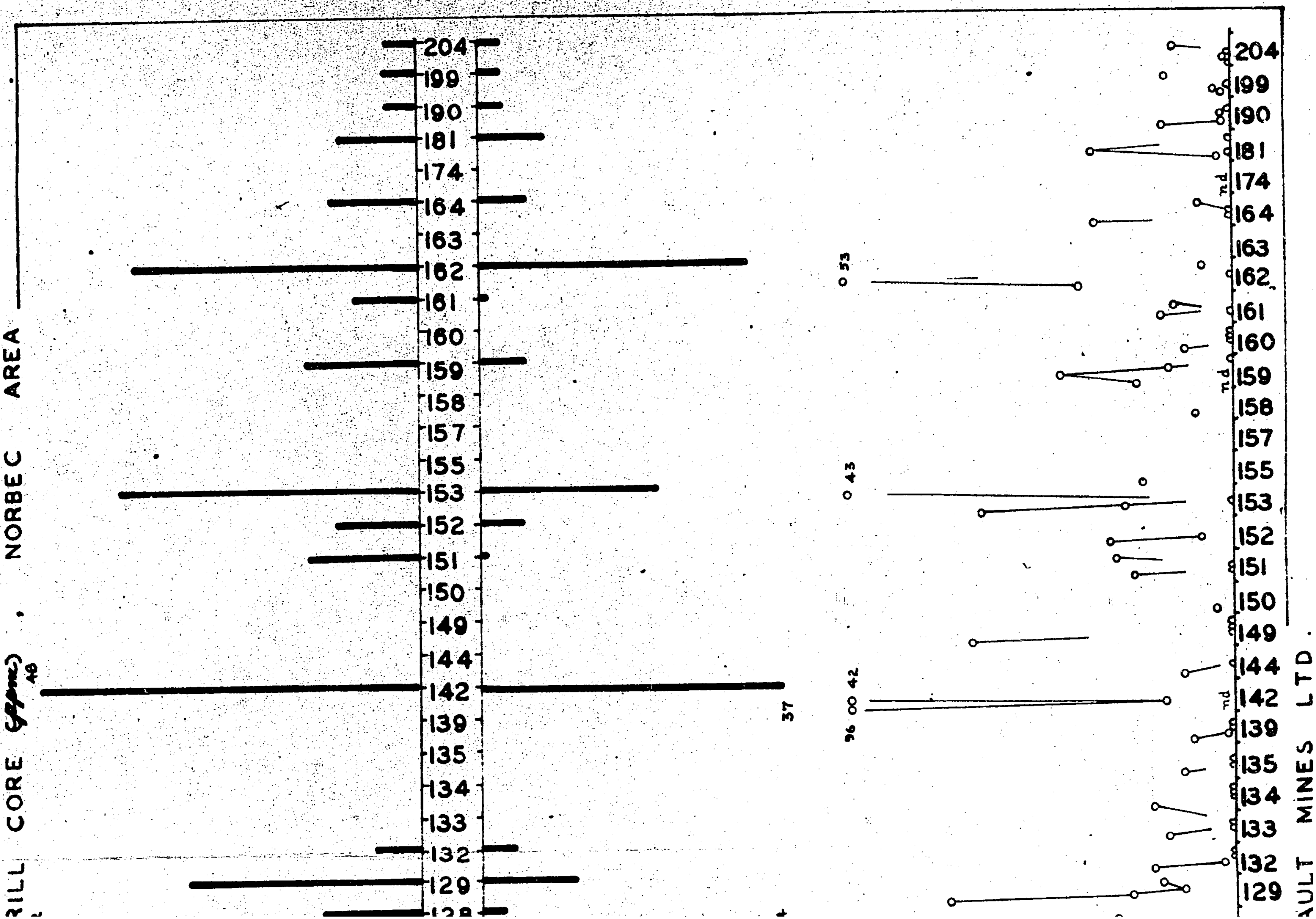
Co Andesite chart 22

$\bar{\bar{x}}$	53.8ppm
Mo	43.0ppm
$\bar{\sigma}$	15.8ppm
FD	Type II
a	63ppm
b	80ppm
C_A	13.9% of $\bar{x}$
R	.48

Andesite samples from some scattered drill holes away from and over the ore body have an unusually high Co content.

Chart 21

Co rhyolite



DRILL CORE (ppm) NORBEC AREA
204
199
190
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174
164
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162
161
160
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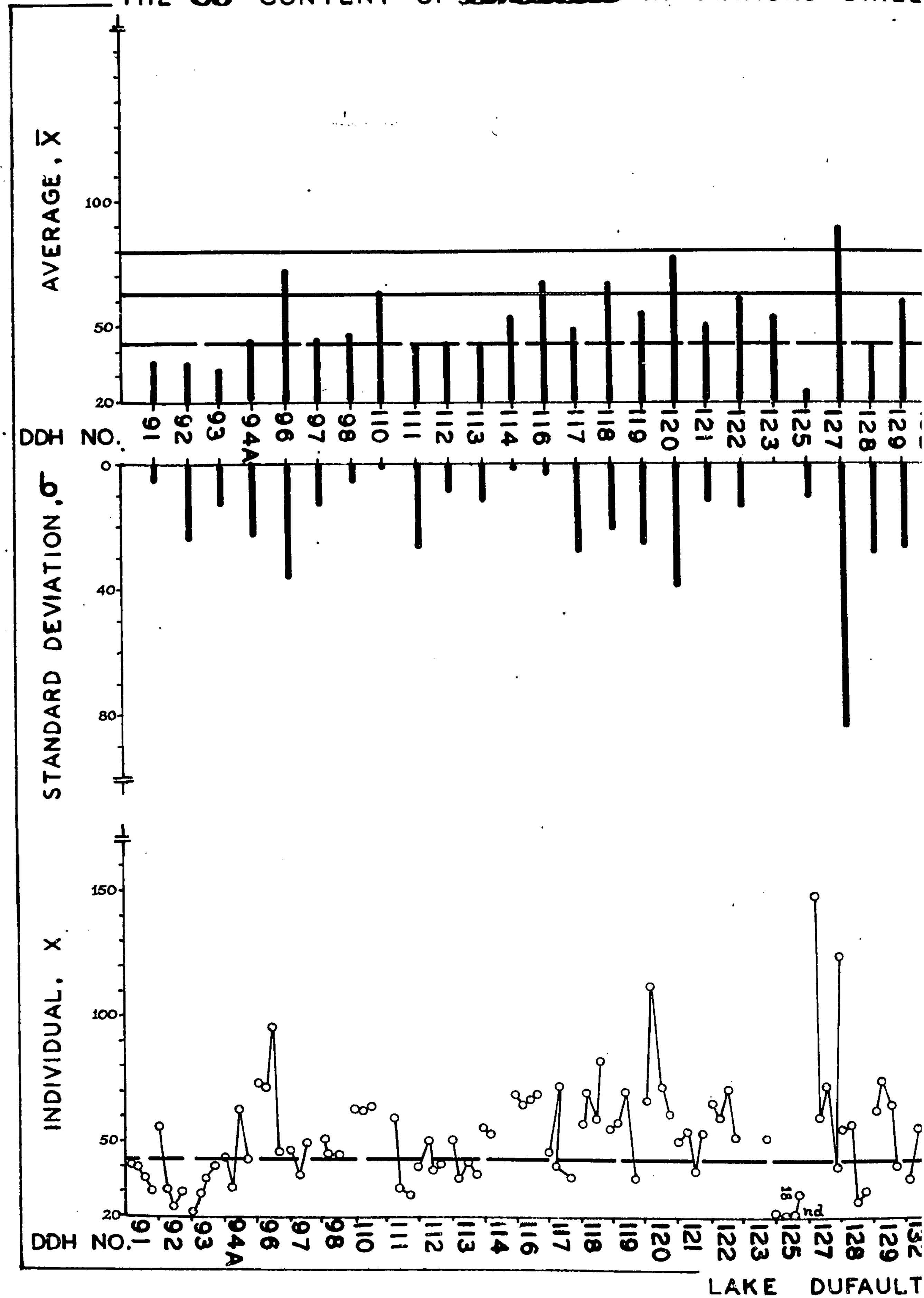
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
53
43
42
96
37
nd
...AULT MINES LTD.

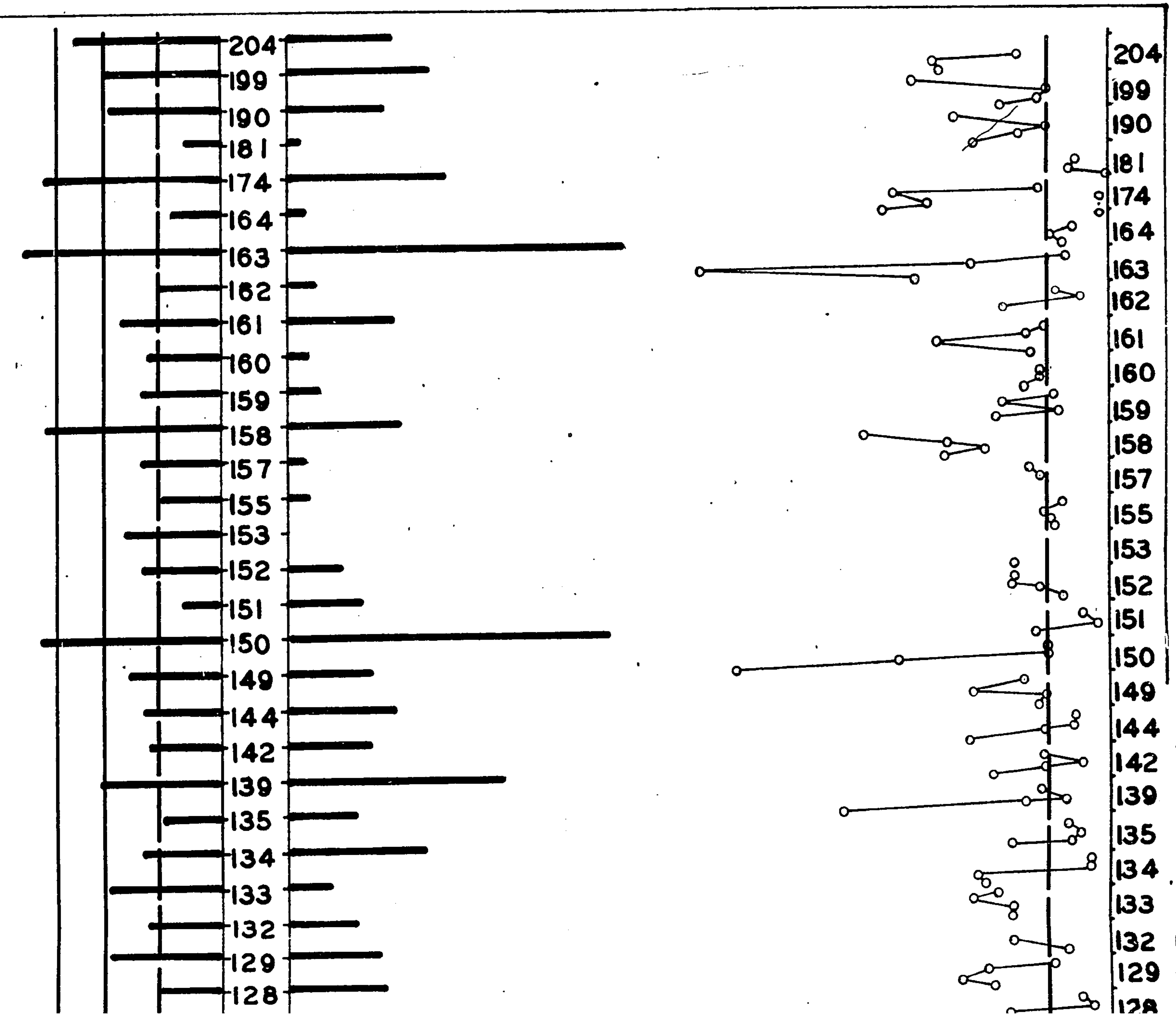
Chart 22

Co andesite

THE Co CONTENT OF Andesite IN DIAMOND DRILL



DRILL CORE (Gypsum) . NORBEC AREA



FAULT MINES LTD.

Chromium (Cr) Rhyolite chart 23

C_A 27.5% of $\bar{x}$
(Detection limit approximately 40ppm)

Most of the rhyolite samples contain less than detectable amounts of Cr. Those that contain greater than 40ppm are often the closest to the main contact and the ore body.

Cr Andesite chart 24

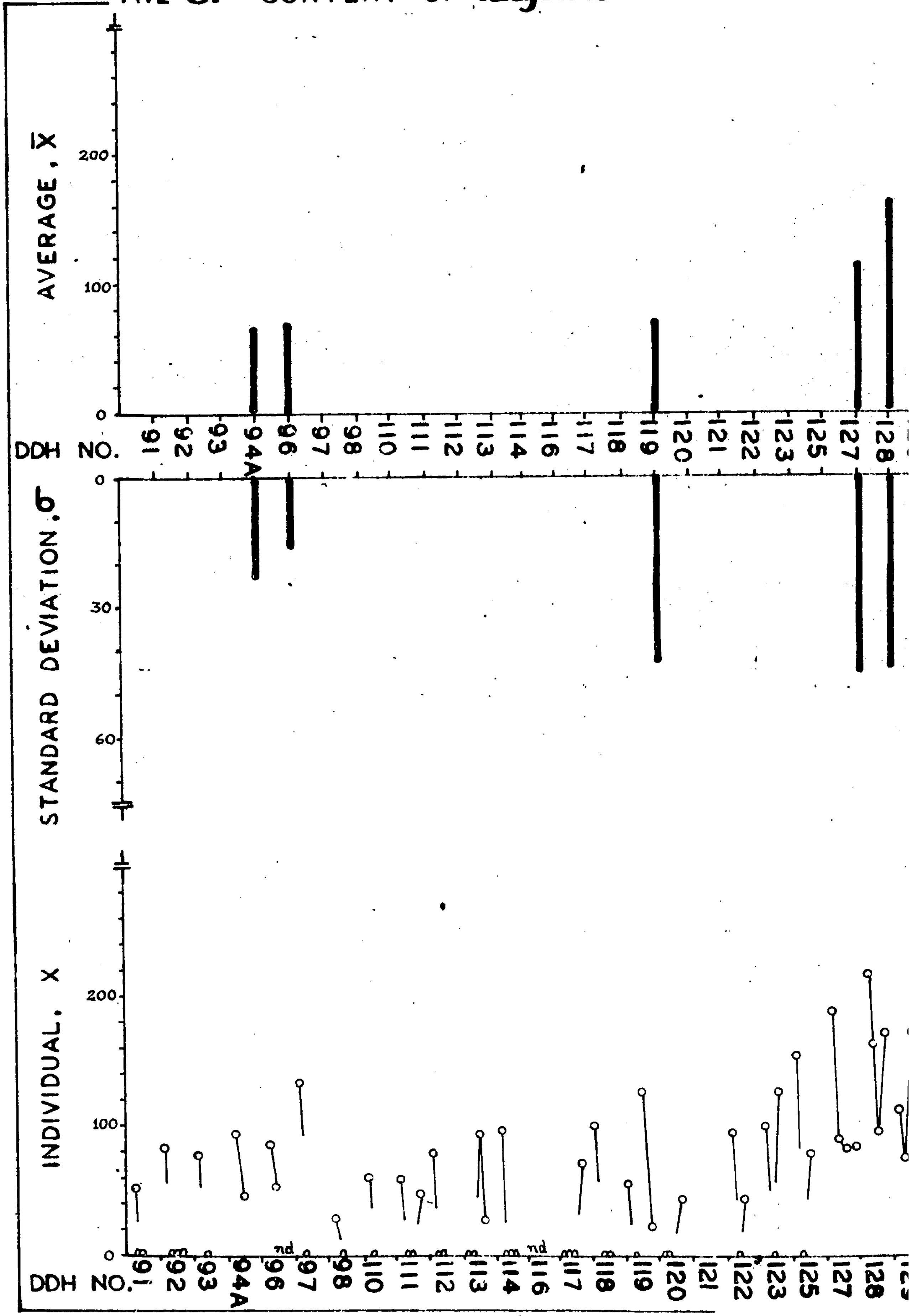
$\bar{\bar{x}}$	197ppm
Mo	155ppm
$\bar{\sigma}$	58ppm
FD	Type II
a	240ppm
b	300ppm
C_A	13.6% of $\bar{x}$
R	.46

Only scattered sections of andesite contain abnormally large amounts of Cr.

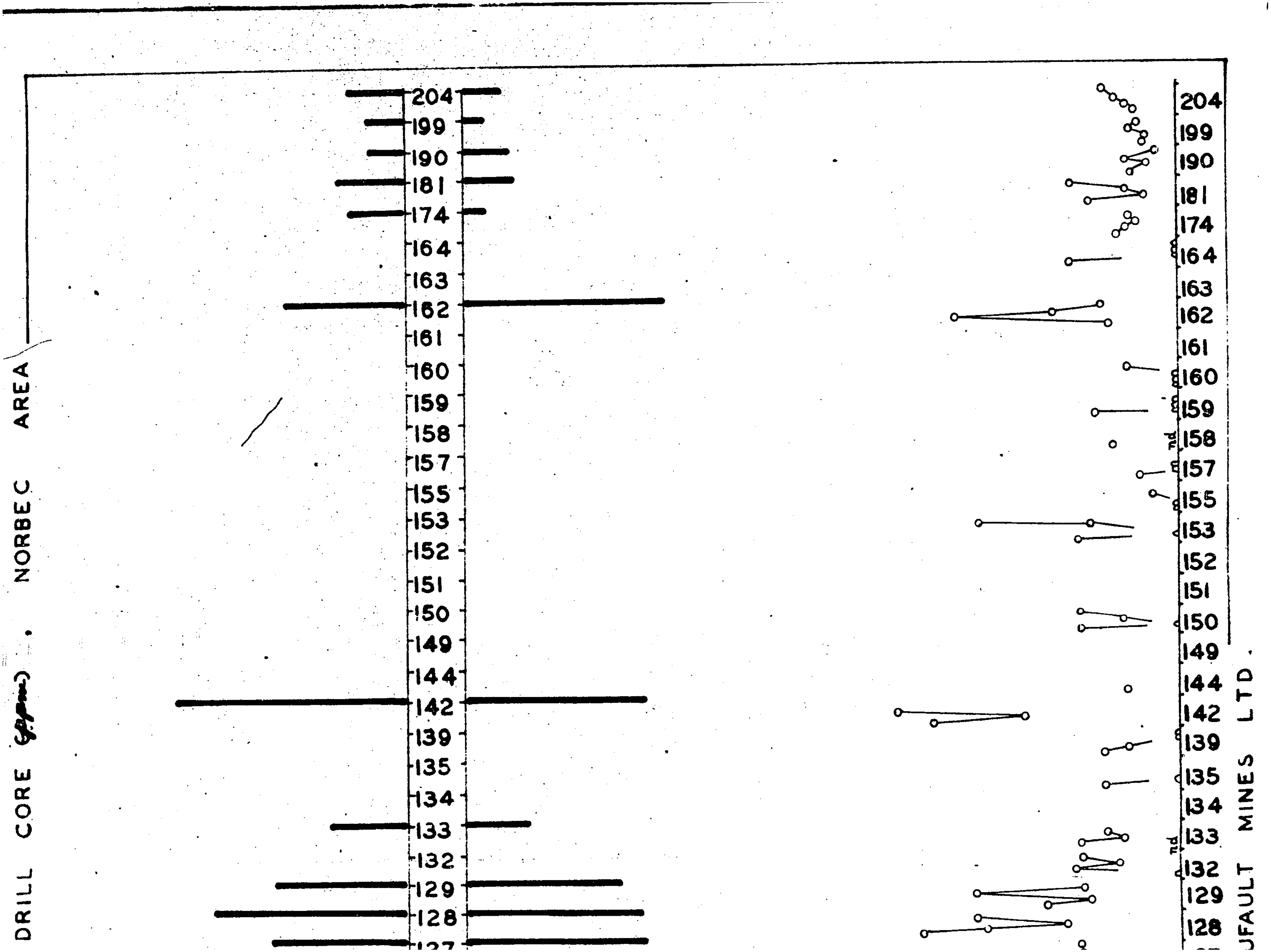
Chart 23

Cr rhyolite

THE Cr CONTENT OF Rhyolite IN DIAMOND DRI



LAKE DUFAU



DRILL CORE
NORBEC AREA
FAULT MINES LTD
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
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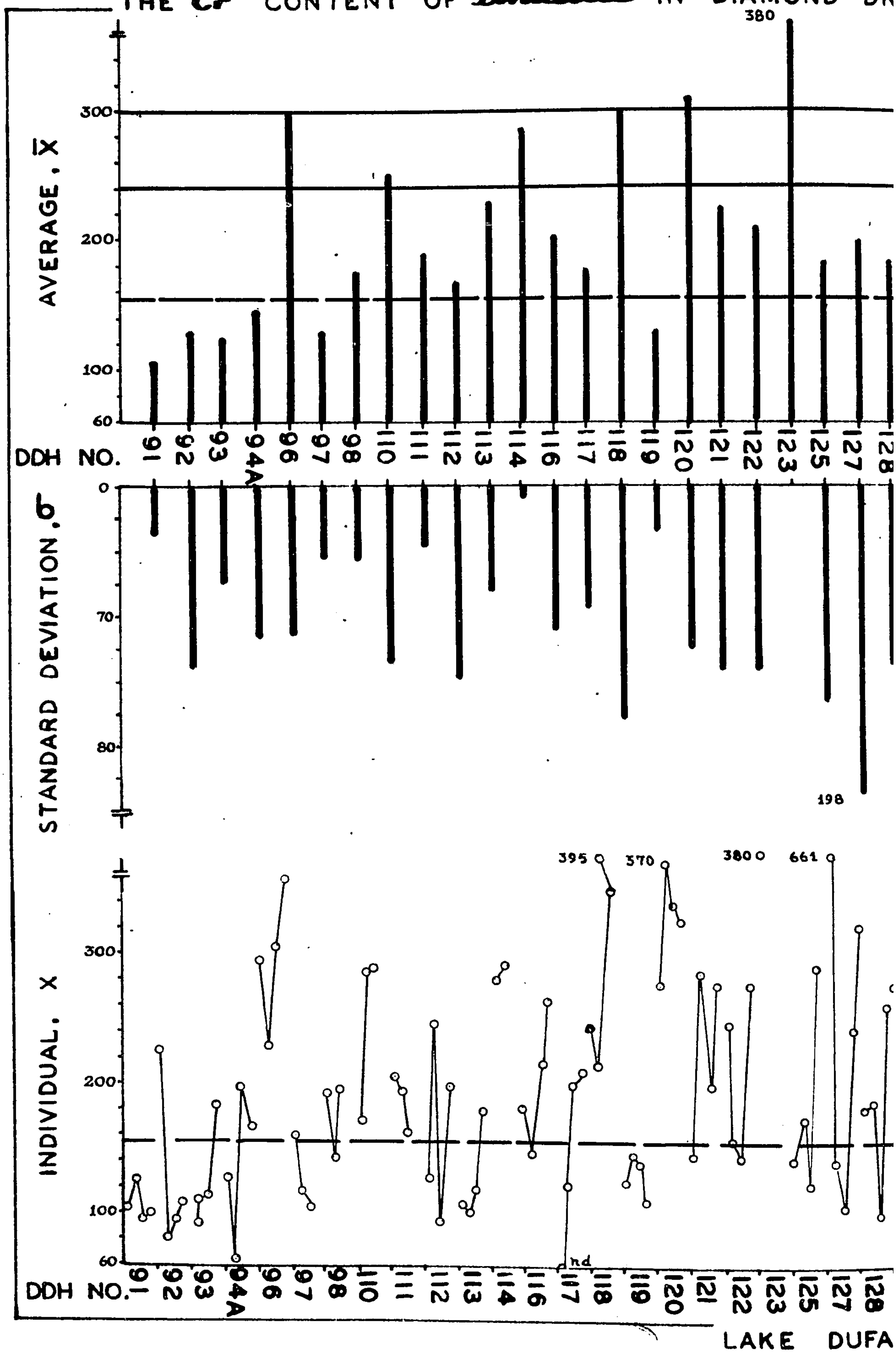
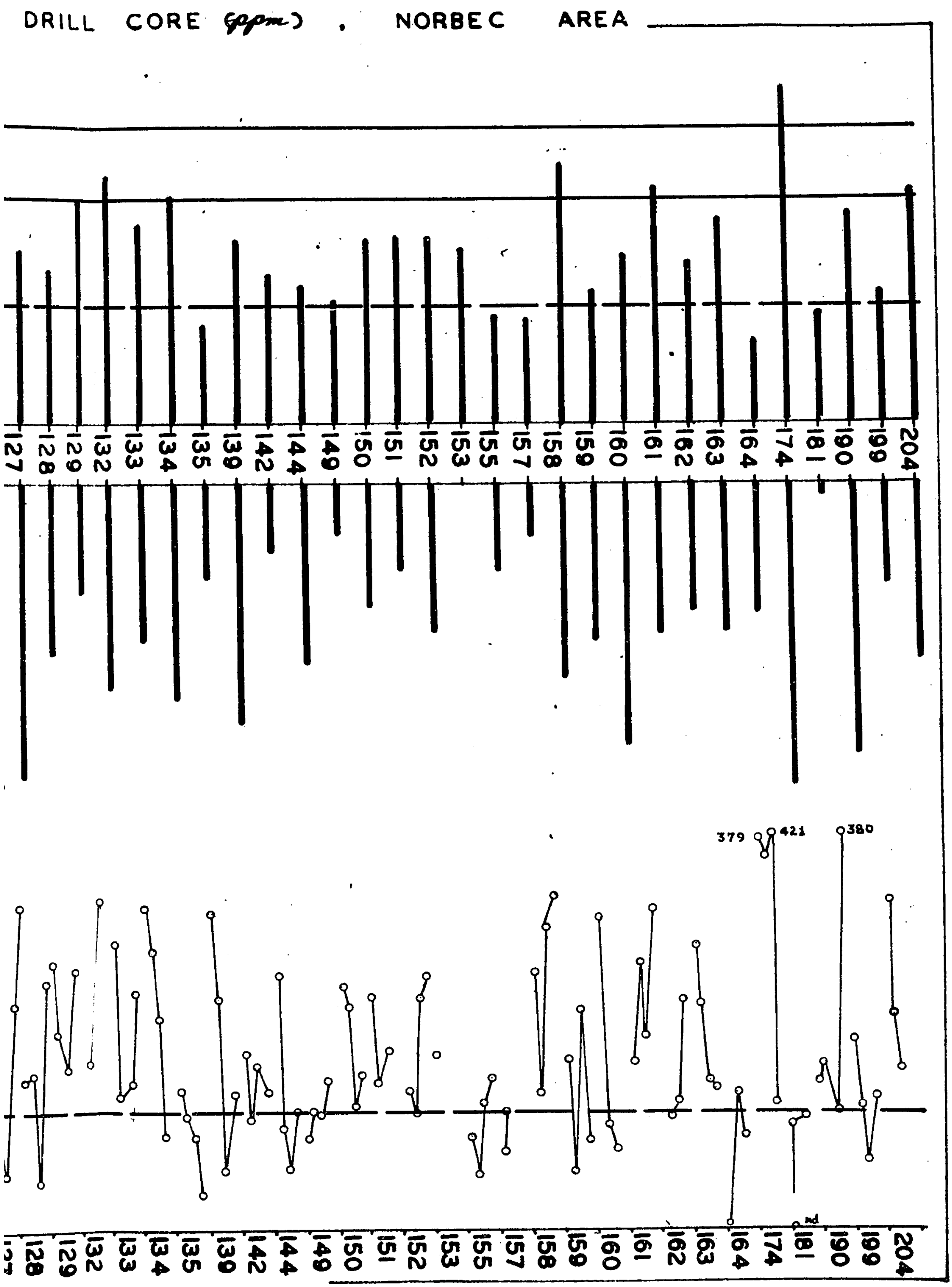
135
134
133
132
129
128

Chart 24

Cr andesite

THE Cr CONTENT OF Andesite IN DIAMOND DR




DRILL CORE (ppm) . NORBEC AREA
127
128
129
132
133
134
135
139
142
144
149
150
151
152
153
155
157
158
159
160
161
162
163
164
174
181
190
199
204
379
421
380
nd
UFAULT MINES LTD.

Copper (Cu) Rhyolite chart 25

$\bar{\bar{x}}$	104ppm
Mo	20ppm
$\bar{\sigma}$	73ppm
FD	Type V
a	80ppm
b	150ppm
c	225ppm
C_A	20.4% of $\bar{\bar{x}}$
R	.29

Holes 96 and 97 in the northwest corner of the property cut rhyolite containing unusually large amounts of Cu. Number 123 cuts rhyolite with a high Cu content. Some holes in the vicinity of the ore body cut rhyolite containing high amounts of Cu. Of these the most significant are numbers 134, 135, 139, 144, 152, 153, 159 and 162.

Cu Andesite chart 26

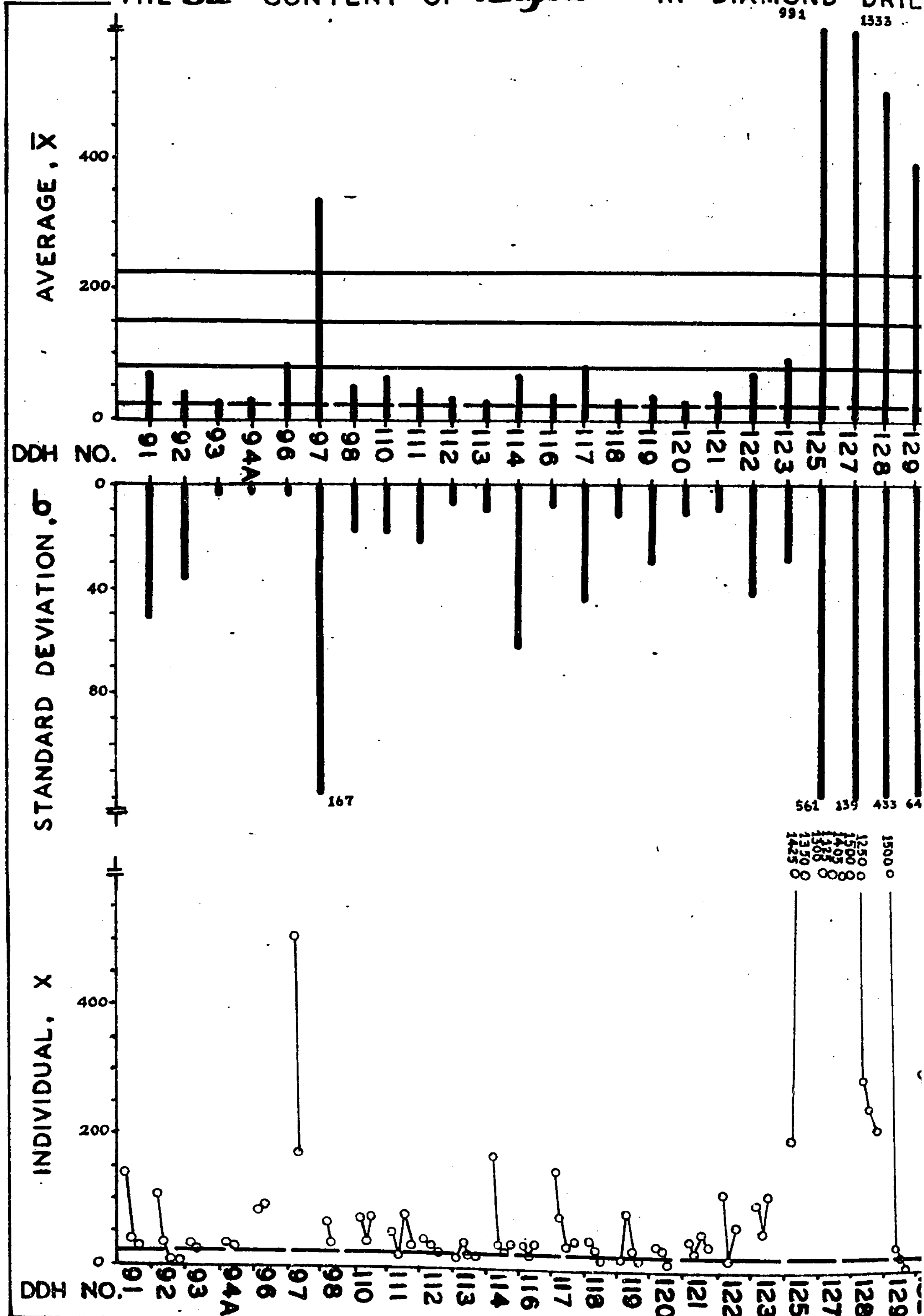
$\bar{\bar{x}}$	119ppm
Mo	70ppm
$\bar{\sigma}$	101ppm
FD	Type IV
a	100ppm
b	150ppm
c	250ppm
C_A	30.5% of $\bar{\bar{x}}$
R	.34

Most sections of andesite averaging greater than 250ppm occur over or near the ore body. Sampled sections of andesite averaging between 100 and 150ppm are scattered throughout the area. Not all the andesite sampled over the ore body has an exceptionally high Cu content. Hole 150 in the Mid-Norbec area cut andesite with a very high Cu content.

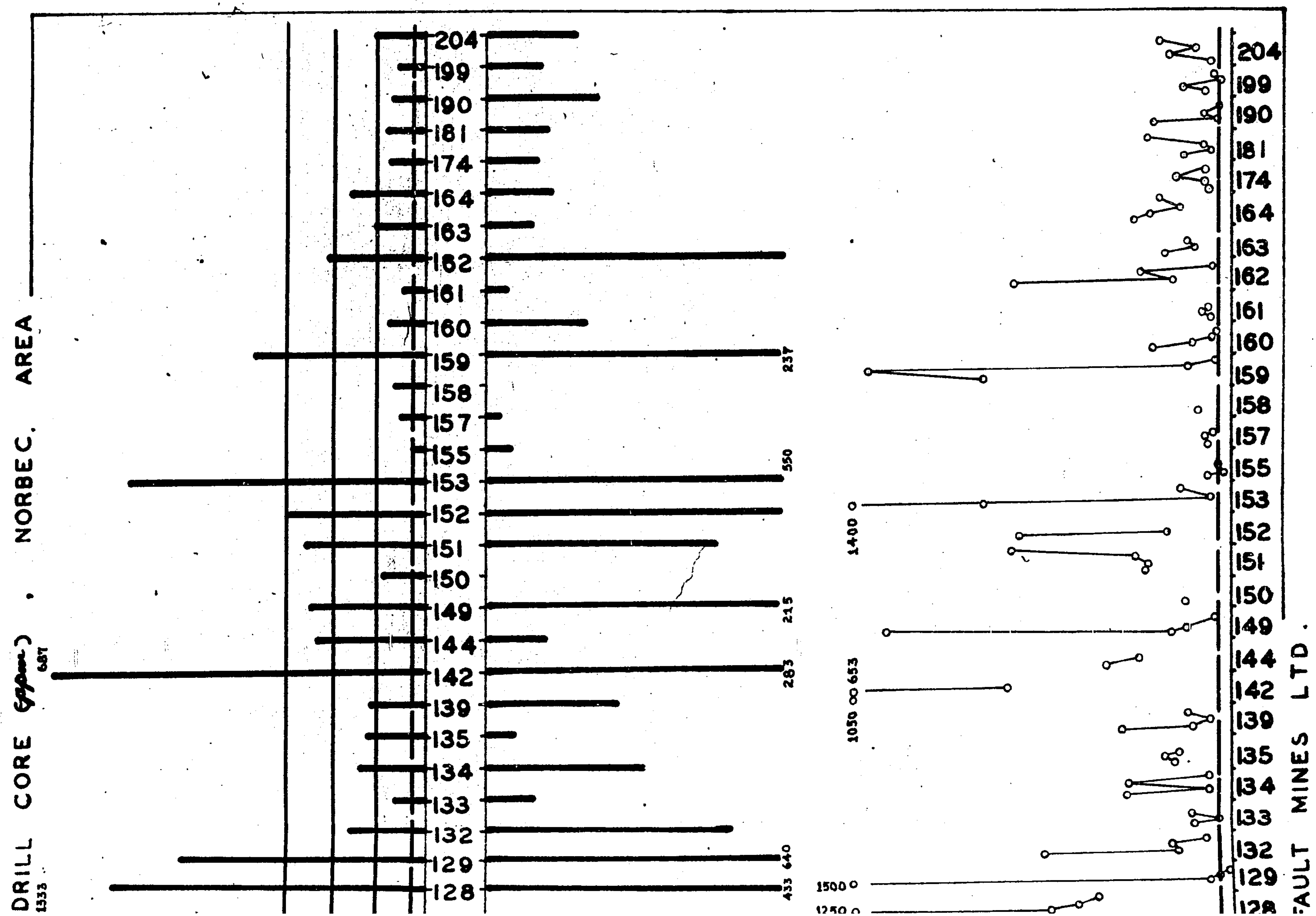
Chart 25

Cu rhyolite

THE Cu CONTENT OF Rhyolite IN DIAMOND DRIL



LAKE DUFAUL

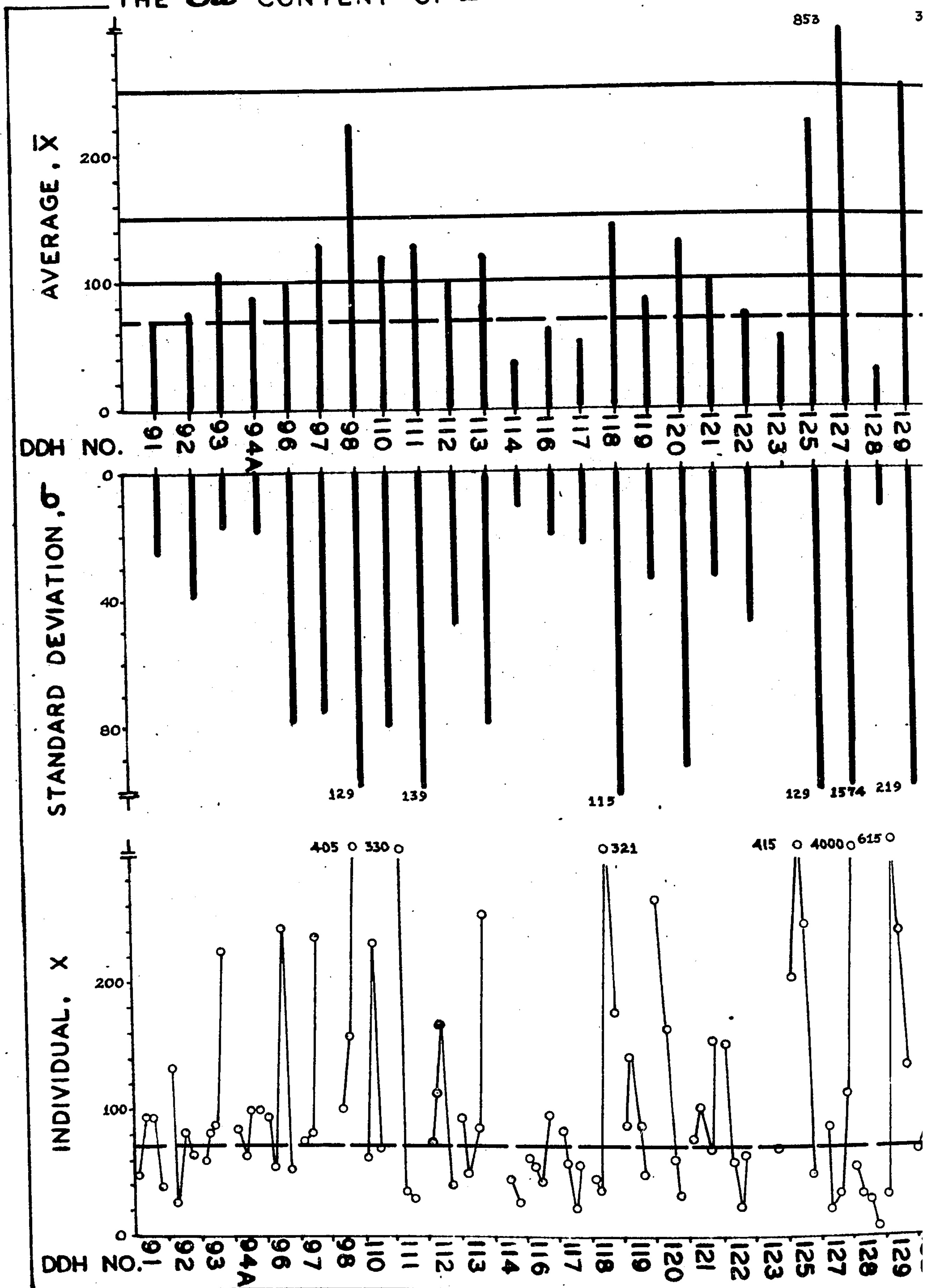


DRILL CORE ( ) NORBEC AREA
FAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
237
550
215
283
640
433
1333
687
1400
1050
653
1500
1250

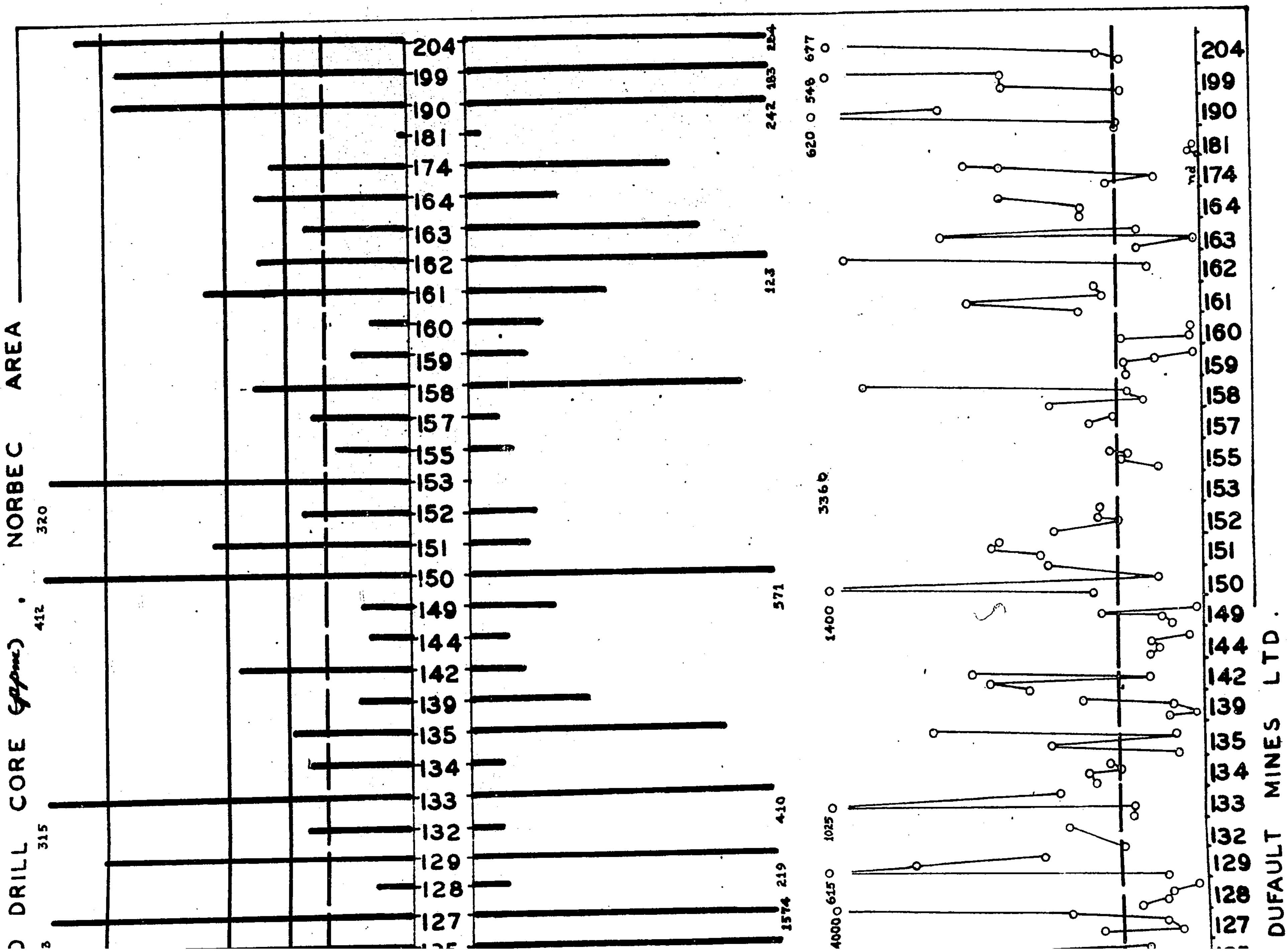
Chart 26

Cu andesite

THE Cu CONTENT OF Andesite IN DIAMOND DRILL



LAKE DUFAUL


DRILL CORE
NORBEC AREA
DUFAULT MINES LTD.
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162
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155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
320
412
315
284
183
242
123
571
410
219
1574
677
546
620
3360
1400
1025
615
4000

Gallium (Ga) Rhyolite chart 27

$\bar{\bar{x}}$ 30ppm
Mo 27ppm
$\bar{\sigma}$ 4.6ppm
FD Type I
ULB 30 + 7ppm
LLB 30 - 7ppm
C_A 9.3% of $\bar{\bar{x}}$
R .60

There are no anomalous values.

Ga Andesite chart 28

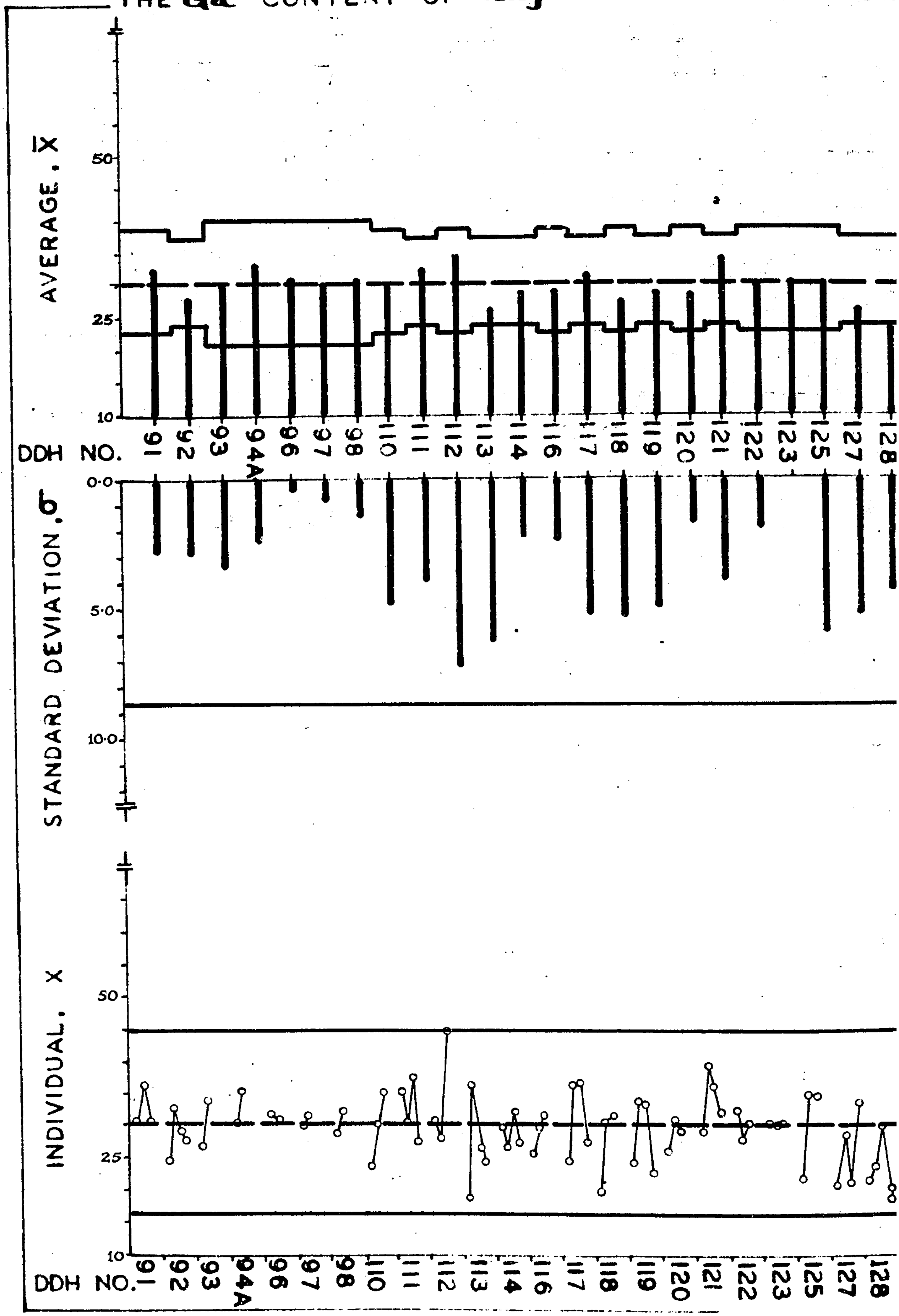
$\bar{\bar{x}}$ 24.5ppm
Mo 24.5ppm
$\bar{\sigma}$ 4.1ppm
FD Type I
ULB 24.5 + 6.1ppm
LLB 24.5 - 6.1ppm
C_A 10.5% of $\bar{\bar{x}}$
R .63

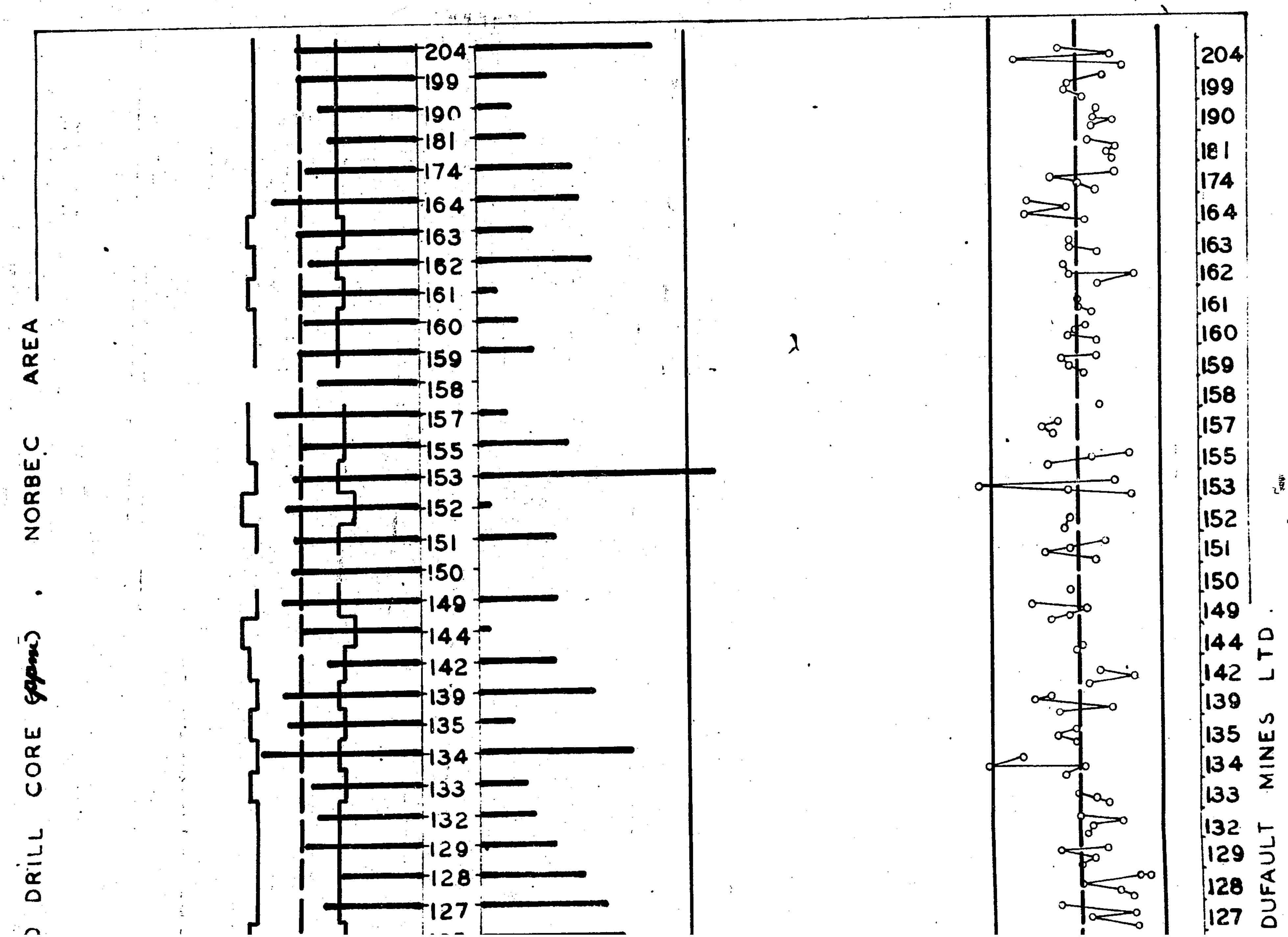
Holes 174 and 190 cut andesite with an unusually high Ga content.

Chart 27

Ga rhyolite

THE *Ga* CONTENT OF *Rhyolite* IN DIAMOND DR





DRILL CORE (Apm) NORBEC AREA
DUFAULT MINES LTD
204
199
190
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174
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162
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153
152
151
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149
144
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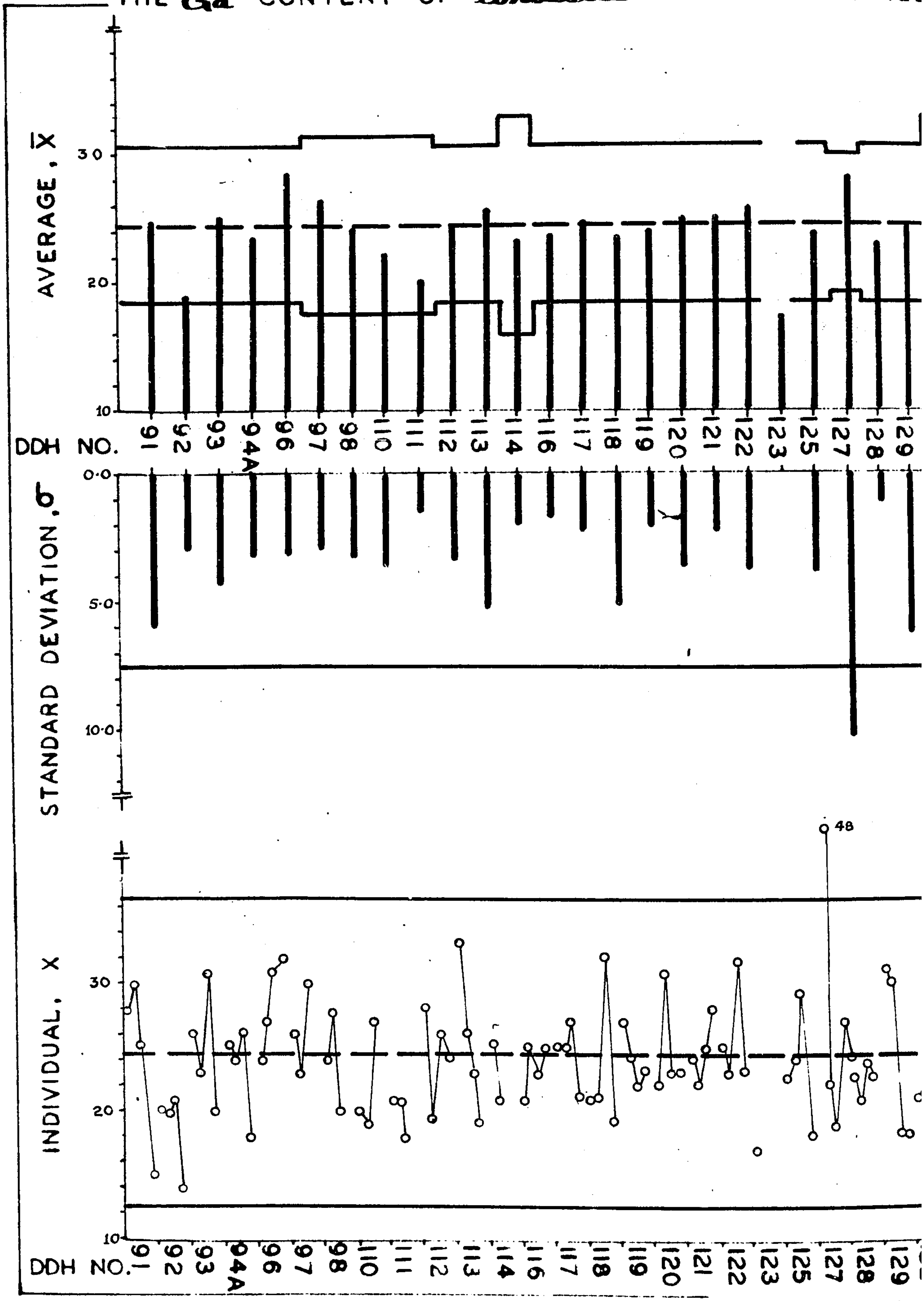
135
134
133
132
129
128
127

Chart 28

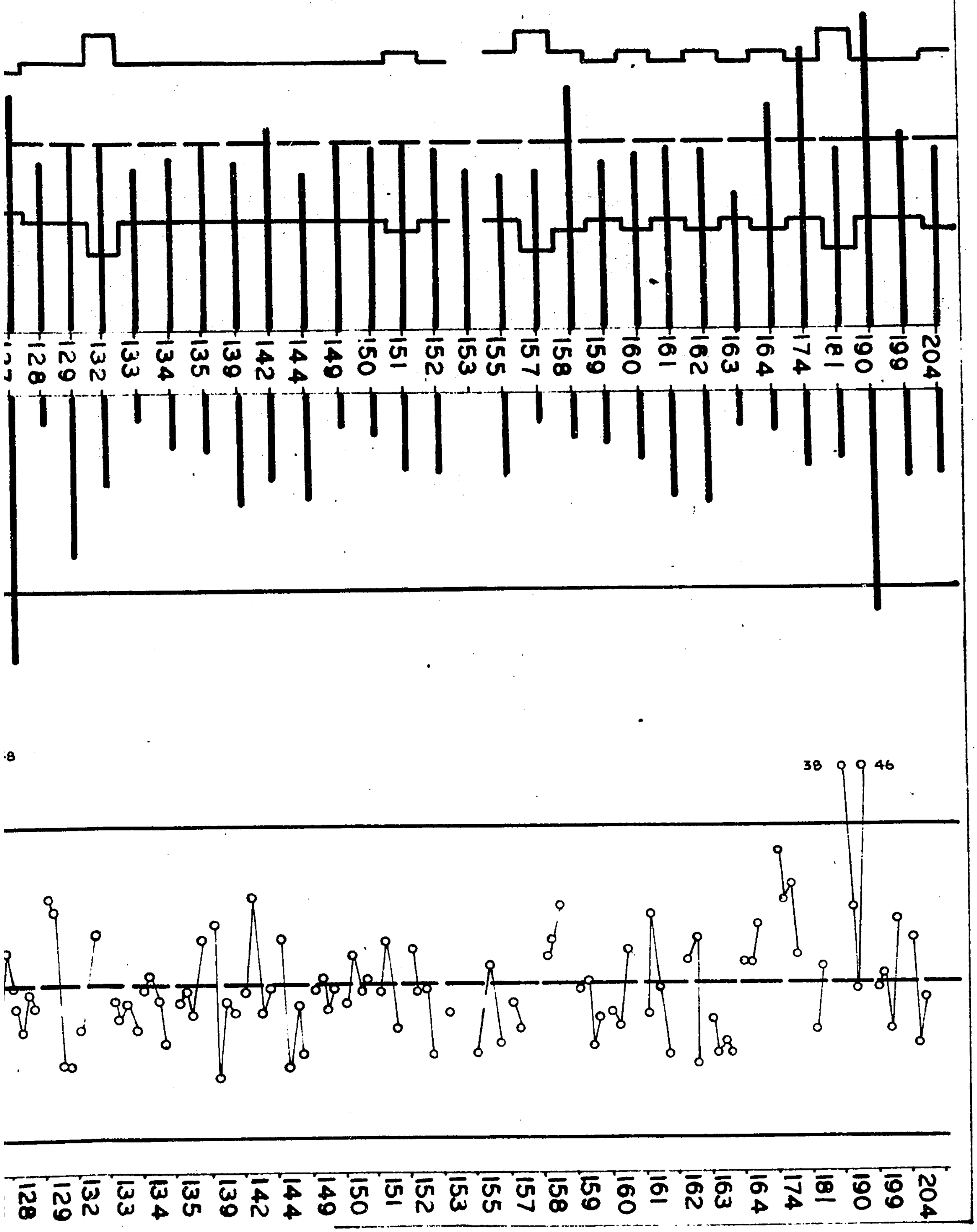
Ga andesite

THE *Ga* CONTENT OF *Andesite* IN DIAMOND DRILL



LAKE DUFAUL

DRILL CORE (ppm) . NORBEC AREA



JFAULT MINES LTD.

Nickel (Ni) Rhyolite chart 29

$\bar{\bar{x}}$	7.8ppm
Mo	1.0ppm
$\bar{\sigma}$	7.3ppm
FD	Type V
a	2.5ppm
b	5.0ppm
c	10.0ppm
C_A	78.7% of $\bar{\bar{x}}$
R	.84

Exceptionally high values for Ni in rhyolite are scattered among all sampled drill holes in the area. One cause of this is that the highest individual values often occur closest to the main contact rather than near the ore body. Also, the analytical error is large.

Ni Andesite chart 30

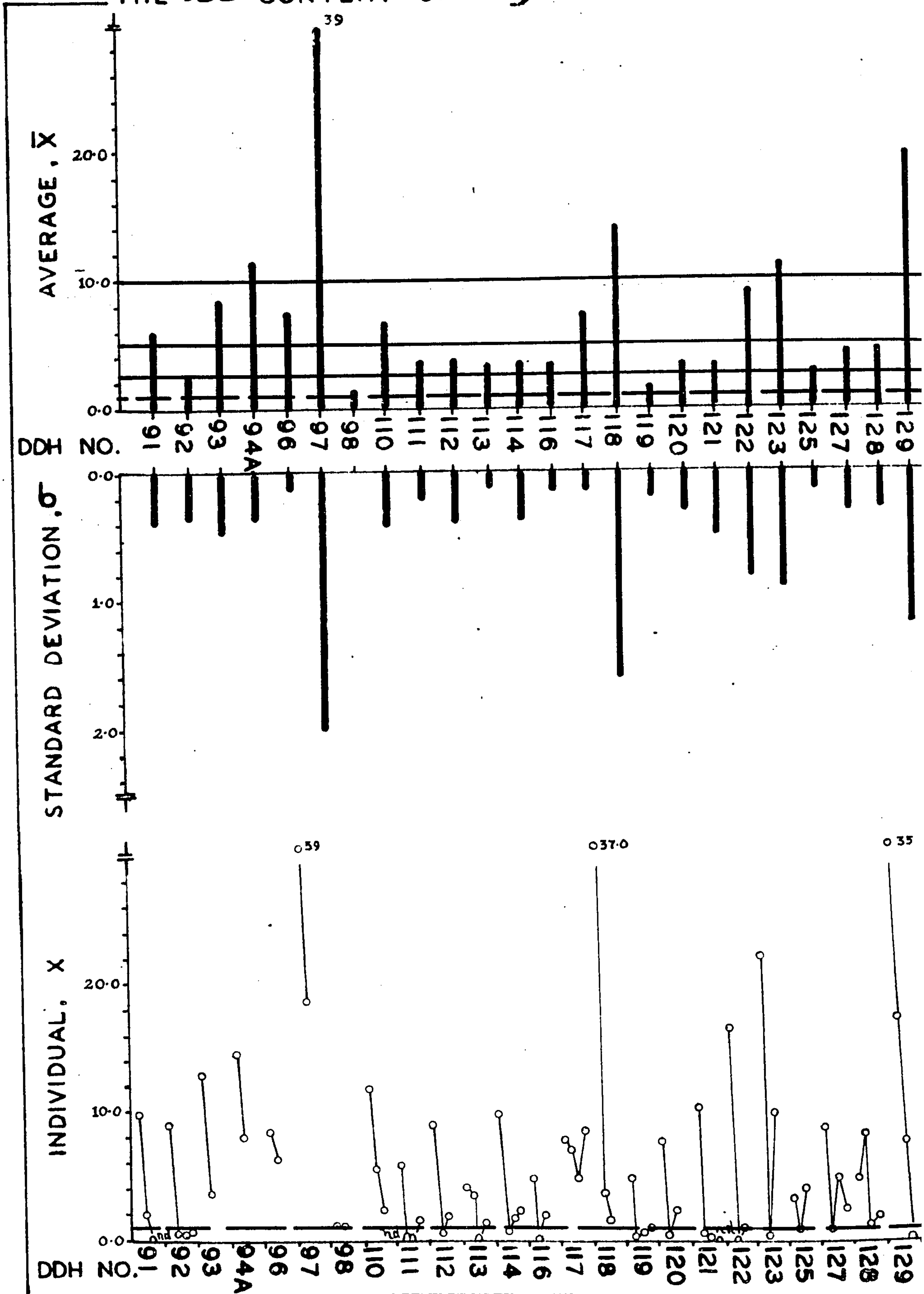
$\bar{\bar{x}}$	104ppm
Mo	50ppm
$\bar{\sigma}$	44ppm
FD	Type V
a	100ppm
b	150ppm
c	200ppm
C_A	30.3% of $\bar{\bar{x}}$
R	.72

Anomalous values for Ni in andesite do not seem to bear any relation to the presence of ore. However, the lowest individual values are often the closest to the main contact.

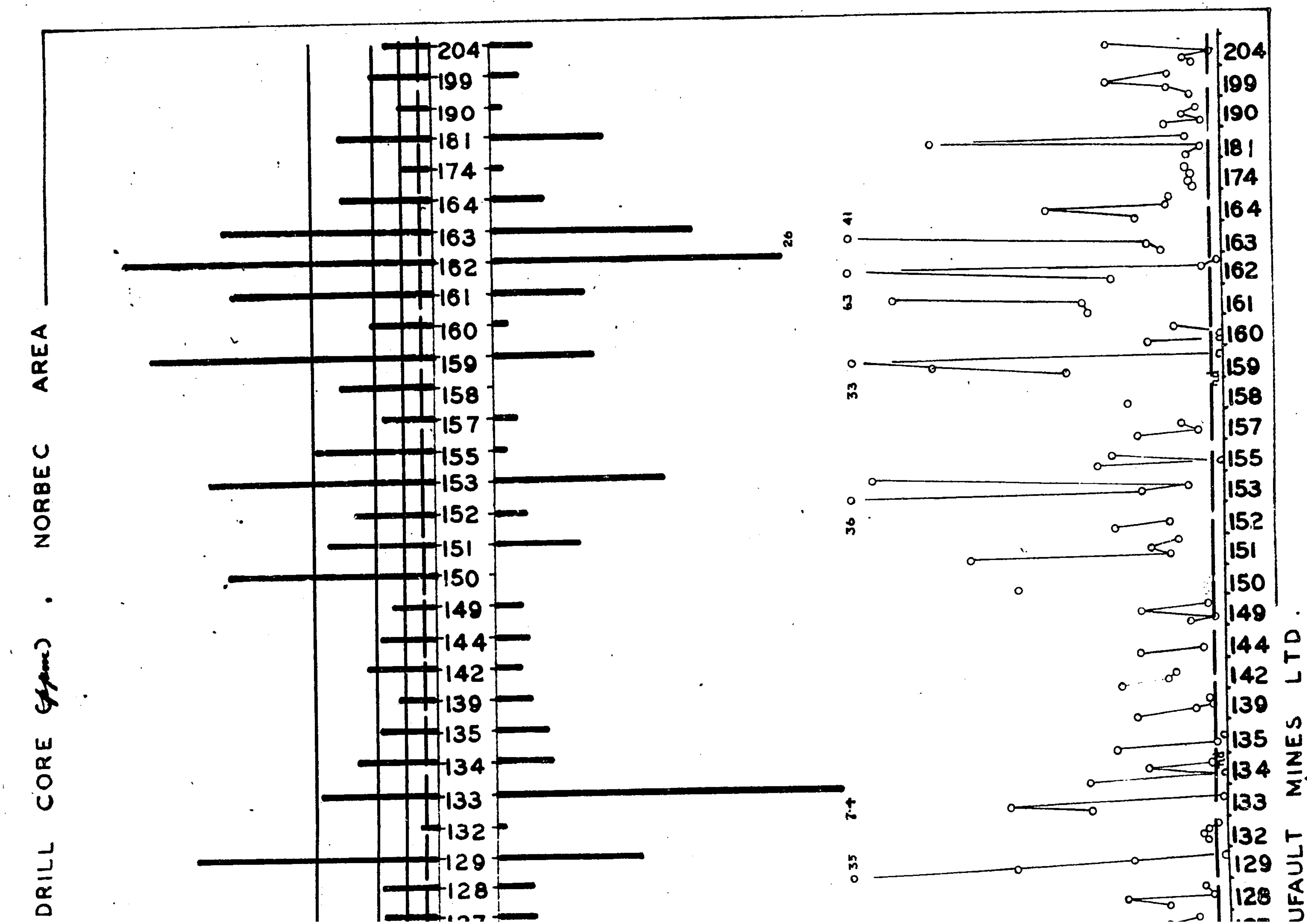
Chart 29

Ni rhyolite

THE *Ni* CONTENT OF *Rhyolite* IN DIAMOND DRILL



LAKE DUFAUL


DRILL CORE (Spec) . NORBEC AREA
UFAULT MINES LTD
204
199
190
181
174
164
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152
151
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149
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142
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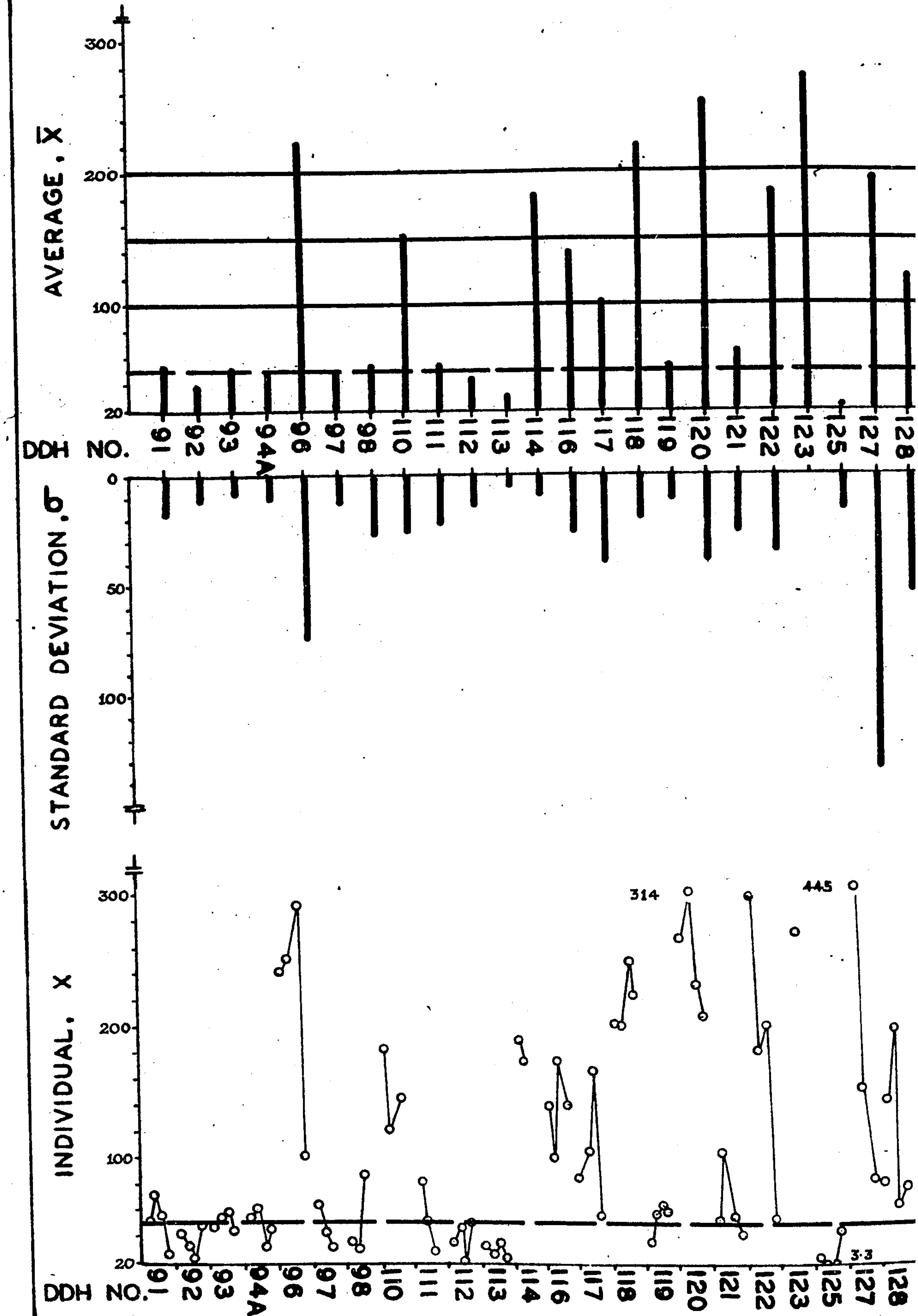
135
134
133
132
129
128
26
41
63
33
36
7.4
35

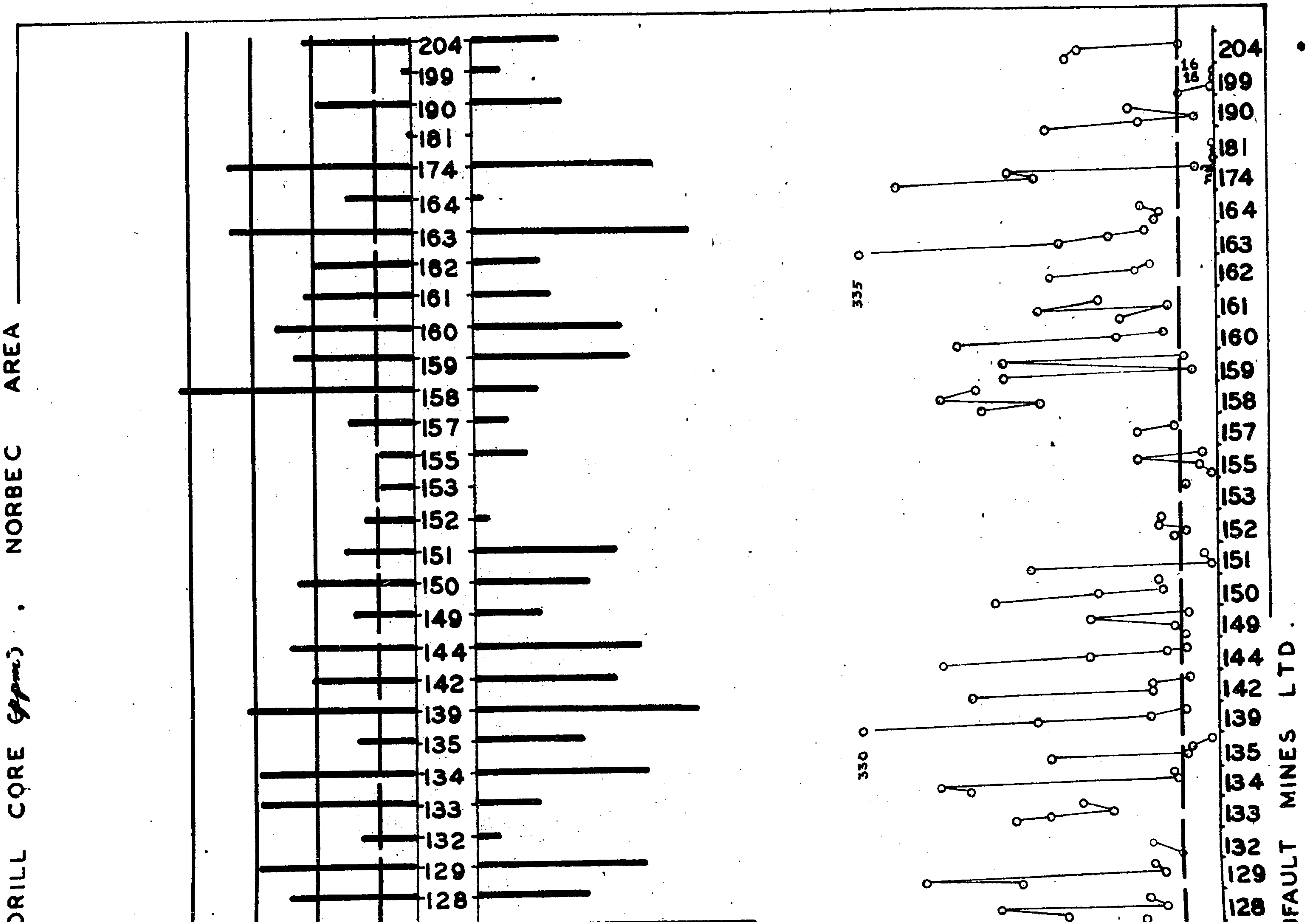
Chart 30

Ni andesite

THE *Ni* CONTENT OF *Andesite* IN DIAMOND DR



LAKE DUFA



DRILL CORE (ppm) . NORBEC AREA
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
335
330
16
18
FAULT MINES LTD

Lead (Pb) Rhyolite chart 31

$\bar{\bar{x}}$	2.4ppm
Mo	0.7ppm
$\bar{\sigma}$	2.4ppm
FD	Type V
a	4ppm
b	7ppm
C_A	16.4% of $\bar{x}$
R	.17

Abnormally high values for Pb in rhyolite occur only around the ore body and in the northwest corner of the property. Some holes which are very close to the ore body (152, 133, 162, 129) are <u>not</u> anomalous.

Pb Andesite chart 32

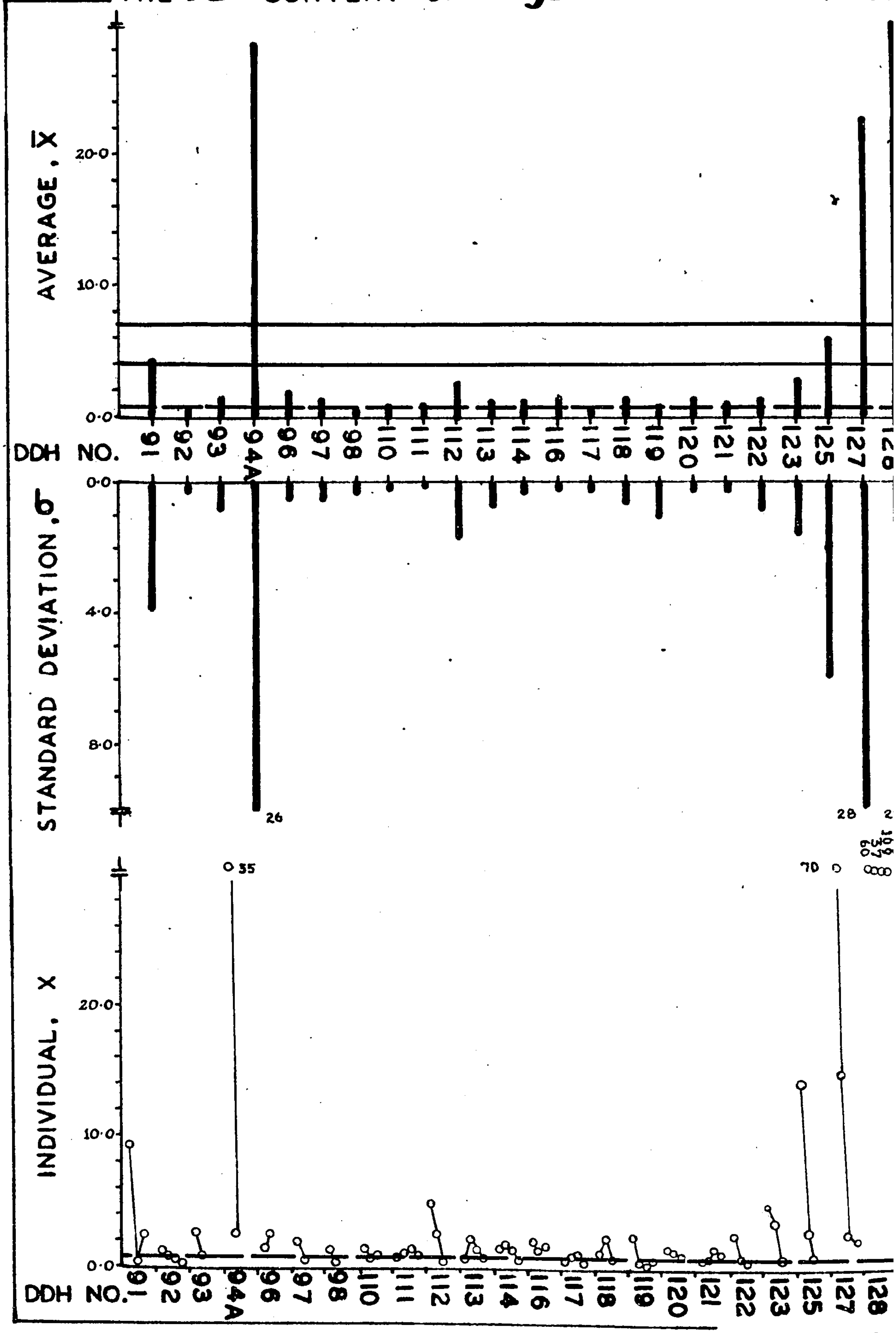
$\bar{\bar{x}}$	1.0ppm
Mo	0.3ppm
$\bar{\sigma}$	.9ppm
FD	Type V
a	1.5ppm
b	3.0ppm
c	6.0ppm
C_A	66.4% of $\bar{x}$
R	.76

The only unusually high values for Pb in andesite occur in sections from drill holes over or close to the ore body or in the northwest corner of the property.

Chart 31

Pb rhyolite

THE *Pb* CONTENT OF *Rhyolite* IN DIAMOND DR



LAKE DUFA

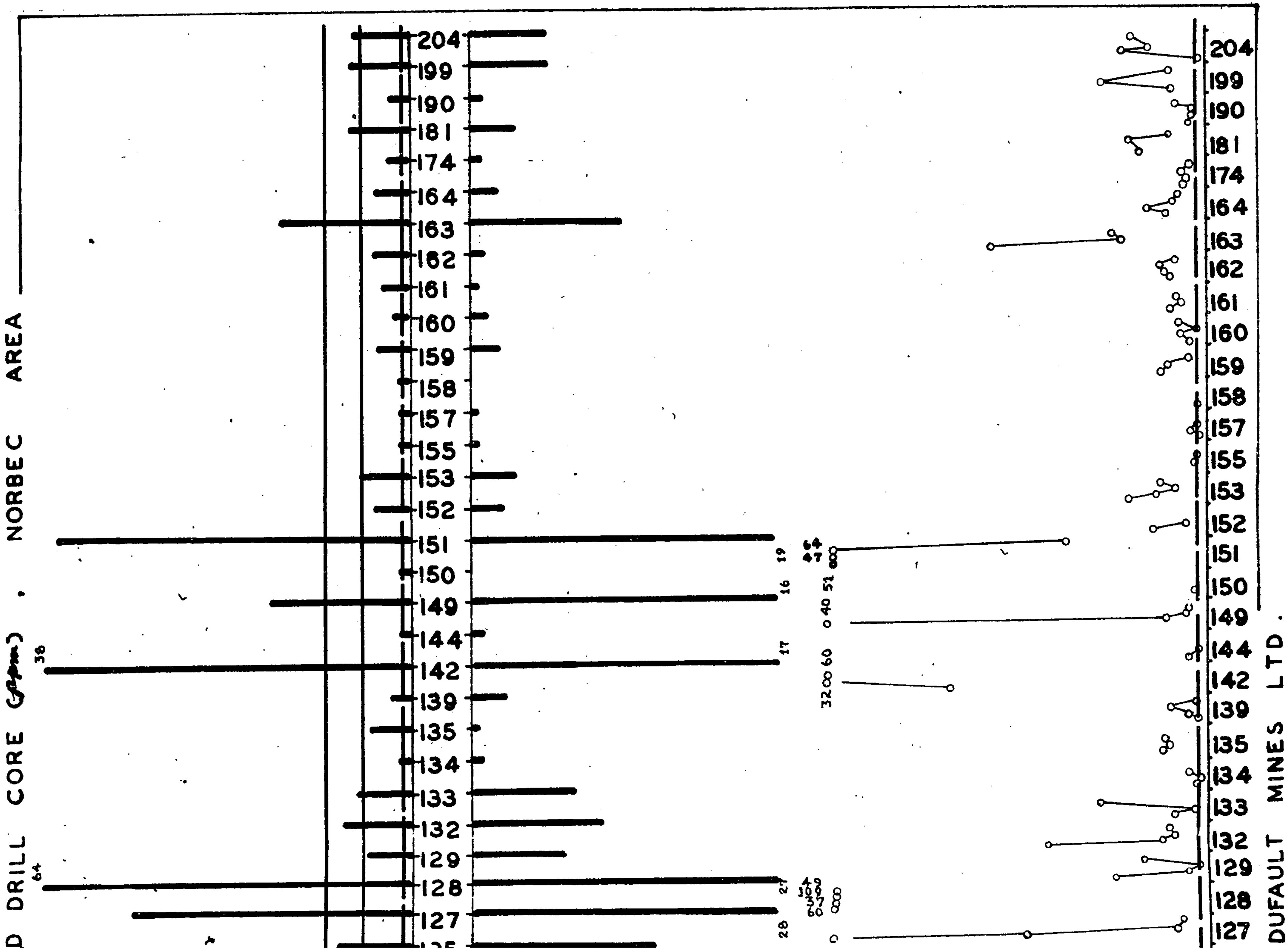
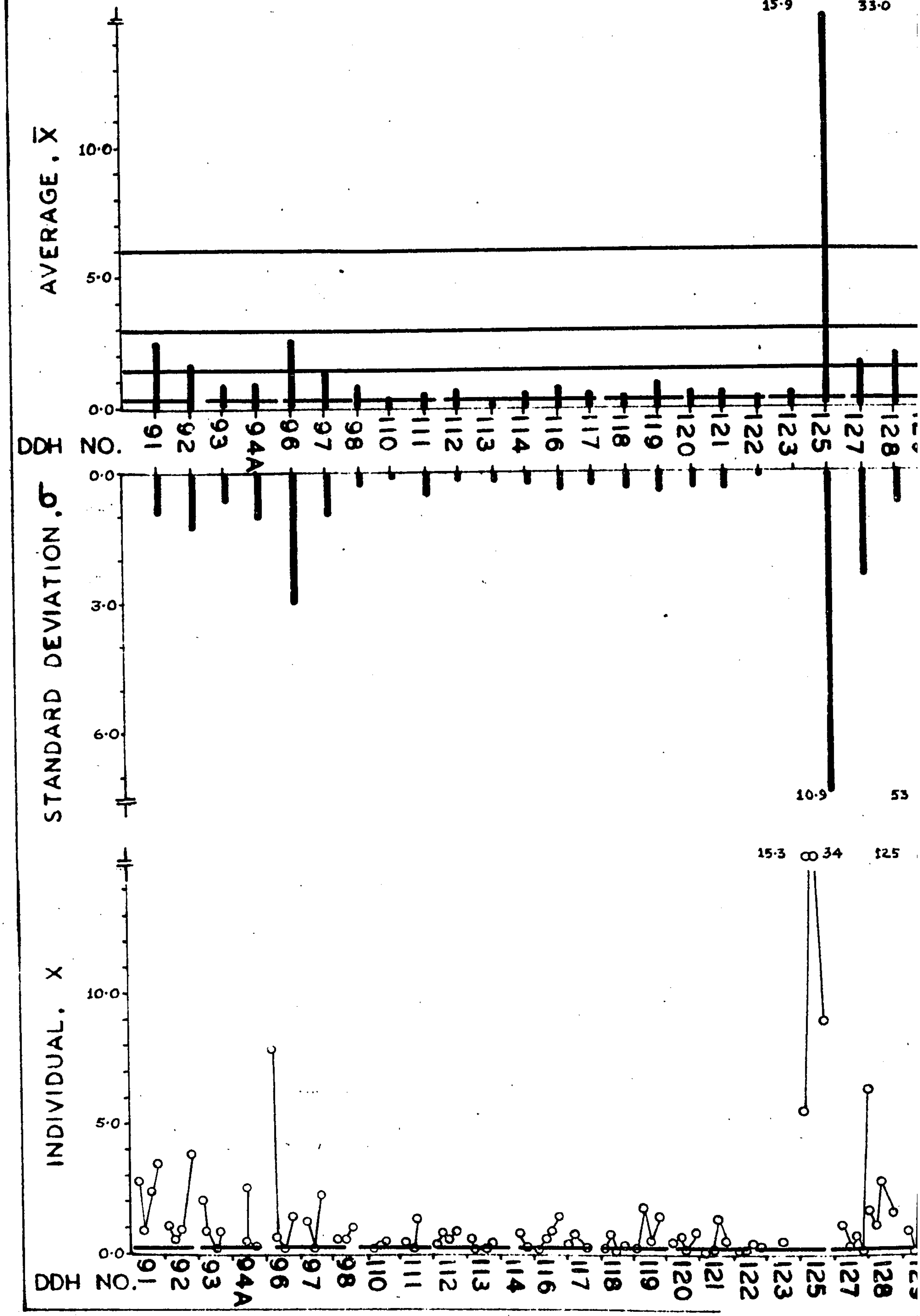

D DRILL CORE (ppm) NORBEC AREA
DUFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127

Chart 32

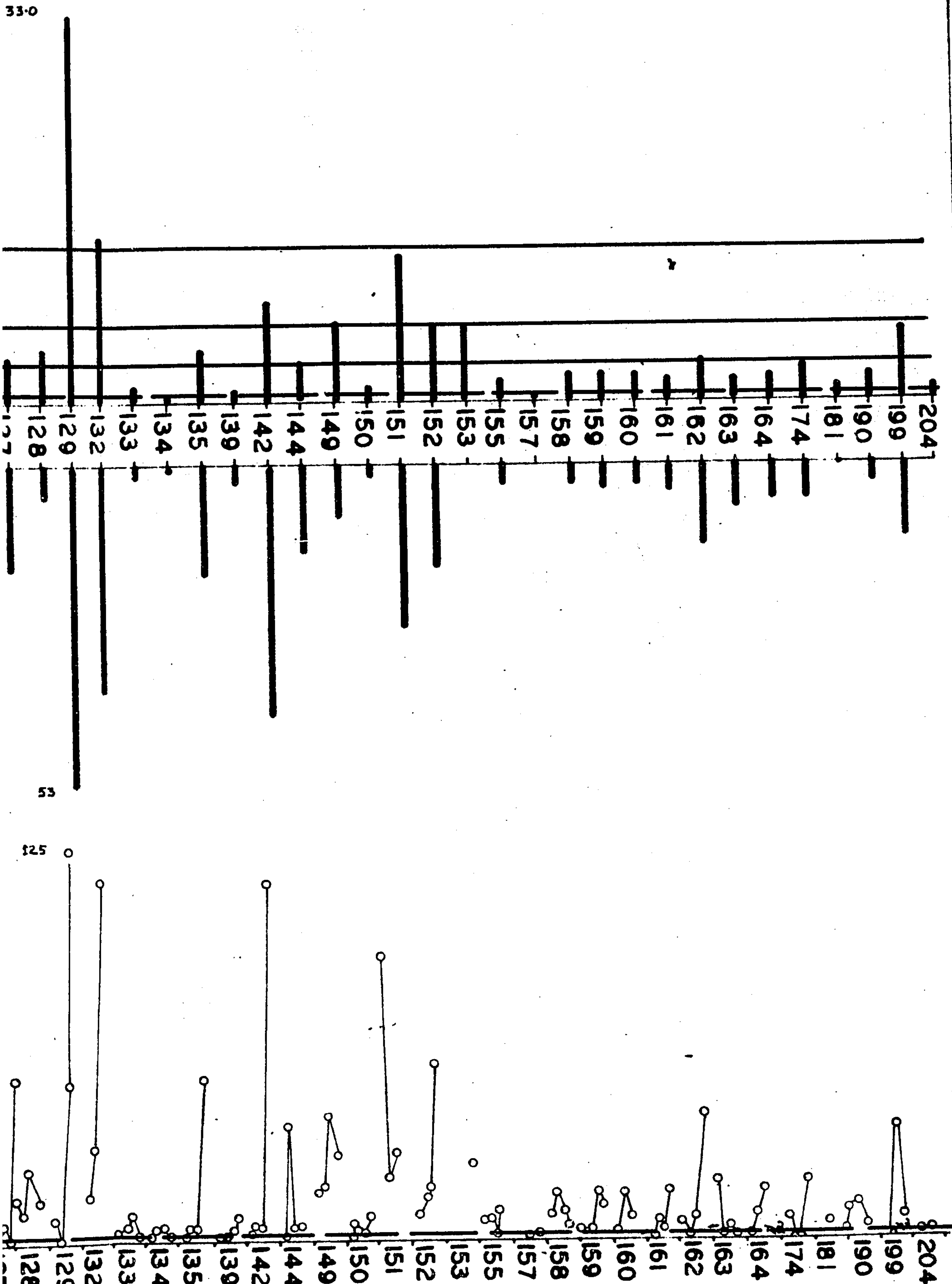
Pb andesite

THE Pb CONTENT OF Andesite IN DIAMOND DRIL



LAKE DUFAU

DRILL CORE (ppm) . NORBEC AREA



UFAULT MINES LTD.

Tin (Sn) Rhyolite chart 33

$\bar{\bar{x}}$	1.0ppm
Mo	0.5ppm
$\bar{\sigma}$	.9ppm
FD	Type IV
a	1.0ppm
b	1.5ppm
c	2.5ppm
C_A	27.8% of $\bar{\bar{x}}$
R	.31

Holes which cut rhyolite with anomalous tin enrichment occur scattered over the whole property, as well as very near the ore body.

Sn Andesite chart 34

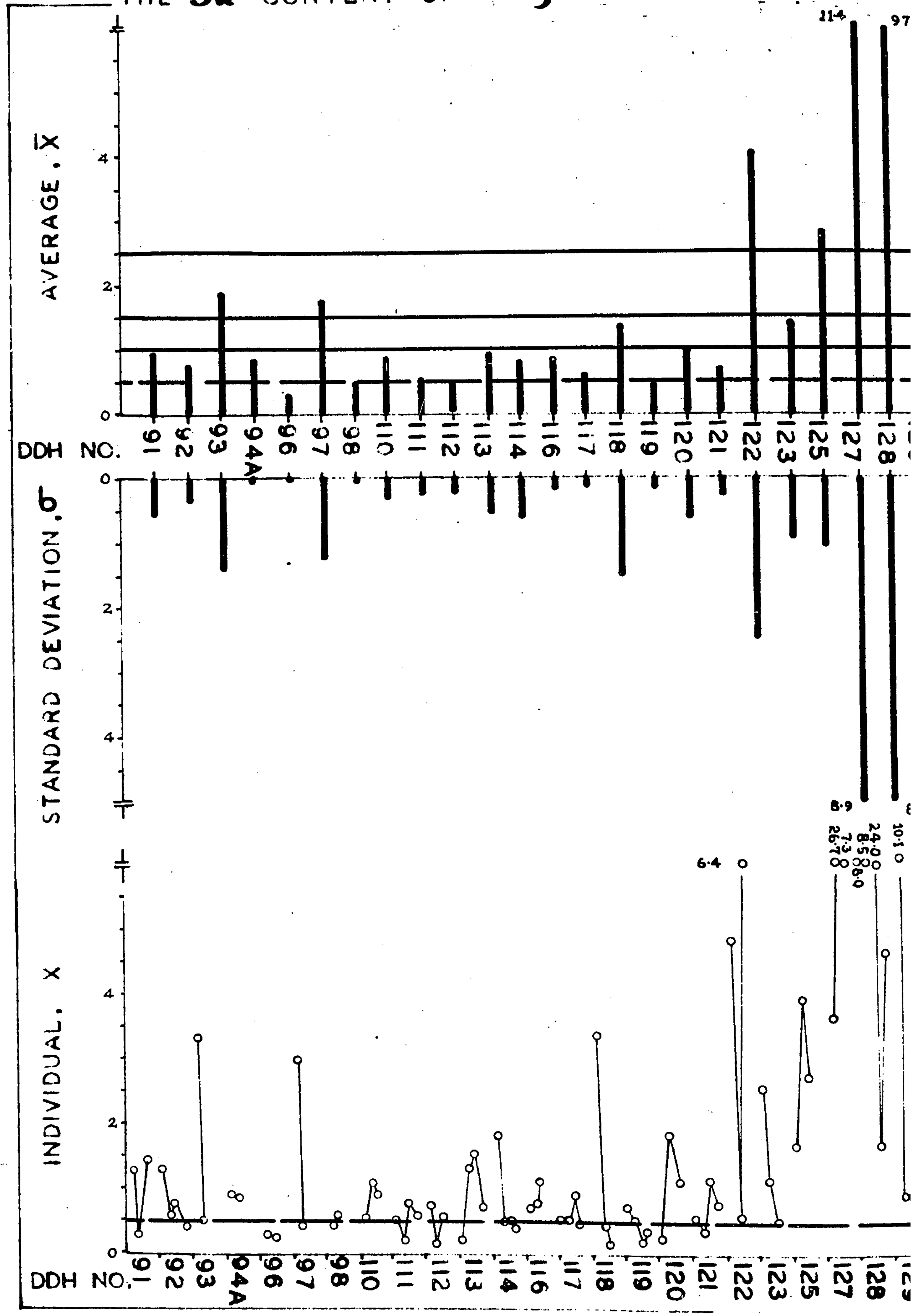
$\bar{\bar{x}}$	4.4ppm
Mo	2.5ppm
$\bar{\sigma}$	2.8ppm
FD	Type IV
a	5.0ppm
b	7.5ppm
C_A	63.3% of $\bar{\bar{x}}$
R	1.0

Abnormally high values for Sn in andesite occur scattered throughout the sampled drill holes. Also, the precision of the analyses is low.

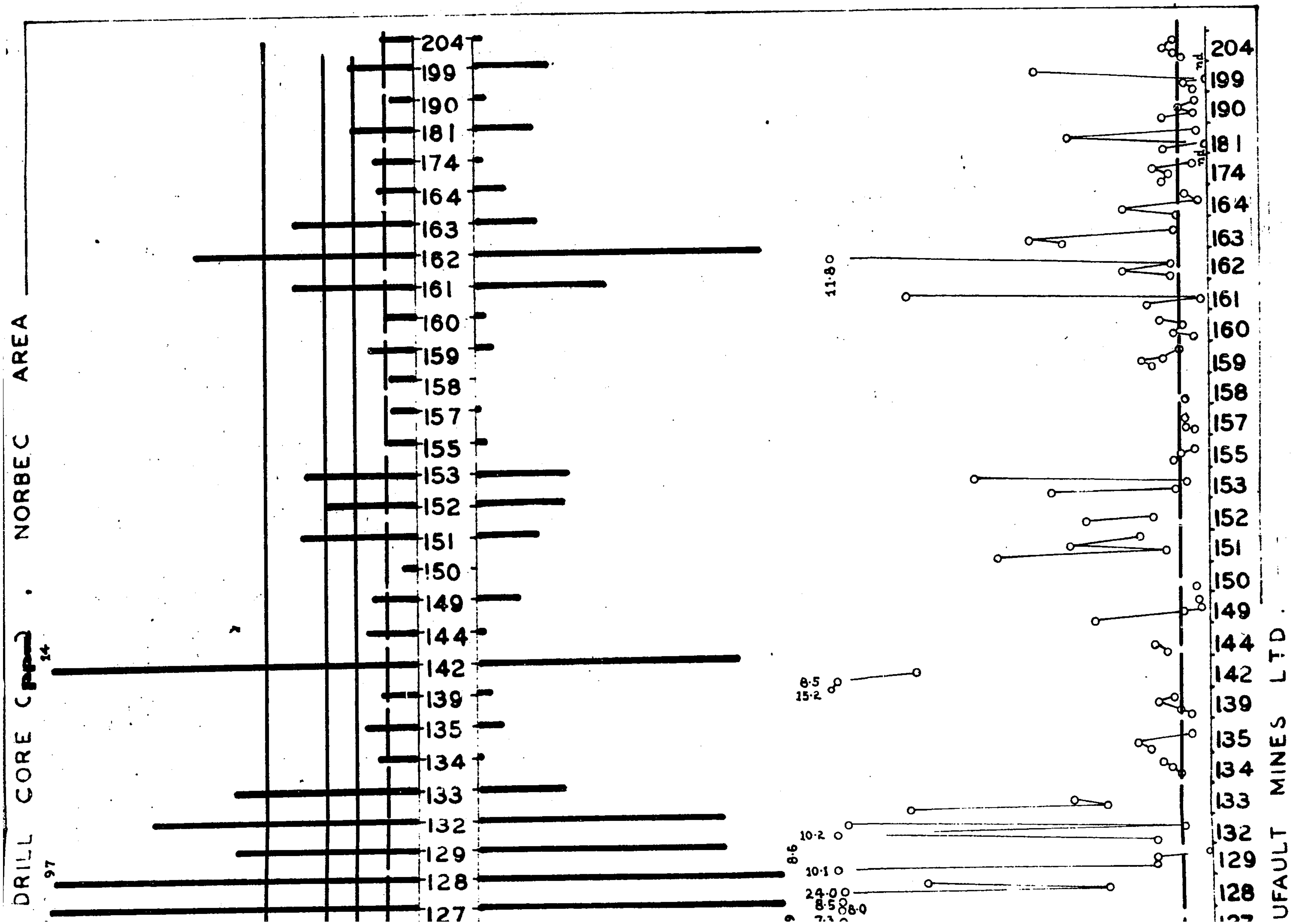
Chart 33

Sn rhyolite

THE Sn CONTENT OF Rhyolite IN DIAMOND DRI



LAKE DUFAU



DRILL CORE
NORBEC AREA
UFAULT MINES LTD
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
11·80
8·5
15·2
10·2
10·1
24·0
8·5
8·0
8·6
97
14

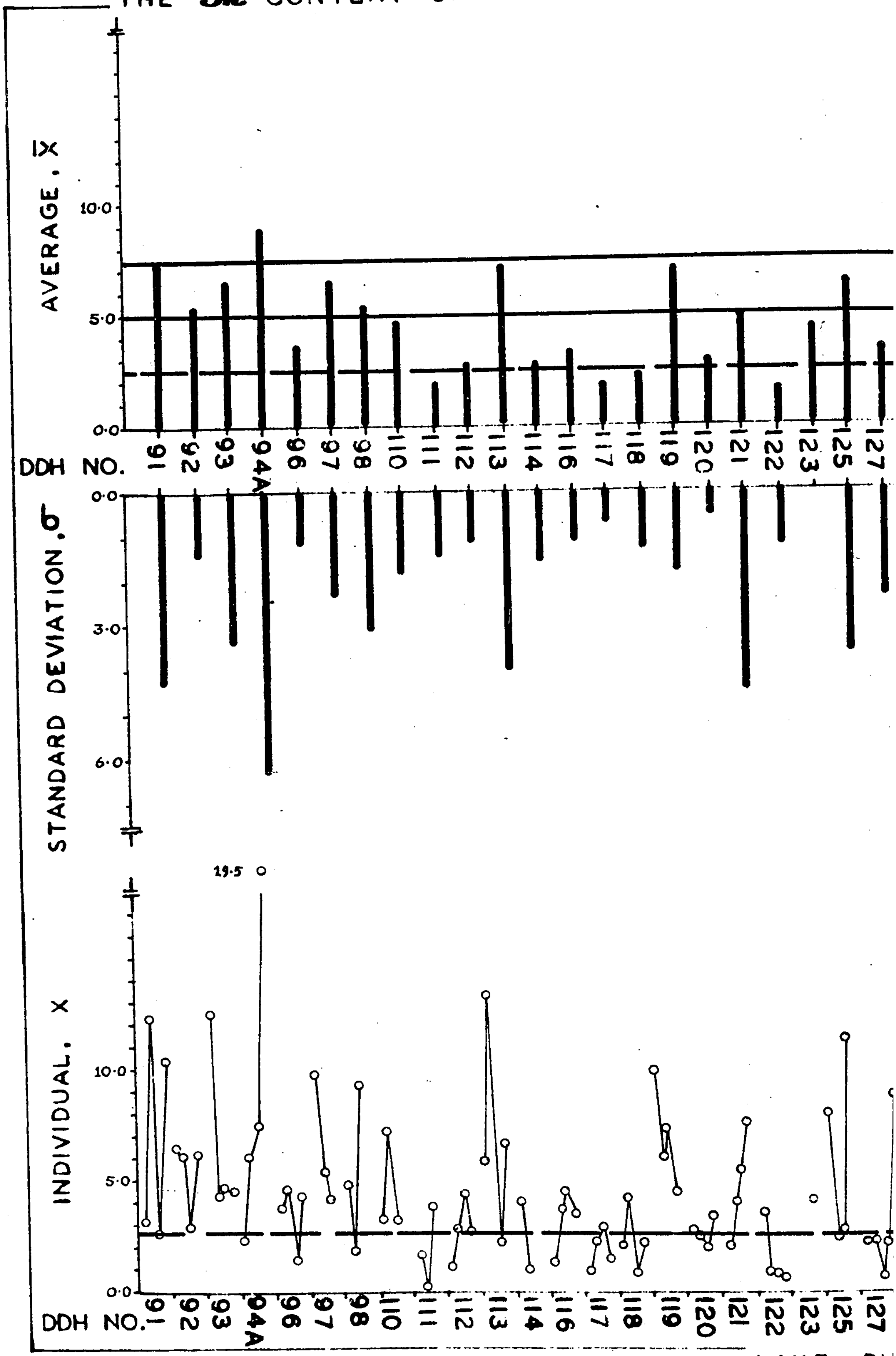
Chart 34

Sn andesite

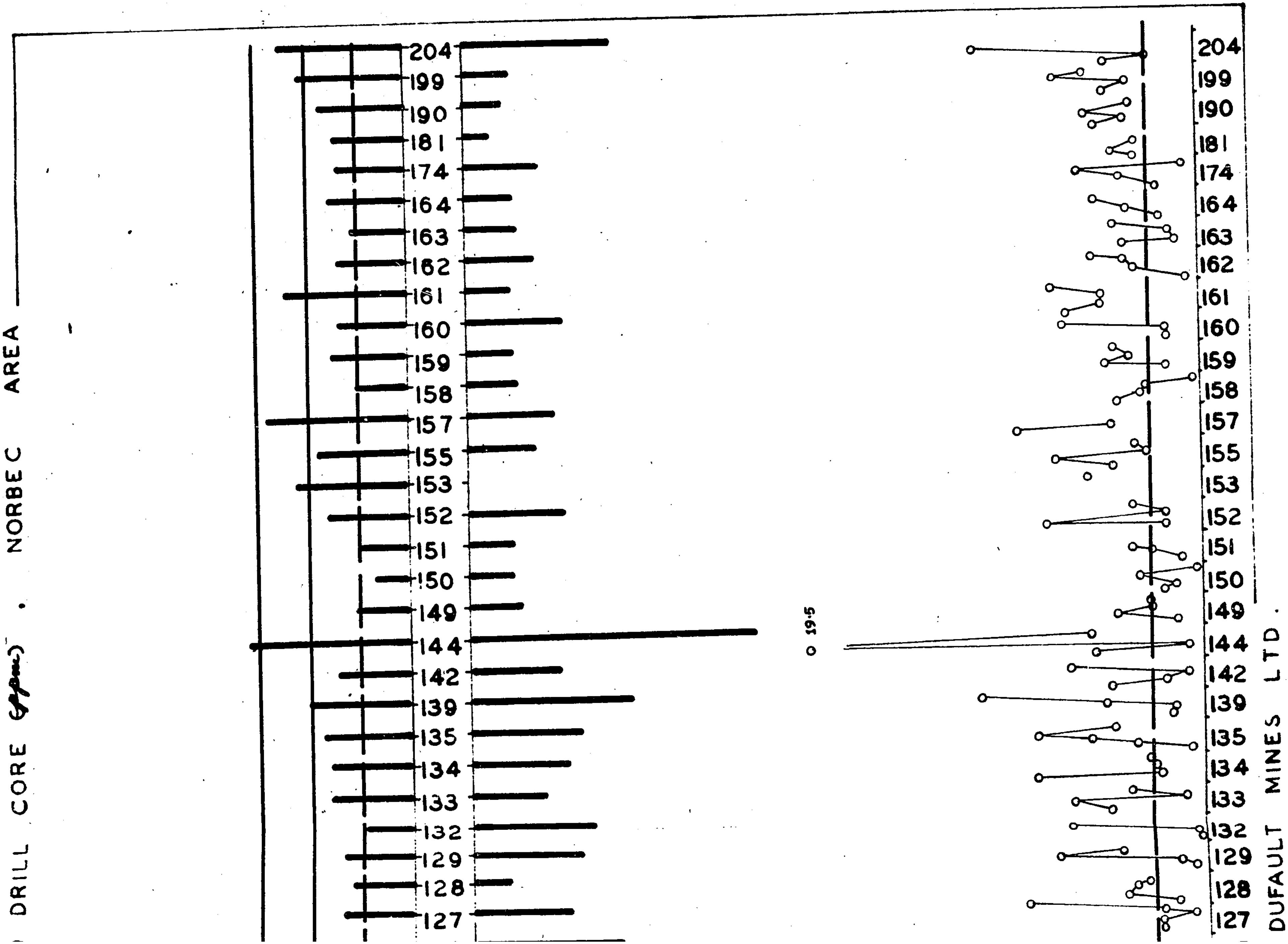
Chart 34

Sn andesite

THE Sn CONTENT OF Andesite IN DIAMOND D



LAKE DU


DRILL CORE
NORBEC AREA
DUFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127
19.5

Strontium (Sr) Rhyolite chart 35

$\bar{\bar{x}}$ 418ppm
Mo 370ppm
$\bar{\sigma}$ 107ppm
FD Type I
ULB 418 + 107ppm
LLB 418 - 107ppm
C_A 25.3% of $\bar{\bar{x}}$
R .98

Two mineralized sections of rhyolite beneath the massive ore body in holes 127 and 128 have unusually low contents of Sr.

Sr Andesite chart 36

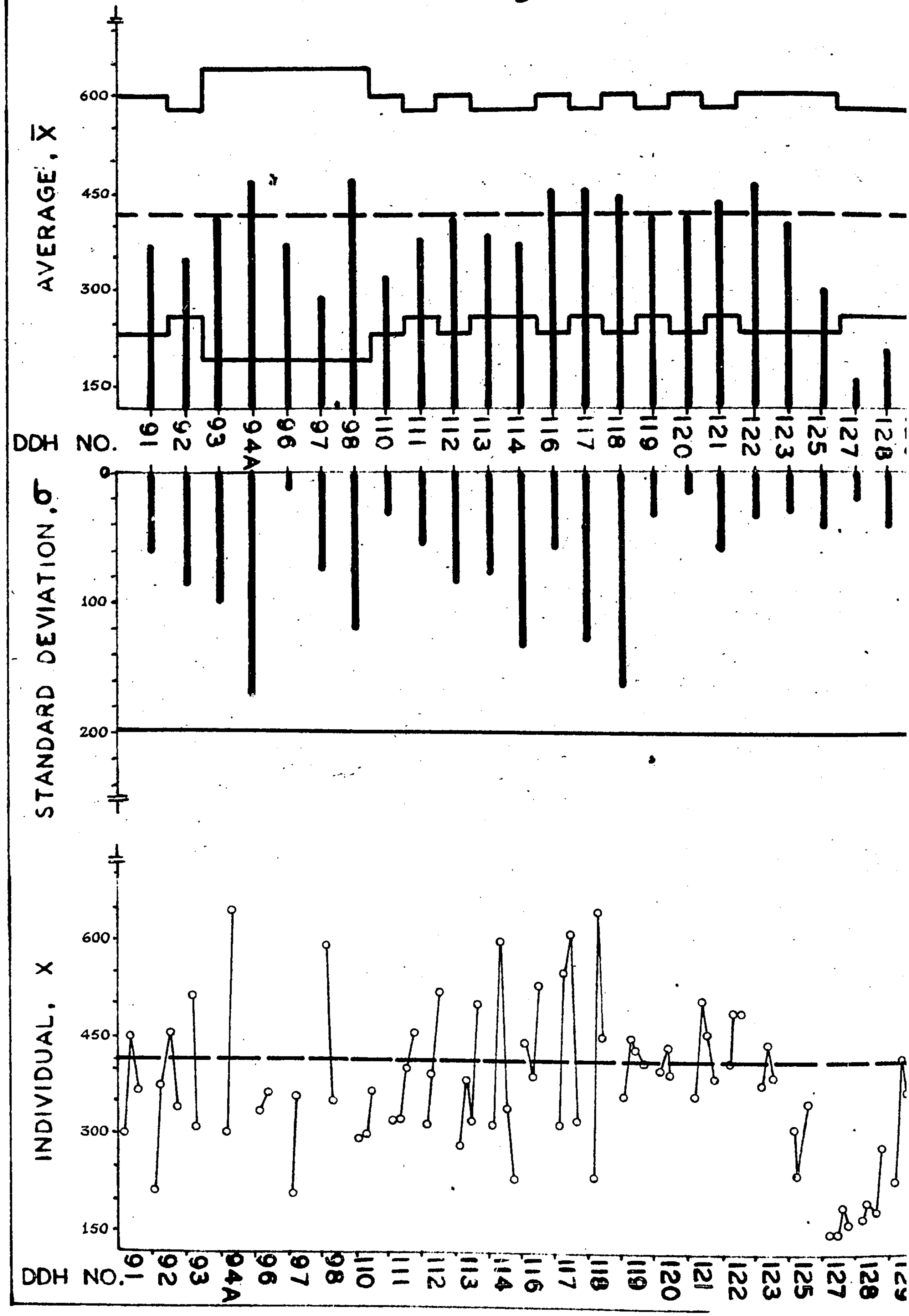
$\bar{\bar{x}}$ 197ppm
Mo 150ppm
$\bar{\sigma}$ 64ppm
FD Type III ?
C_A 30% of $\bar{\bar{x}}$
R .90

The analyses for Sr at this low level are strongly suspect. No conclusions were drawn from the lateral distribution of Sr in andesite.

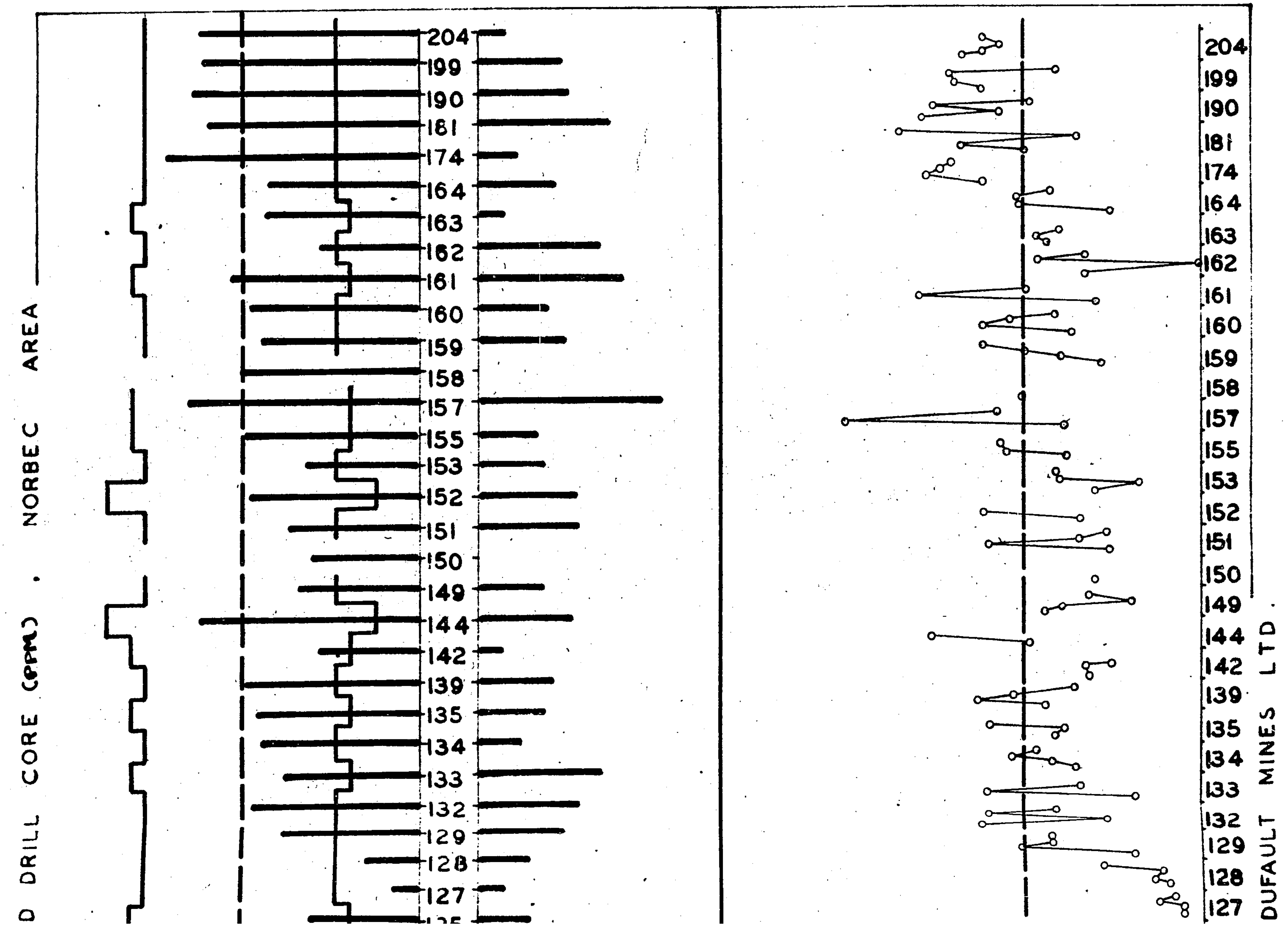
Chart 35

Sr rhyolite

THE Sr CONTENT OF *Rhyolite* IN DIAMOND DRI



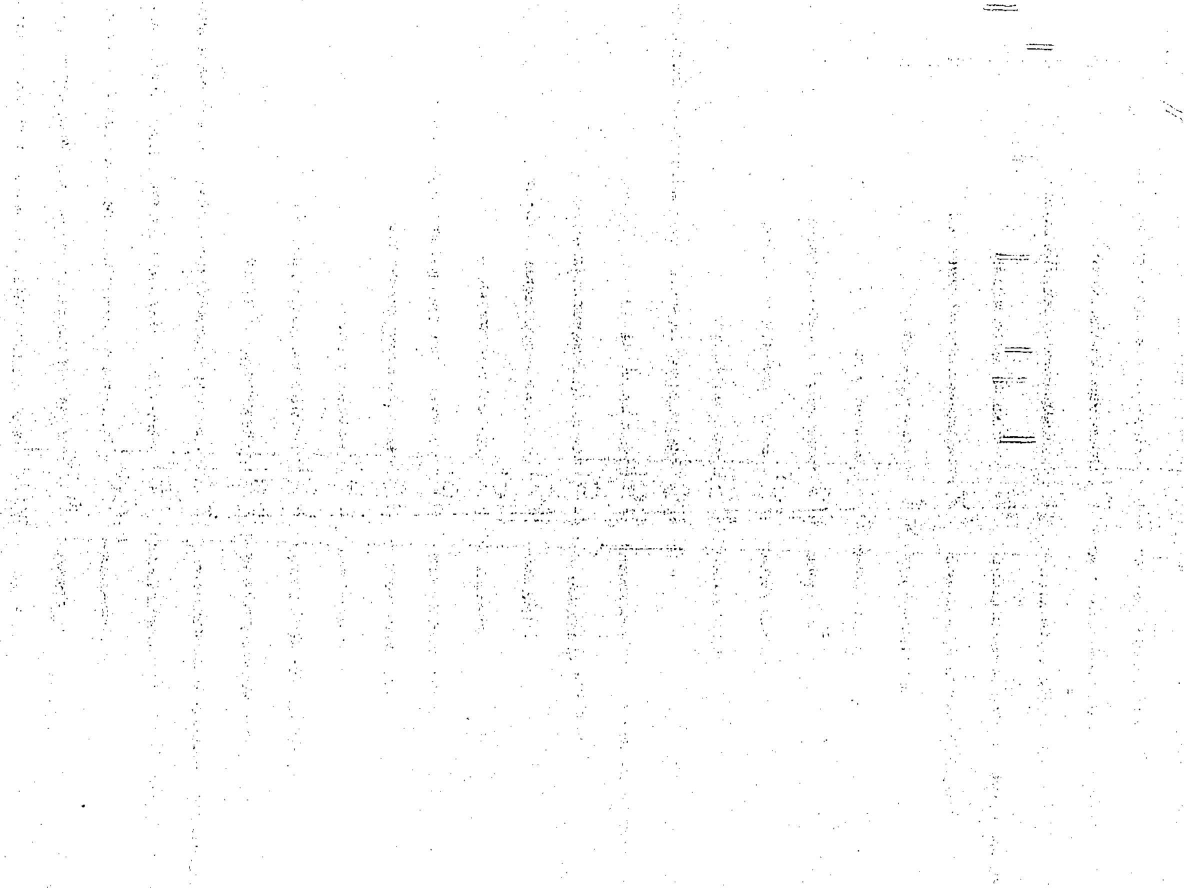
LAKE DUFAU



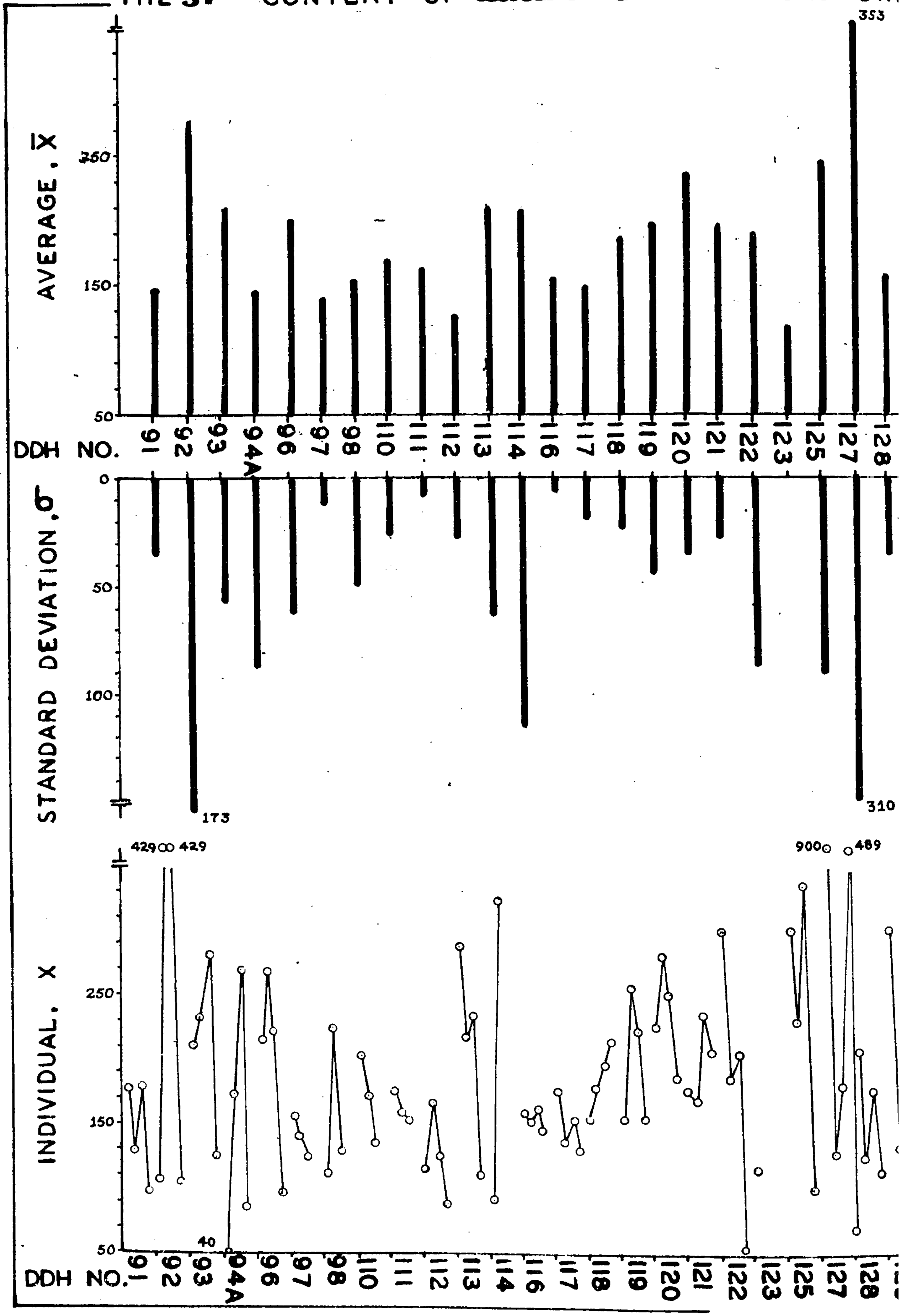
D DRILL CORE (PPM) . NORBEC AREA
DUFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127

Chart 36

Sr andesite

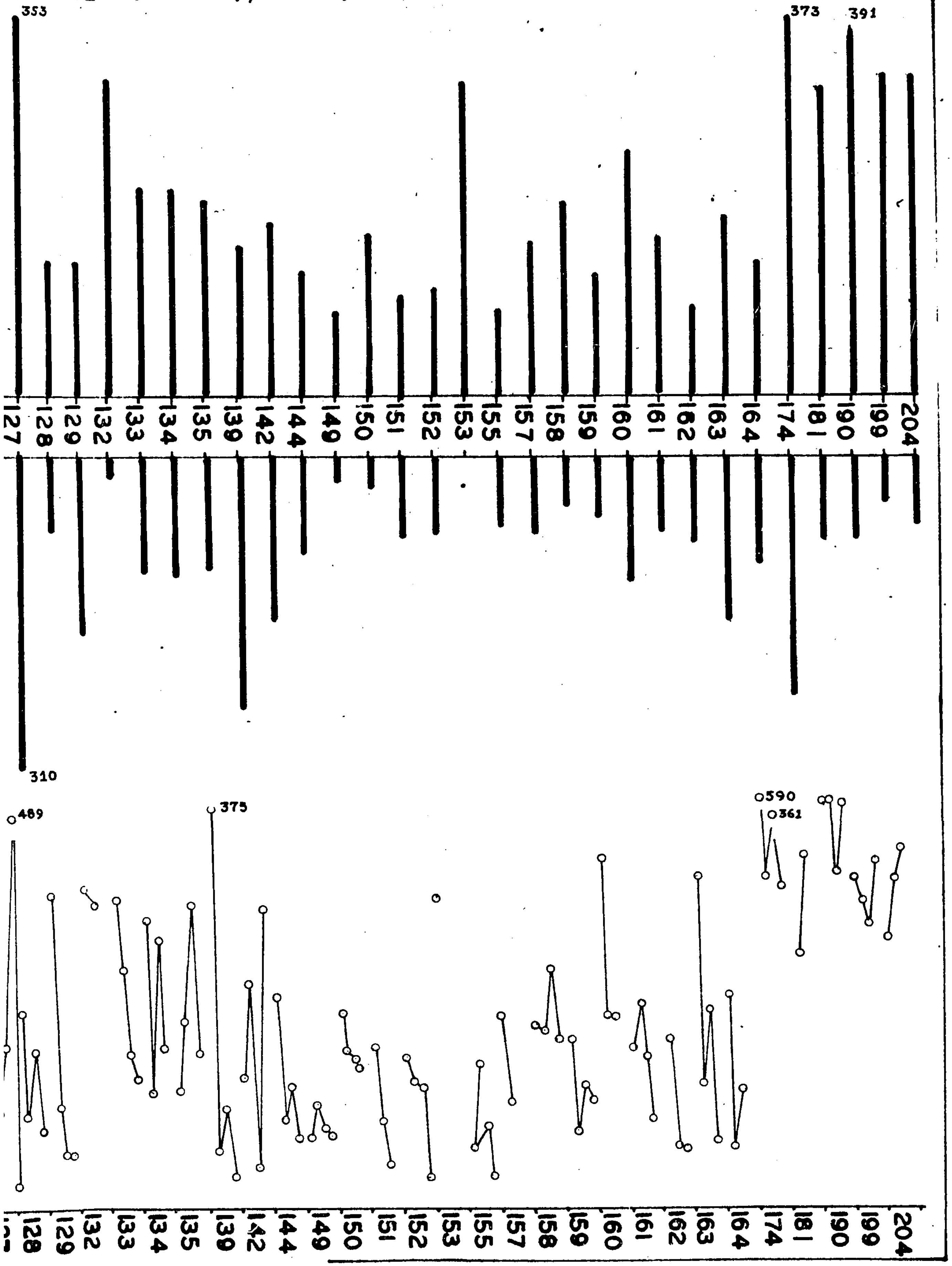


THE Sr CONTENT OF Andesite IN DIAMOND DRI



LAKE DUFAU

DRILL CORE (ppm) . NORBEC AREA



UFAULT MINES LTD.

Yittrium (Y) Rhyolite chart 37

$\bar{\bar{x}}$	70ppm
Mo	50ppm
$\bar{\sigma}$	15ppm
FD	Type I
ULB	70 + 23ppm
LLB	70 - 23ppm
C_A	19.3% of $\bar{x}$
R	.90

Holes 96 and 164 cut rhyolite which has an unusually high content of Y. Holes 127 and 181 cut rhyolite which has an exceptionally low Y content.

Y Andesite chart 38

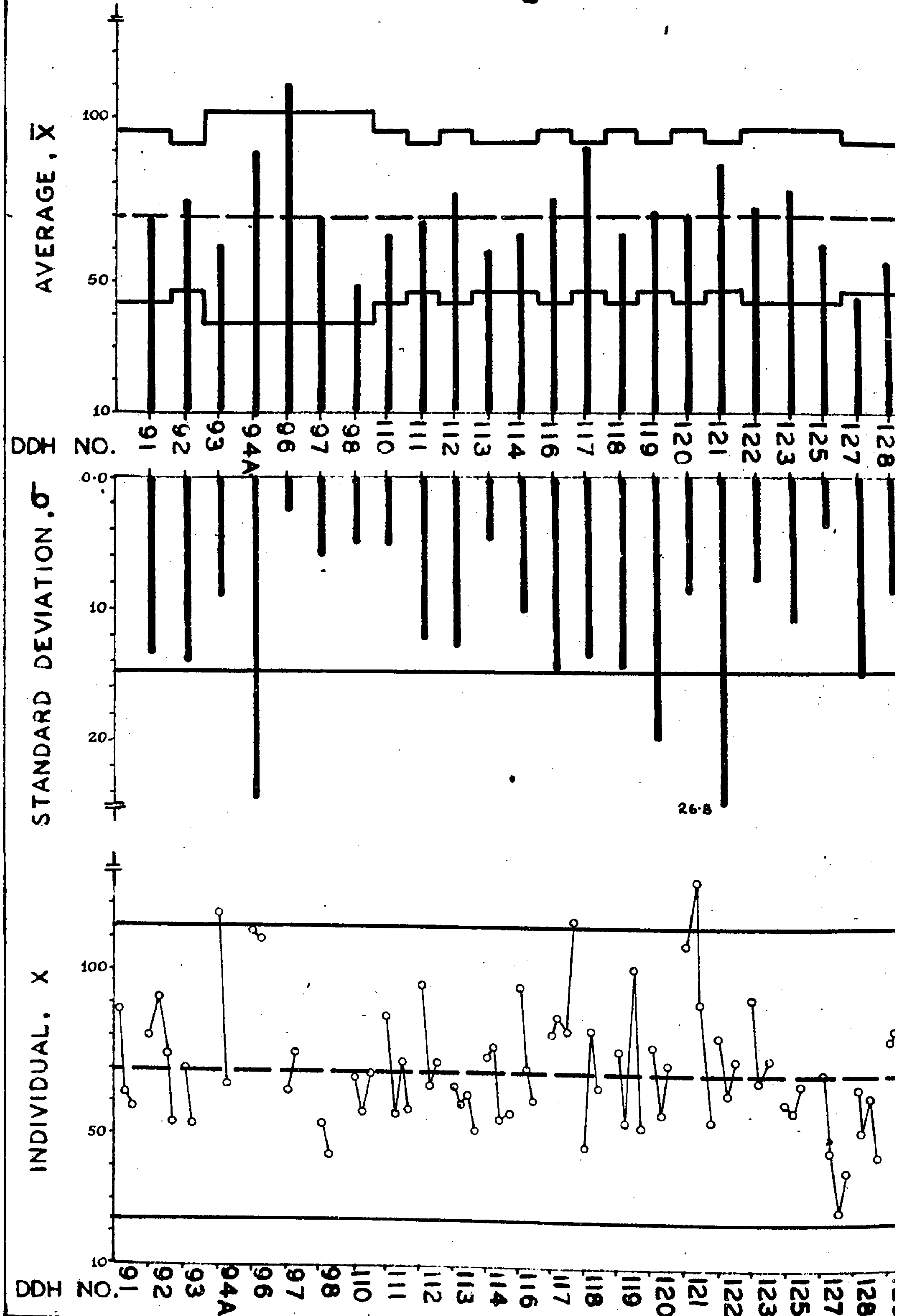
$\bar{\bar{x}}$	24ppm
Mo	20ppm
$\bar{\sigma}$	6.3ppm
FD	Type I
ULB	24 + 9.5ppm
LLB	24 - 9.5ppm
C_A	17.1% of $\bar{x}$
R	.65

A section logged as andesite in hole 125 is unusually high in Y, probably because at least two of the samples are actually rhyolite. Andesite cut by hole 113 also has an unusually high Y content.

Chart 37

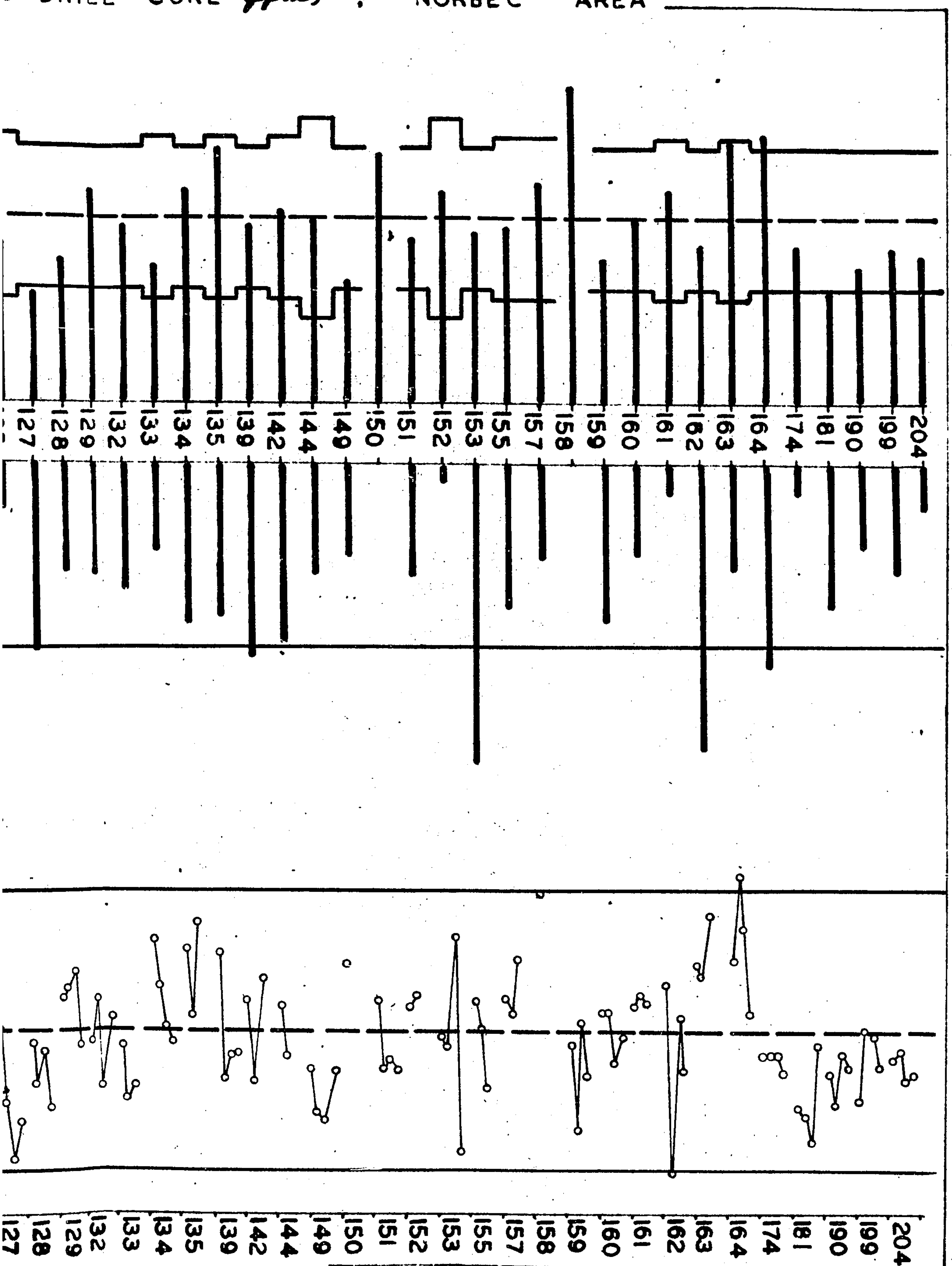
Y rhyolite

THE Y CONTENT OF *Rhyolite* IN DIAMOND DR



LAKE DUFAU

D DRILL CORE (ppm) . NORBEC AREA

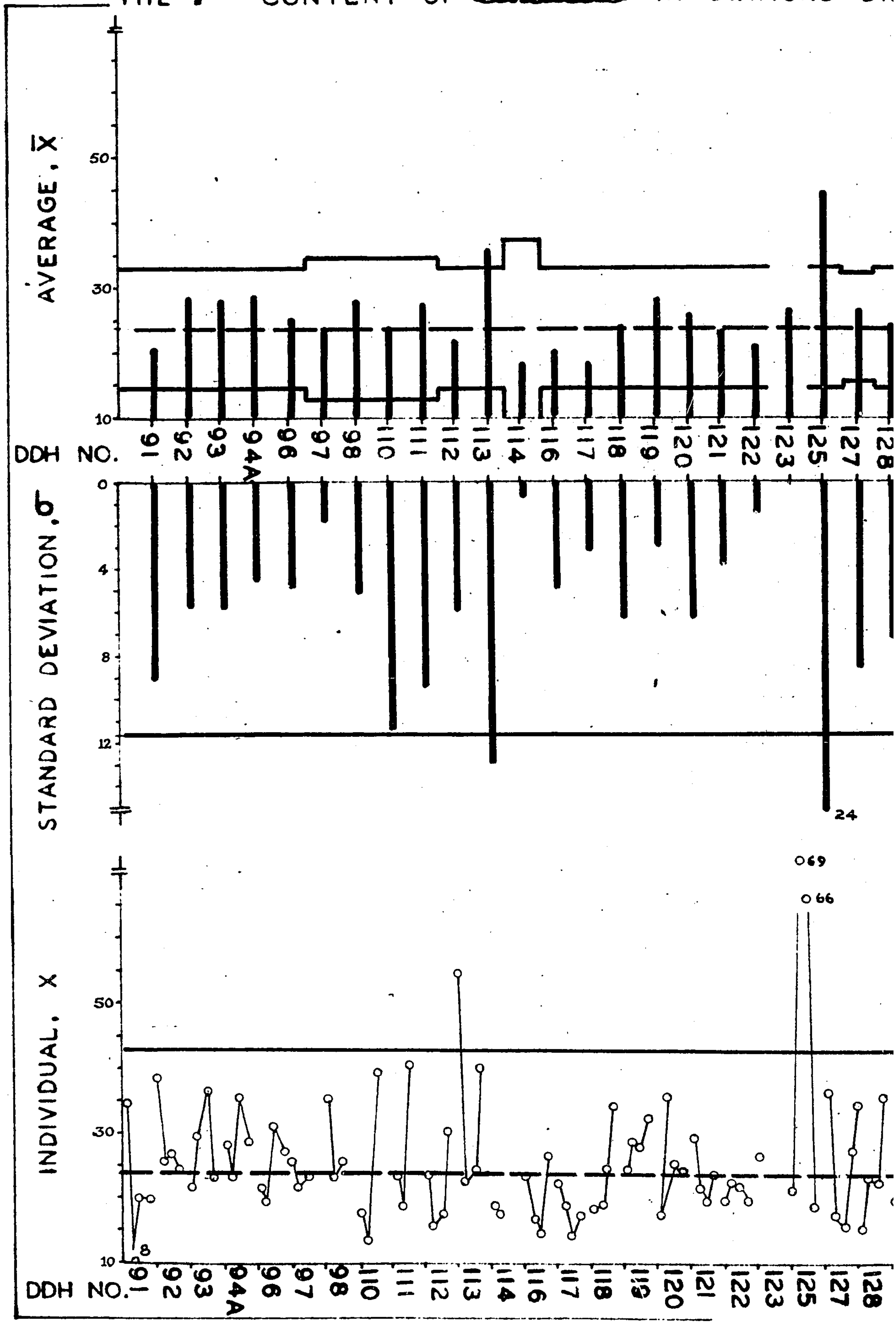


)UFAULT MINES LTD.

Chart 38

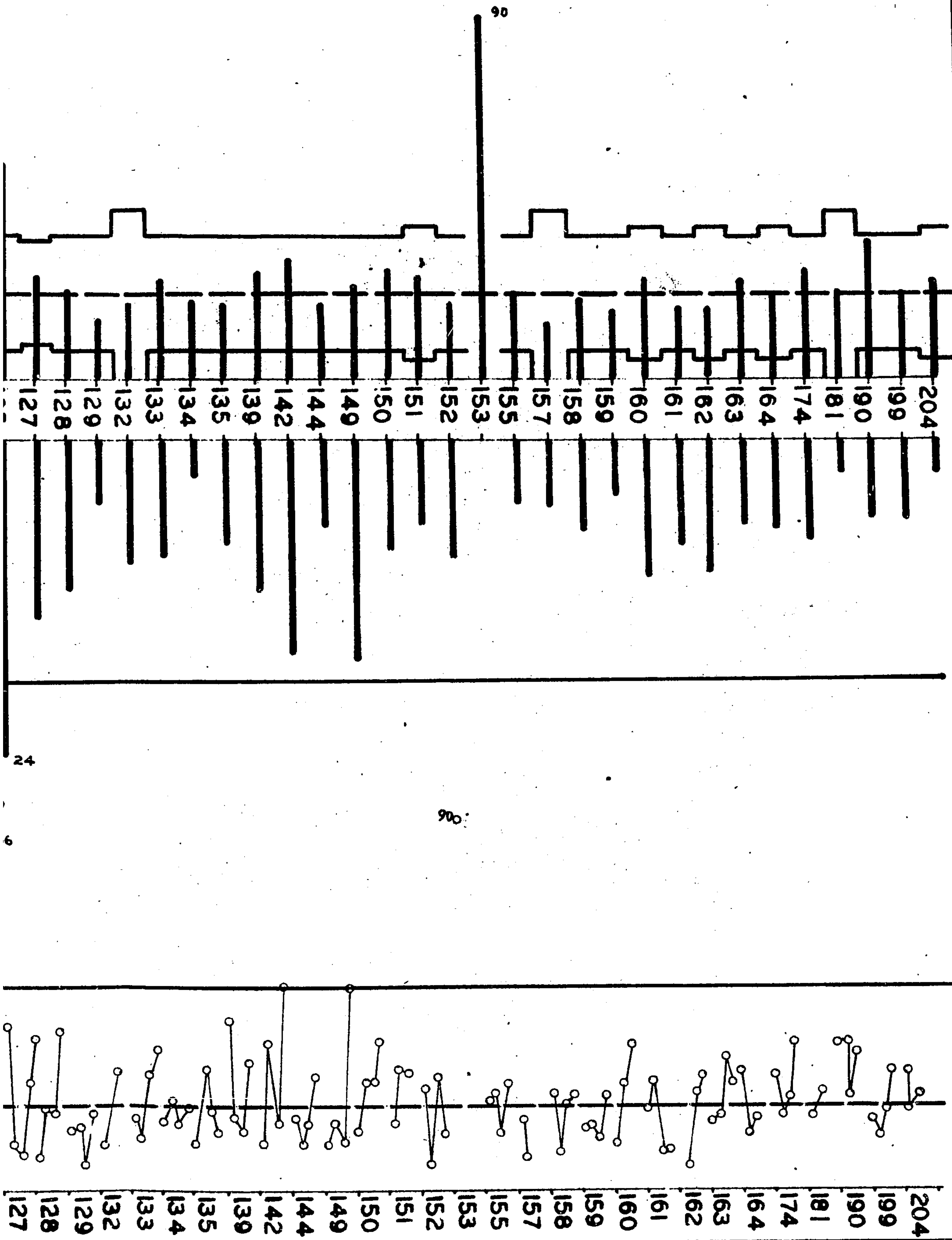
Y andesite

THE Y CONTENT OF Andesite IN DIAMOND DR



LAKE DUFA

D DRILL -OR (ppm) , NORBEC AREA



DUFAULT MINES LTD.

Zinc (Zn) Rhyolite chart 39

$\bar{\bar{x}}$	394ppm
Mo	180ppm
$\bar{\sigma}$	349ppm
FD	Type II
a	350ppm
b	500ppm
c	1000ppm
C_A	10.3% of $\bar{x}$
R	.12

Rhyolite near the ore body contains unusually high amounts of Zn, whether or not it is obviously mineralized. Two holes in the northwest Norbec area (94A, 97) also cut rhyolite with an unusually high Zn content.

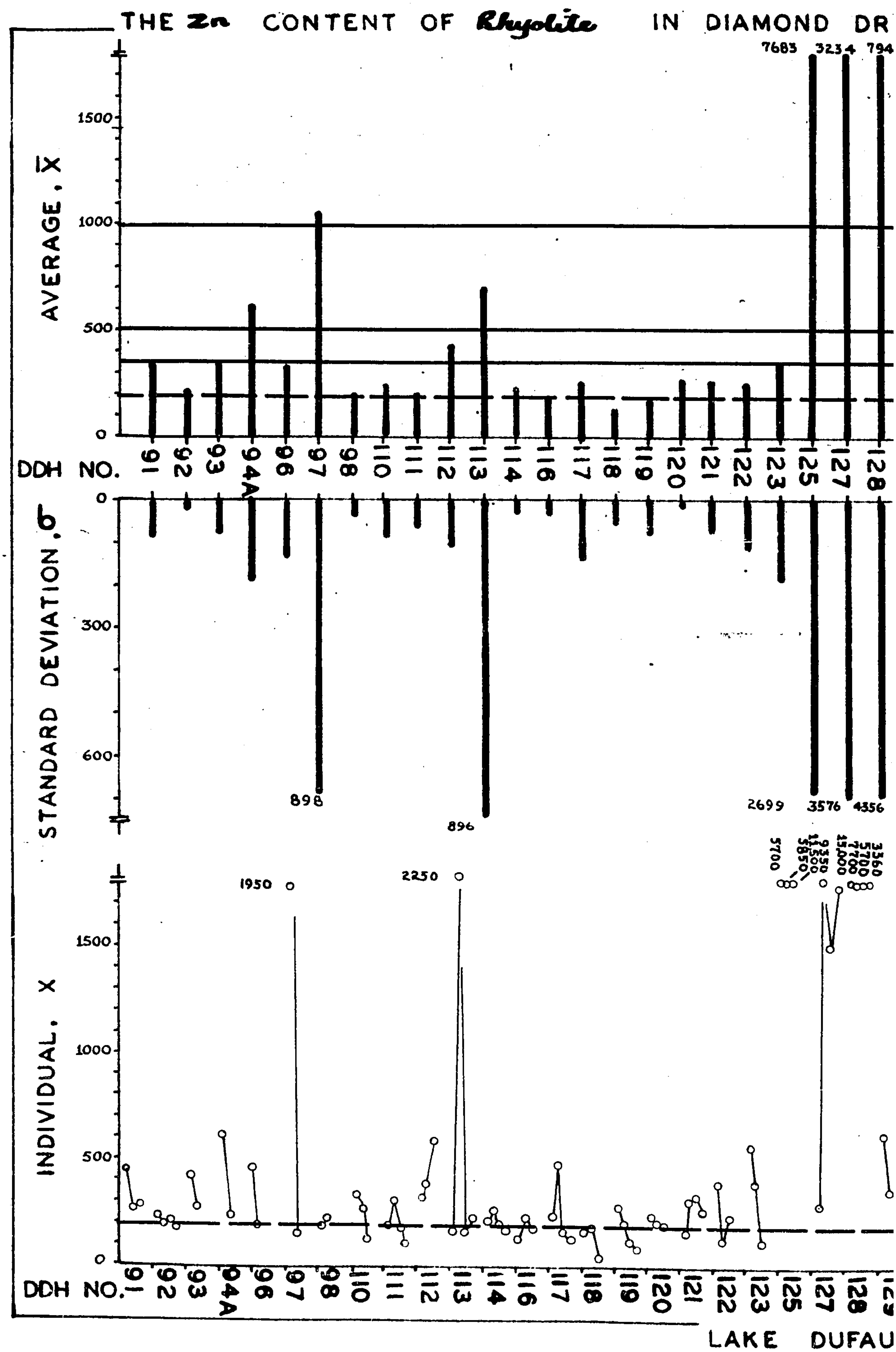
Zn Andesite chart 40

$\bar{\bar{x}}$	240ppm
Mo	160ppm
$\bar{\sigma}$	103ppm
FD	Type IV
a	250ppm
b	500ppm
C_A	19.5% of $\bar{x}$
R	.46

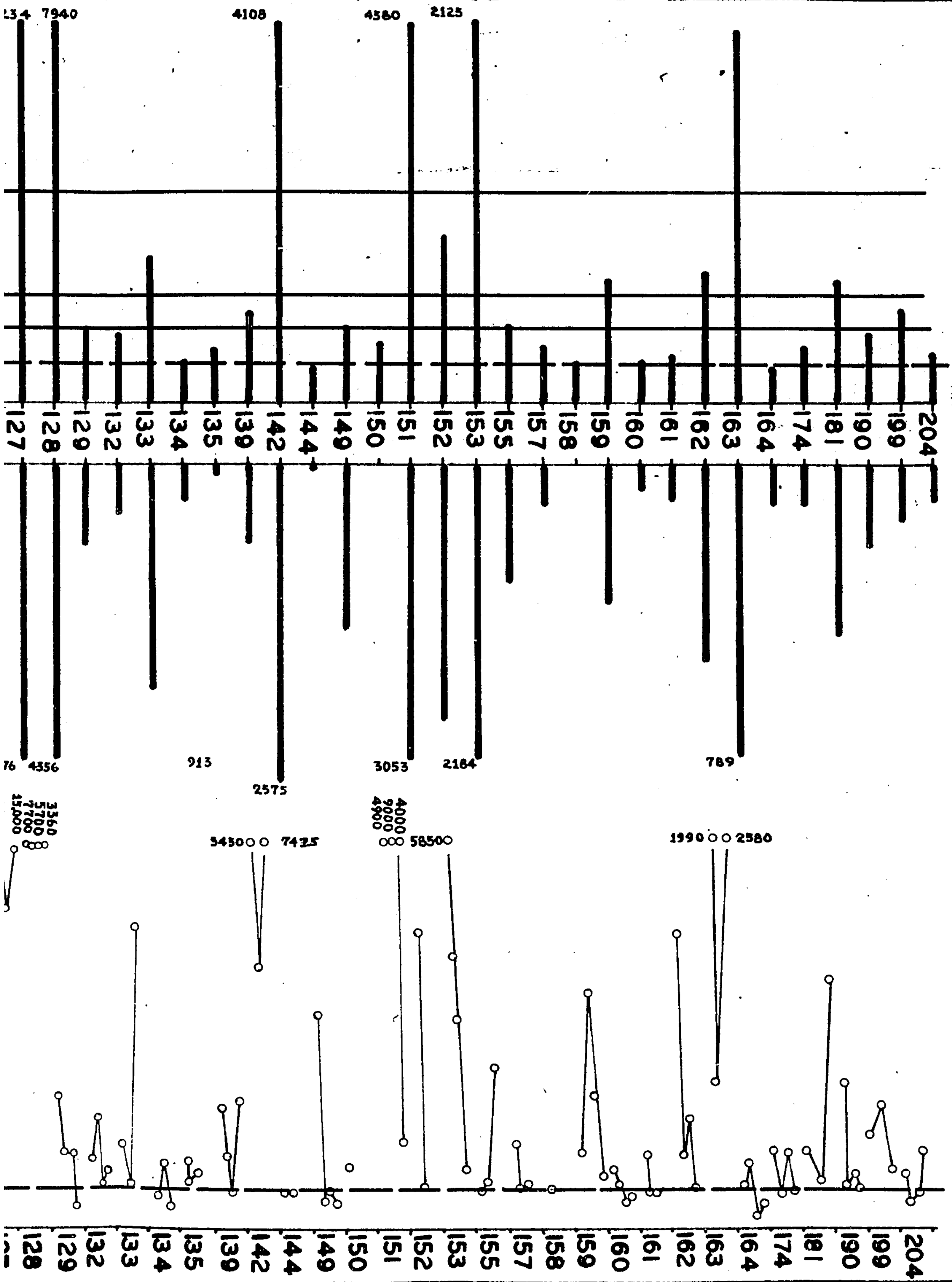
Most sections of andesite which contain abnormally high amounts of Zn come from drill holes located over or near the ore body. Other similar sections are located in the northwest corner of the property (96), north of the ore body (110) and in the Mid-Norbec area (150).

Chart 39

Zn rhyolite


THE Zn CONTENT OF Rhyolite IN DIAMOND DR
AVERAGE, X̄
STANDARD DEVIATION, σ
INDIVIDUAL, X
DDH NO.
91 92 93 94A 96 97 98 110 111 112 113 114 116 117 118 119 120 121 122 123 125 127 128
7683 3234 794
898 896 2699 3576 4356
1950 2250
LAKE DUFAU

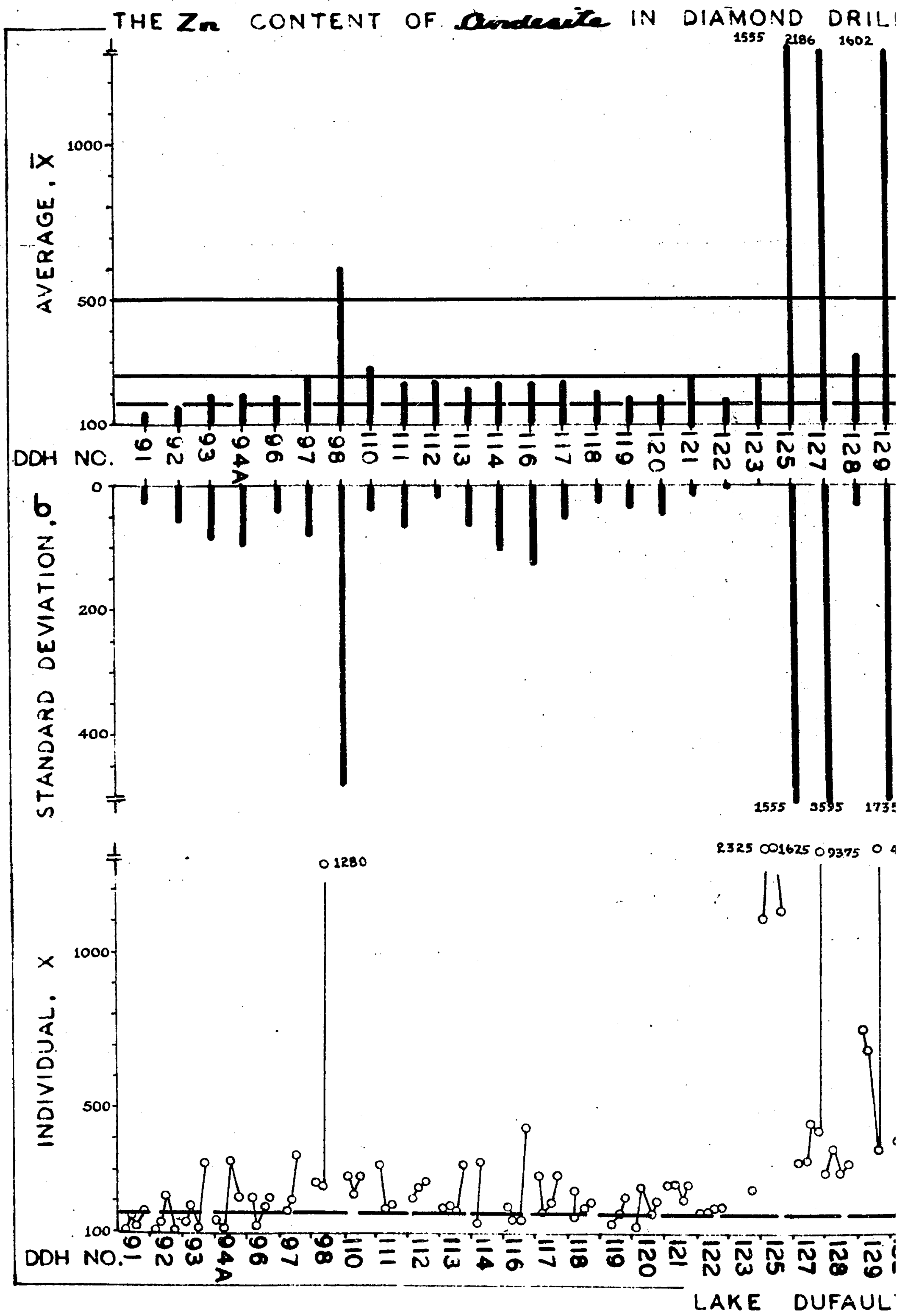
DRILL CORE (PPM) , NORBEC AREA

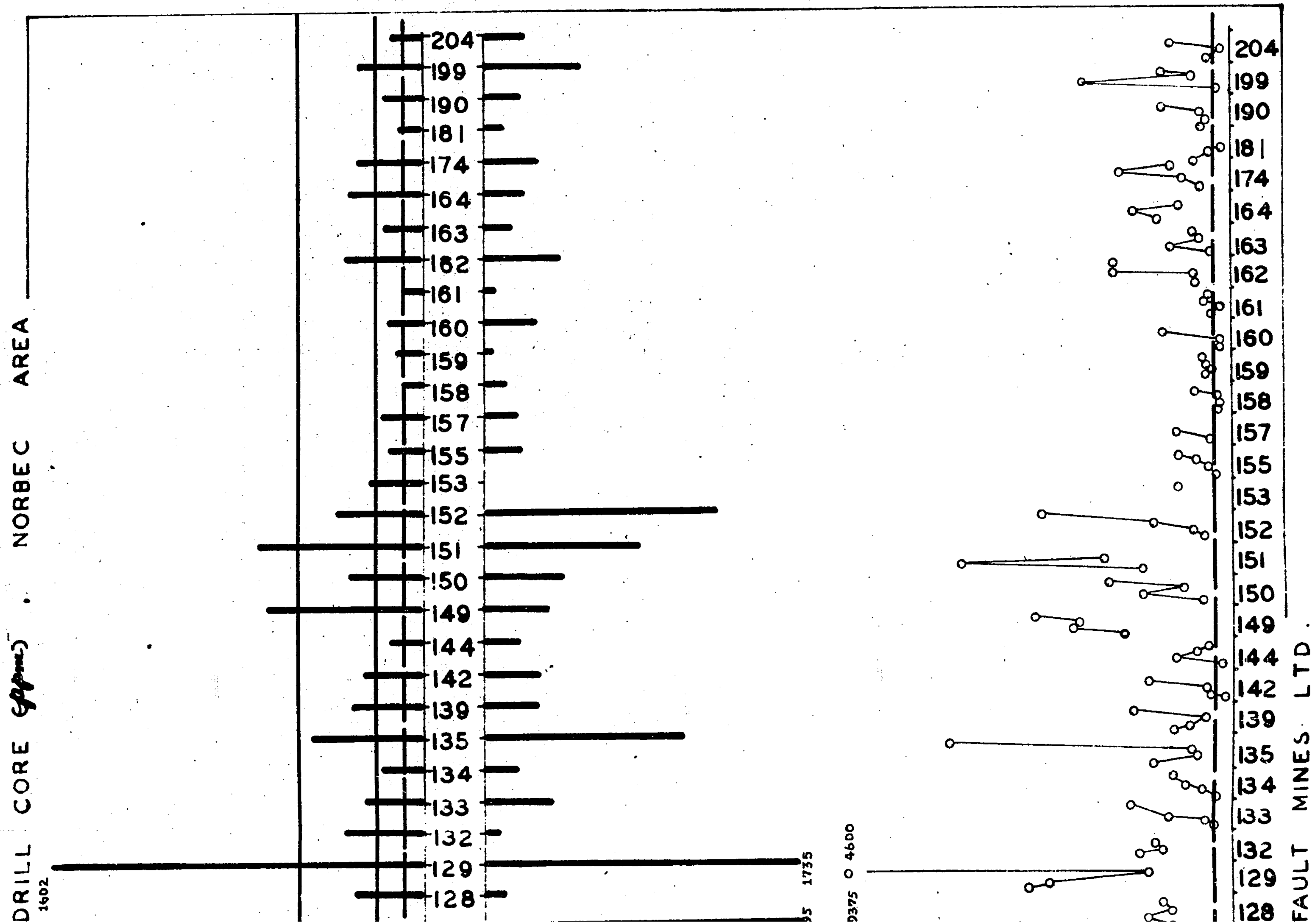


UFAULT MINES LTD.

Chart 40

Zn andesite


THE Zn CONTENT OF Andesite IN DIAMOND DRIL
AVERAGE, X̄
STANDARD DEVIATION, σ
INDIVIDUAL, X
DDH NO.
91 92 93 94A 96 97 98 110 111 112 113 114 116 117 118 119 120 121 122 123 125 127 128 129
1555 2186 1602
1555 3595 1735
2325 1625 9375
1280
100 500 1000
0 200 400
LAKE DUFAUL


DRILL CORE
NORBEC AREA
FAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
1602
1735
4600
0375

Zirconium (Zr) Rhyolite chart 41

$\bar{\bar{x}}$	405ppm
Mo	260ppm
$\bar{\sigma}$	149ppm
FD	Type II
a	450ppm
b	600ppm
C_A	27.9% of $\bar{\bar{x}}$
R	.76

Holes 121 and 142 cut rhyolite containing unusually high amounts of Zr. Rhyolite with a Zr content slightly higher than usual was cut by several scattered drill holes.

Zr Andesite chart 42

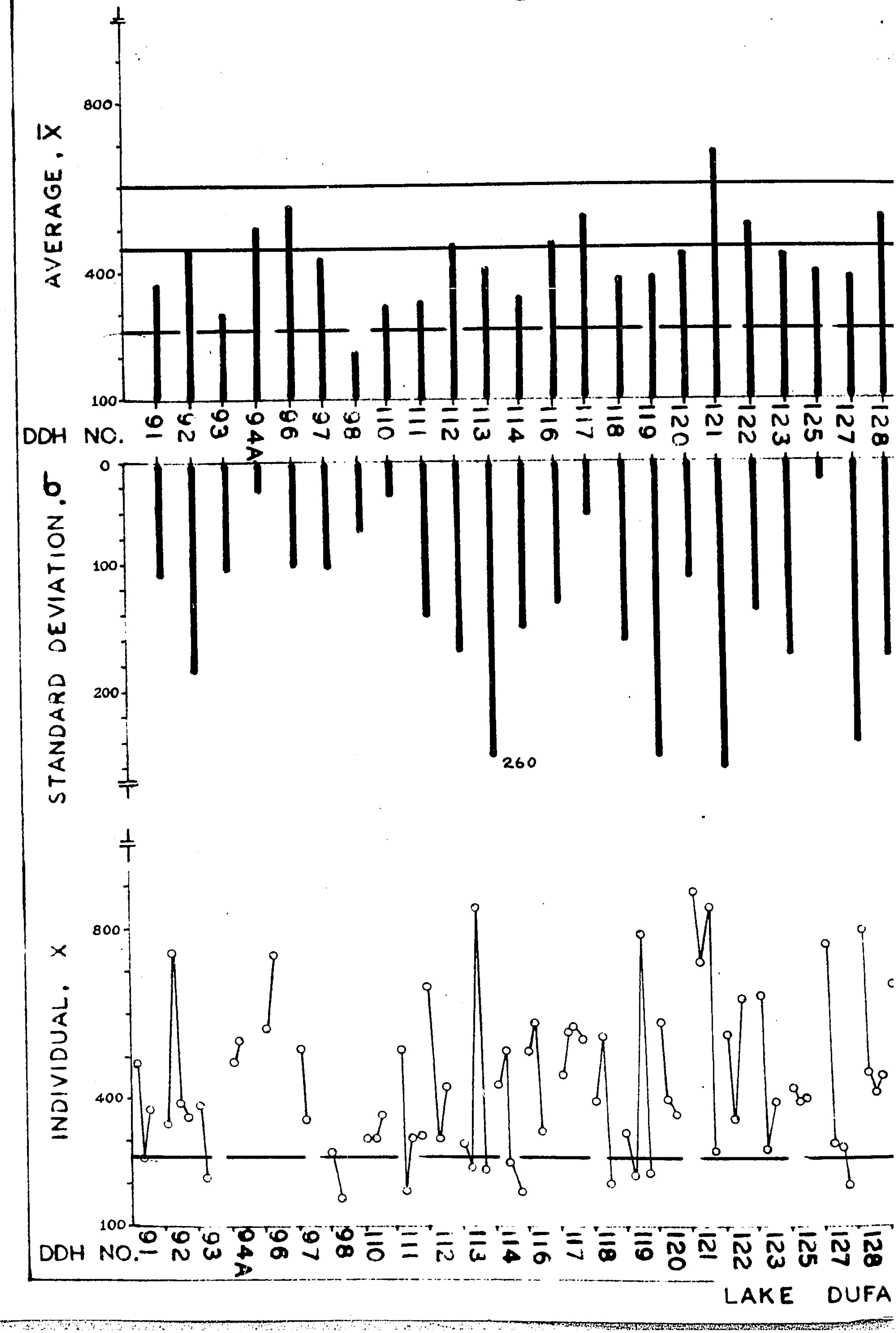
$\bar{\bar{x}}$	180ppm
Mo	180ppm
$\bar{\sigma}$	43ppm
FD	Type I
ULB	180 + 65ppm
LLB	180 - 65ppm
C_A	17.5% of $\bar{\bar{x}}$
R	1.0

A few scattered drill holes cut andesite with an unusually high Zr content. The two anomalous samples from hole 125 are probably rhyolite.

Chart 41

Zr rhyolite

THE Zr CONTENT OF *Rhyolite* IN DIAMOND DRI



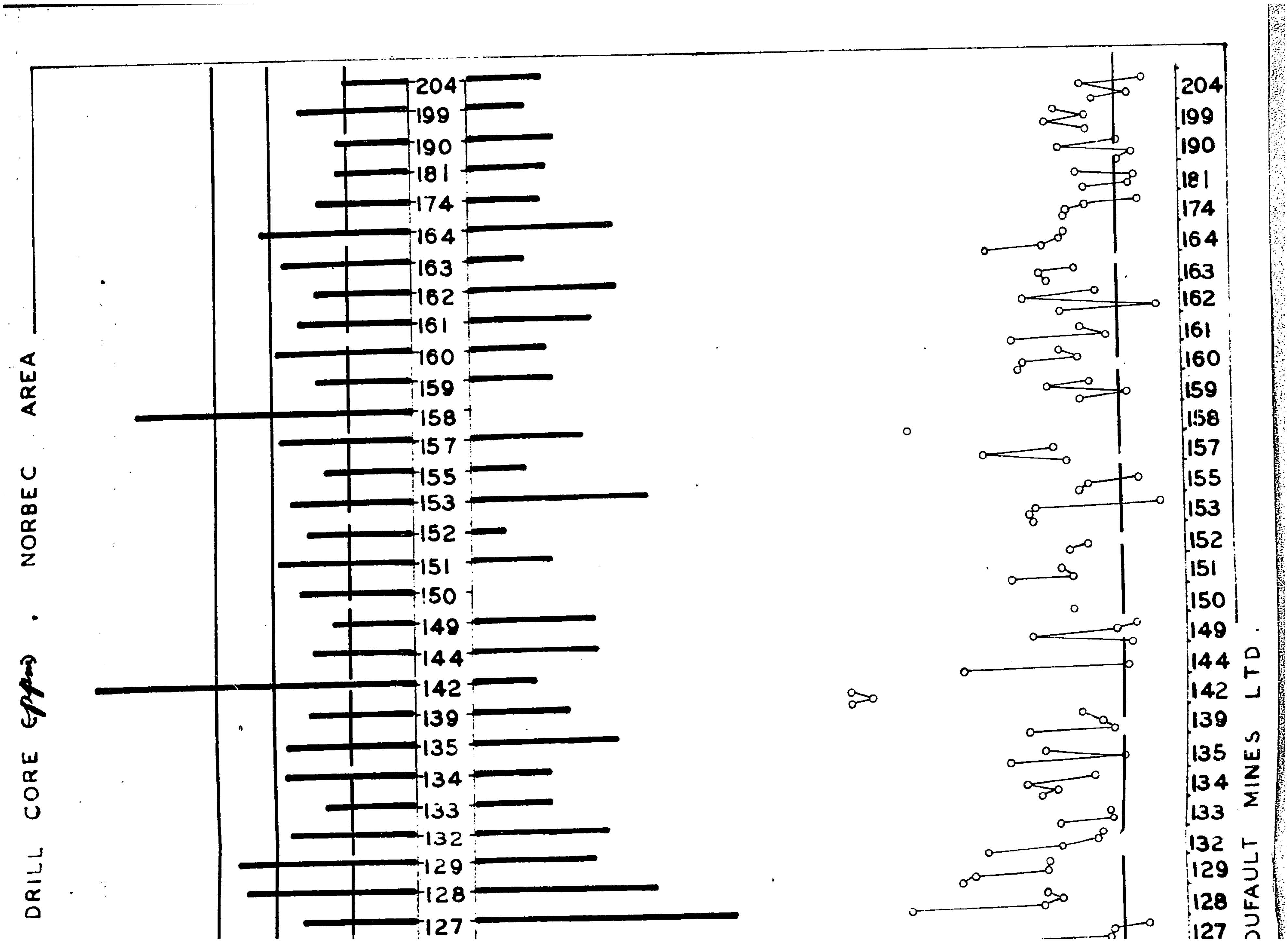
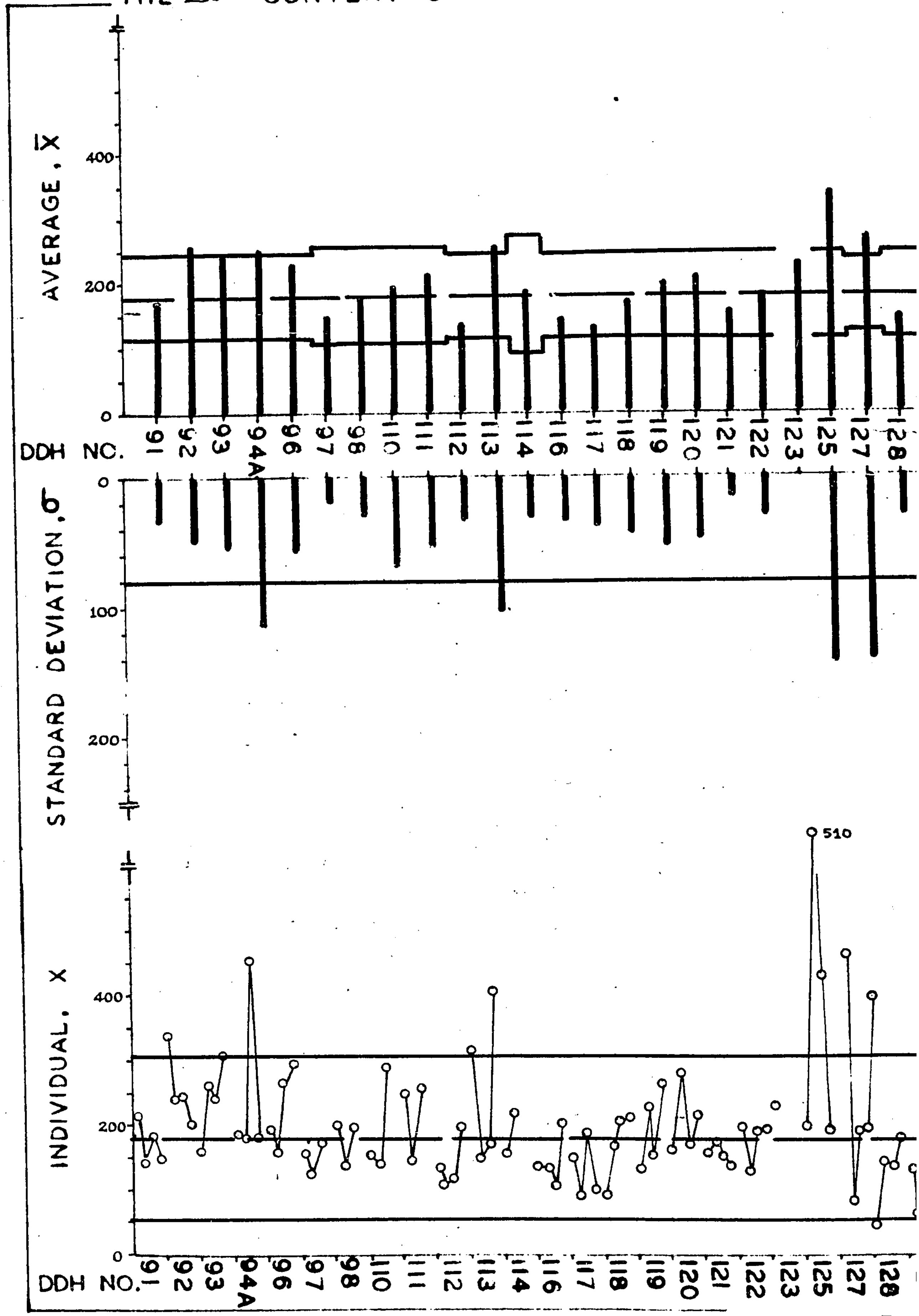

DRILL CORE . NORBEC AREA
DUFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127

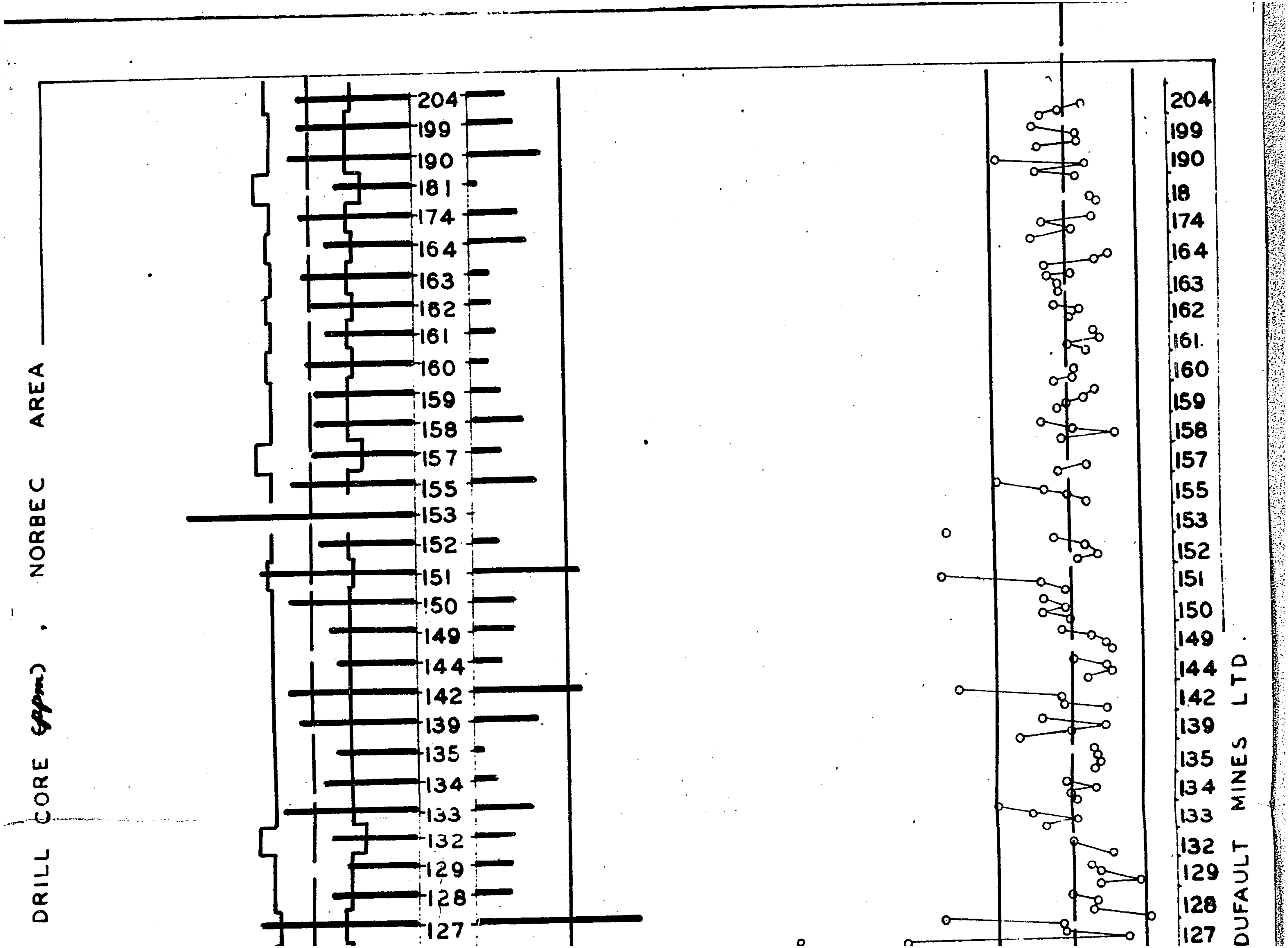
Chart 42

Zr andesite

THE Zr CONTENT OF Andesite IN DIAMOND DRI



LAKE DUFA


DRILL CORE (ppm) . NORBEC AREA
DUFAULT MINES LTD.
204
199
190
181
174
164
163
162
161
160
159
158
157
155
153
152
151
150
149
144
142
139
135
134
133
132
129
128
127

APPENDIX C

Analytical Results for

Bedded, Cherty Tuff

LAKE DUFAULT MINES LTD.
NORBEC AREA
Analytical Results
Tuff

SiO_2

*159[1]	51.4%
*135	53.3
*139	53.6
*163	54.0
119	56.4
118	57.5
*164	59.0
121	60.7
*174	61.0
*144	61.3
155	61.8
157	62.6
116	62.7
*181	64.3
150	66.0
158	66.8

Mdn: 61.0%
Range: 15.4%
r: 5/3

TiO_2

*164	.40%
*139	.50
*174	.52
119	.54
150	.59
*181	.63
158	.65
157	.66
121	.68
155	.71
118	.75
*144	.78
*190	.79
*159	.88
116	.96
*163	1.02
*135	1.08

Mdn: 0.68%
Range: 0.68%
r: 4/5

Al_2O_3

*164	11.8%
*174	13.3
155	13.9
*163	14.1
118	14.1
158	14.5
150	15.3
*135	15.8
*139	15.85
119	16.8
121	16.9
*181	18.2
*159	18.4
157	19.0
*144	20.0
116	20.2

Mdn: 15.8%
Range: 8.14%
r: 4/4

Fe_2O_3

157	8.8%
*135	8.98
*181	10.6
*159	10.7
*190	11.2
*163	11.7
121	12.0
155	12.7
158	13.2
*164	13.8
150	14.4
*144	14.5
116	17.0
119	17.5
*174	17.7
118	19.0
*139	24.6

Mdn: 13.2%
Range: 15.8%
r: 5/4

*samples near the orebody
1 diamond drill hole

Table C1

LAKE DUFAULT MINES LTD.
NORBEC AREA
Analytical Results
Tuff

MnO

121[1]	.09%
157	.10
*190	.10
*181	.11
*174	.12
*164	.13
*139	.14
116	.15
*144	.15
155	.16
*135	.16
*163	.17
158	.18
118	.18
150	.20
*159	.23
119	7.47

Mdn: 0.15%
Range: 0.14%
(except 7.47)
r: 5/4

CaO

*139	1.54%
*190	2.36
119	3.88
*144	4.43
116	4.8
*174	4.83
*181	4.84
121	5.14
157	5.57
150	5.6
158	6.4
155	6.45
*163	7.0
*135	7.35
*164	8.0
118	8.25
*159	9.5

Mdn: 5.5%
Range: 7.96%
r: 5/4

K_2O

*139	.84%
118	.94
150	1.06
*159	1.07
*135	1.18
*164	1.52
116	1.62
158	1.64
157	1.7
155	1.73
*144	1.86
119	1.93
*163	1.95
*174	2.12
*181	2.2
121	2.69
*190	2.8

Mdn: 1.7%
Range: 1.96%
r: 4/5

MgO

*135	.19%
*181	1.21
*164	1.46
119	1.75
150	1.77
*174	2.3
155	2.41
157	2.66
*190	2.79
158	2.86
*139	2.97
121	3.17
116	3.2
*159	3.45
118	3.46
*144	3.49
*163	3.82

Mdn: 2.8%
Range: 2.62
r: 5/4

* samples near the orebody
1 diamond drill hole

Table C2

LAKE DUFAULT MINES LTD.
NORBEC AREA
Analytical Results
Tuff

Na_2O

*174[1]	.93%	
*181	.95	
*164	1.00	
119	1.09	
*190	1.24	
155	1.33	
*163	1.42	
158	1.44	
——	——	
116	1.56	
118	1.85	
150	1.94	
*139	2.0	
121	2.14	
*144	2.18	
157	3.06	Mdn: 1.5%
*159	3.32	Range: 2.57%
*135	3.5	r: 5/4

Ag

*190	.34ppm	
*135	.64	
*159	.69	
*144	.83	
119	.98	
157	1.02	
116	1.17	
118	1.17	
——	——	
*181	1.25	
*139	1.33	
121	1.53	
*163	1.54	
150	1.57	
158	2.16	
155	2.21	Mdn: 1.25ppm
*164	4.23	Range: 4.36ppm
*174	4.70	r: 4/5

Bi

*135	1.3	
157	1.4	
121	1.47	
*181	1.5	
*159	1.5	
118	1.7	
——	——	
150	2.4	
*144	2.5	
*174	3.5	
*139	3.6	
158	4.9	Median: 2.4ppm
*190	6.0	Range: 6.1ppm
155	7.4	r: 3/4

Cd

118	.4ppm	
*135	.4	
157	.7	
155	.7	
*144	.9	
158	1.1	
——	——	
*163	1.3	
*139	1.4	
*174	1.6	
*190	1.6	Median: 1.2ppm
*181	2.0	Range: 2.0ppm
*164	2.4	r: 2/6

* samples near the orebody
1 diamond drill hole

Table C3

LAKE DUFAULT MINES LTD.
NORBEC AREA
Analytical Results
Tuff

Ge

138[1]	.7
118	1.0
*144	1.2
157	1.2
*181	1.2

121	1.3
119	1.4
*164	1.6
150	2.3
*135	2.4

Median: 1.25ppm
Range: 1.7ppm
r: 2/2

Ni

*159	27.3ppm
*135	38.0
*164	44.0
155	47.5
*190	49.0
119	51.0
158	53.9
*144	57.3

*163	67.3
*139	70.0
150	72.0
157	76.0
116	77.0
118	86.8
*174	88.0
121	105.17

Median: 60ppm
Range: 77.9ppm
r: 5/3

Pb

118	.5ppm
*144	.7
*164	.9
*190	1.7
150	1.8
116	2.8
119	2.9
121	3.47

*159	4.6
*181	5.0
157	5.3
*139	6.7
*135	7.0
158	9.3
*163	14.4
155	25.3
*174	48.0

Median: 4.6ppm
Range: 24.8ppm
r: 3/6

Sn

157	.1
*159	.2
*135	1.5
*181	2.2
150	2.3
121	2.37
*144	2.8
119	3.5

118	4.0
*164	4.2
*163	4.7
158	5.3
*139	5.5
116	8.2
*190	8.8
*174	12.4
155	21.2

Median: 4.0ppm
Range: 21.1ppm
r: 4/5

* samples near the orebody
1 diamond drill hole

Table C5

LAKE DUFAULT MINES LTD.
NORBEC AREA
Analytical Results
Tuff

Sr

116[1]	228ppm	
*144	254	
*139	283	
119	284	
*164	294	
*163	305	
157	317	
158	340	

121	345.67	
150	347	
*159	357.5	
155	371	
*190	372	
118	398.5	Median: 340ppm
*135	461	Range: 285ppm
*174	513	r: 4/4

Y

118	22.0ppm	
*163	24.7	
*135	26.0	
150	27.5	
*144	27.6	
158	29.7	
*164	30.0	
121	31.27	

*159	35.4	
116	36.0	
155	36.6	
*139	37.0	
119	37.0	
157	38.0	Median: 32ppm
*174	45.0	Range: 23ppm
*190	45.0	r: 4/4

Zn

*164	245.0ppm	
*159	270.0	
121	270.67	
*190	280.0	
150	438.0	
119	513.0	
116	1225.0	
118	1635.0	

*174	1815.0	
*135	1915.0	
155	1945.0	
*181	2040.0	
157	2140.0	
158	2280.0	
*144	2605.0	Median: 1800ppm
*139	3035.0	Range: 3925ppm
*163	4170.0	r: 3/6

Zr

150	192ppm	
*164	194	
*163	217	
121	222.67	
155	225	
*144	231.5	
157	250	
158	255.5	

119	270	
*174	273.5	
*159	288	
139	301.5	
*135	334	
*190	358	Median: 260ppm
118	387.5	Range: 223ppm
116	415	r: 3/4

* samples near the orebody
1 diamond drill hole

Table C6

APPENDIX D

Summary of Anomalous Values of the Elements in Rhyolite and Andesite

Table D1

Summary of Anomalous Values for Major Elements in Rhyolite[1]

DDH	SiO_2	TiO_2	Al_2O_3	CaO	K_2O	Na_2O
91	1	0	0	0	0	0
92	1	0	0	0	0	0
93	1	0	0	0	0	-1
94A	1	0	0	0	0	0
96	0	2	0	0	0	0
97	1	0	0	0	0	0
98	1	0	0	0	0	0
110	0	0	0	0	0	-1
111	0	0	0	0	0	0
112	0	0	0	0	0	-1
113	0	0	0	0	0	0
114	0	0	0	0	0	0
116	0	0	0	0	0	0
117	0	0	0	0	0	-1
118	0	0	0	0	0	-1
119	0	0	0	0	0	0
120	0	0	0	0	0	0
121	0	0	0	0	0	0
122	0	0	0	0	0	0
123	0	0	0	0	0	0
125	0	2	0	-2	0	2
127	1	0	0	-2	0	2
128	2	0	0	0	0	1
129	0	0	0	2	0	1
132	0	0	0	2	0	1
133	0	0	0	2	0	0
134	0	2	0	0	0	0
135	0	0	0	0	0	0
139	1	2	0	0	0	0
142	2	0	0	2	0	1
144	0	0	0	0	0	-1
149	0	0	0	0	0	0
150	0	0	0	0	0	0
151	1	0	0	0	0	1
152	0	0	0	0	0	-1
153	0	2	0	0	0	0
155	0	0	0	0	0	-1
157	0	0	0	0	0	-1
158	0	0	0	0	0	0
159	0	0	0	0	0	0
160	0	0	0	0	0	0
161	0	0	0	0	0	0
162	0	0	0	0	0	1
163	0	0	0	0	0	0
164	0	0	0	0	0	-1
174	0	0	0	0	0	0
181	0	0	0	2	0	0
190	0	0	0	2	0	0
199	0	0	0	0	2	-1
204	0	0	0	0	0	0

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, Type I; -2 < LLB, Type 1
   for Na_2O -1 = 3.3 - 4.4%, 1 = 1.7 - 0.5%, 2 < .5%
   0 = background values

Table D2

Summary of Anomalous Values for Trace Elements in Rhyolite[1]

DDH	Ga	Ni	Sr	Y	Zr
91	0	2	0	0	0
92	0	1	0	0	0
93	0	2	0	0	0
94A	0	2	0	0	0
96	0	2	0	2	0
97	0	2	0	0	0
98	0	0	0	0	0
110	0	2	0	0	0
111	0	1	0	0	0
112	0	1	0	0	0
113	0	1	0	0	0
114	0	1	0	0	0
116	0	1	0	0	0
117	0	2	0	0	0
118	0	2	0	0	0
119	0	0	0	0	0
120	0	1	0	0	0
121	0	1	0	0	2
122	0	2	0	0	0
123	0	2	0	0	0
125	0	1	0	0	0
127	0	1	-2	-2	0
128	0	1	-2	0	0
129	0	2	0	0	0
132	0	0	0	0	0
133	0	2	0	0	0
134	0	2	0	0	0
135	0	2	0	0	0
139	0	1	0	0	0
142	0	2	0	0	2
144	0	1	0	0	0
149	0	1	0	0	0
150	0	0	0	0	0
151	0	2	0	0	0
152	0	2	0	0	0
153	0	2	0	0	0
155	0	2	0	0	0
157	0	1	0	0	0
158	0	0	0	0	0
159	0	2	0	0	0
160	0	2	0	0	0
161	0	2	0	0	0
162	0	2	0	0	0
163	0	2	0	2	0
164	0	2	0	0	0
174	2	0	0	0	0
181	0	2	0	0	0
190	2	1	0	0	0
199	0	2	0	0	0
204	0	1	0	0	0

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, TypeI; -2 < LLB, Type I
   0 = background values

Table D3

Summary of Anomalous Values for "Ore-Major" Elements in Rhyolite[1]

DDH	Fe_2O_3	MnO	MgO	Sum
91	0	0	2	2
92	0	2	0	2
93	0	0	1	1
94A	0	0	0	0
96	0	0	0	0
97	1	0	1	2
98	0	0	2	2
110	0	0	0	0
111	0	0	0	0
112	0	0	0	0
113	0	2	0	2
114	0	0	0	0
116	0	0	0	0
117	0	0	0	0
118	0	0	0	0
119	0	0	0	0
120	0	0	0	0
121	0	0	2	2
122	0	0	1	1
123	0	0	1	1
125	2	0	0	2
127	2	0	2	4
128	2	2	1	5
129	2	2	2	6
132	2	2	2	6
133	2	2	1	5
134	0	0	2	2
135	0	0	0	0
139	0	1	0	1
142	2	1	2	5
144	0	0	0	0
149	0	0	1	1
150	0	0	0	0
151	1	0	1	2
152	0	0	0	0
153	1	0	2	3
155	0	0	0	0
157	0	0	0	0
158	0	0	0	0
159	0	0	0	0
160	0	0	0	0
161	0	0	0	0
162	2	1	1	4
163	0	0	0	0
164	0	0	0	0
174	0	0	0	0
181	0	0	2	2
190	0	0	0	0
199	0	0	2	2
204	0	0	0	0

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, Type 1; -2 < LLB, Type 1
   0 = background values

Table D4

Summary of Anomalous Values for "Ore-Trace" Elements in Rhyolite[1]

DDH	Ag	Cu	Pb	Sn	Zn	Sum
91	0	0	1	0	0	1
92	0	0	0	0	0	0
93	0	0	0	2	0	2
94A	0	0	2	0	2	4
96	0	0	0	0	0	0
97	1	2	0	2	2	7
98	0	0	0	0	0	0
110	0	0	0	0	0	0
111	0	0	0	0	0	0
112	0	0	0	0	1	1
113	0	0	0	0	2	2
114	0	0	0	0	0	0
116	1	0	0	0	0	1
117	0	0	0	0	0	0
118	0	0	0	1	0	1
119	0	0	0	0	0	0
120	0	0	0	1	0	1
121	0	0	0	0	0	0
122	0	0	0	2	0	2
123	0	0	0	1	1	2
125	2	2	1	2	2	9
127	2	2	1	2	2	9
128	2	2	2	2	2	10
129	2	2	0	2	1	7
132	1	1	1	2	0	5
133	0	0	0	2	2	4
134	0	1	0	0	0	1
135	0	1	1	0	0	2
139	0	1	0	0	1	2
142	2	2	2	2	2	10
144	0	2	0	0	0	2
149	2	2	2	0	1	7
150	0	0	0	0	0	0
151	0	0	0	0	0	10
152	2	2	0	1	2	7
153	2	2	1	2	2	9
155	0	0	0	0	1	1
157	0	0	0	0	0	0
158	0	0	0	0	0	0
159	2	2	0	0	2	6
160	0	0	0	0	0	0
161	0	0	0	2	1	3
162	1	2	0	2	2	7
163	2	0	1	2	2	7
164	1	1	0	0	0	2
174	0	0	0	0	0	0
181	1	0	1	1	2	5
190	1	0	0	0	0	1
199	1	0	1	1	2	5
204	1	0	1	0	0	2

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, Type 1; -2 < LLB, Type 1
   0 = background values

Table D5

Summary of Anomalous Values for Major Elements in Andesite[1]

DDH	SiO_2	TiO_2	Fe_2O_3	MnO	CaO	K_2O	MgO	Na_2O
91	0	-2	0	0	0	1	0	0
92	0	-2	-2	0	0	0	0	0
93	0	-2	0	0	0	1	0	0
94A	0	-2	0	0	0	1	0	0
96	0	0	0	0	0	1	2	0
97	0	0	0	0	0	1	0	2
98	0	0	0	0	0	0	0	0
110	0	0	0	0	2	0	0	0
111	0	0	0	0	0	1	0	0
112	0	0	0	0	0	2	0	0
113	0	0	0	0	0	0	0	0
114	0	0	0	0	2	2	0	0
116	0	0	0	0	2	1	0	0
117	0	0	0	0	0	1	0	0
118	0	0	0	0	2	0	0	0
119	0	0	0	0	0	0	0	0
120	0	0	0	0	2	1	-2	0
121	0	0	0	0	0	0	0	0
122	0	0	0	0	2	0	0	0
123	0	0	0	0	0	1	0	0
125	2	-2	2	2	-2	2	0	0
127	0	0	0	2	0	0	0	0
128	0	0	0	0	2	0	0	0
129	0	0	0	2	2	1	0	0
132	0	0	0	2	0	2	2	0
133	0	0	0	0	0	0	0	0
134	0	0	0	0	2	0	0	0
135	0	0	0	0	0	0	0	0
139	0	0	0	0	0	2	0	0
142	0	0	0	0	0	2	0	0
144	0	0	0	0	0	1	0	0
149	0	0	0	2	2	2	0	0
150	0	0	2	2	0	0	0	0
151	0	0	0	0	0	2	0	0
152	0	0	0	0	0	0	0	0
153	0	0	0	0	0	1	0	0
155	0	0	0	0	0	1	0	0
157	0	0	0	0	0	0	0	0
158	0	0	0	0	2	1	-2	0
159	0	0	0	0	0	1	0	0
160	0	0	0	0	0	1	0	0
161	0	-2	0	0	0	1	0	0
162	0	0	0	0	0	1	0	0
163	0	0	0	0	0	0	2	0
164	0	0	0	2	0	0	0	0
174	0	0	0	0	0	1	0	0
181	0	0	0	0	0	0	0	0
190	2	-2	0	0	0	1	0	0
199	2	-2	0	0	0	1	0	0
204	2	0	0	0	0	0	2	0

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, Type I; -2 < LLB, Type I
   0 = background values

Table 6

Summary of Anomalous Values for Trace Elements in Andesite[1]

DDH	Co	Cr	Ni	Ga	Sn	Y	Zr
91	0	0	0	0	1	0	0
92	0	0	0	0	1	0	2
93	0	0	0	0	1	0	0
94A	0	0	0	0	2	0	2
96	1	1	2	0	0	0	0
97	0	0	0	0	1	0	0
98	0	0	0	0	1	0	0
110	1	1	2	0	0	0	0
111	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0
113	0	0	0	0	1	2	2
114	0	1	2	0	0	0	0
116	0	0	1	0	0	0	0
117	0	0	1	0	0	0	0
118	1	1	2	0	0	0	0
119	0	0	0	0	1	0	0
120	1	2	2	0	0	0	0
121	0	0	0	0	0	0	0
122	0	0	1	0	0	0	0
123	0	2	2	0	0	0	0
125	0	0	0	0	1	2	2
127	2	0	2	0	0	0	2
128	0	0	1	0	0	0	0
129	0	0	1	0	0	0	0
132	0	1	0	0	0	0	0
133	0	0	1	0	0	0	0
134	0	1	1	0	0	0	0
135	0	0	0	0	0	0	0
139	1	0	2	0	0	0	0
142	0	0	1	0	0	0	0
144	0	0	1	0	2	0	0
149	0	0	0	0	0	0	0
150	2	0	1	0	0	0	0
151	0	0	0	0	0	0	2
152	0	0	0	0	0	0	0
153	0	0	0	0	1	0	0
155	0	0	0	0	0	0	0
157	0	0	0	0	1	0	0
158	2	1	2	0	0	0	0
159	0	0	1	0	0	0	0
160	0	0	1	0	0	0	0
161	0	1	1	0	0	0	0
162	0	0	0	0	0	0	0
163	2	0	2	0	0	0	0
164	0	0	0	0	0	0	0
174	2	2	2	0	0	0	0
181	0	0	0	0	0	0	0
190	0	0	0	2	0	0	0
199	0	0	0	1	0	0	0
204	2	1	1	1	0	0	0

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, Type I; -2 < LLB, Type I
   0 = background values

Table D7

Summary of Anomalous Values for "Ore-Trace" Elements in Andesite[1]

DDH	Ag	Cu	Pb	Zn	Sum
91	0	0	1	0	1
92	0	0	0	0	0
93	0	1	0	0	1
94A	0	0	2	0	2
96	0	1	0	0	1
97	0	1	0	0	1
98	0	2	0	2	4
110	0	1	0	1	2
111	0	1	0	0	1
112	0	1	0	0	1
113	0	1	0	0	1
114	0	0	0	0	0
116	0	0	0	0	0
117	0	0	0	0	0
118	0	1	0	0	1
119	0	0	0	0	0
120	0	1	0	0	1
121	0	1	0	0	1
122	0	0	0	0	0
123	0	0	0	0	0
125	2	2	1	2	7
127	2	2	2	2	8
128	0	0	2	2	4
129	2	2	0	2	6
132	1	0	1	2	4
133	0	2	0	2	4
134	0	0	0	0	0
135	1	0	1	2	4
139	0	0	0	2	2
142	1	1	2	2	6
144	0	0	0	0	0
149	2	0	2	2	6
150	2	2	0	2	6
151	2	2	2	2	8
152	0	0	0	2	2
153	2	2	1	2	7
155	0	0	0	0	0
157	0	0	0	0	0
158	0	1	0	0	1
159	0	0	0	0	0
160	0	0	0	0	0
161	0	2	0	0	2
162	0	1	0	2	3
163	0	0	1	0	1
164	0	1	0	2	3
174	2	1	0	2	5
181	0	0	1	0	1
190	1	2	0	0	3
199	2	2	1	2	7
204	0	2	1	0	3

1. 1 = a-b; 2 = b for frequency distributions of Types II to V
   2 > ULB, Type 1; -2 < LLB, Type 1
   0 = background values

APPENDIX E

Test for Systematic Vertical Variation of Elements in Rhyolite and Andesite

Table E-1

NUMBER OF DIAMOND DRILL HOLES SHOWING SYSTEMATIC VERTICAL VARIATION IN WAITE RHYOLITE

(HOLES AWAY FROM ORE)

	Element "Added" to top		Element "Removed" from top		No Change
Number of Samples ⟶	≥3	=2	≥3	=2	
SiO_2	14	3	16	1	3
TiO_2	9	4	10	1	13
Al_2O_3	12	2	18	4	1
Fe_2O_3	16	6	13	0	1
MnO	13	1	14	3	5
CaO	14	6	12	1	4
K_2O	13	3	16	3	1
MgO	16	7	13	0	1
Na_2O	14	3	11	5	3
Ag	14	6	14	1	2
Co	22	4	4	1	3
Cr	12	7	12	0	0
Cu	21	5	8	1	4
Ga	7	3	19	4	3
Pb	17	7	7	1	5
Ni	24	6	6	0	1
Sn	11	5	20	1	0
Sr	7	2	22	5	1
Y	19	5	11	2	0
Zn	24	4	7	1	1
Zr	20	4	9	2	2

Table E-2

NUMBER OF DIAMOND DRILL HOLES SHOWING SYSTEMATIC VERTICAL VARIATION IN WAITE RHYOLITE

(HOLES NEAR TO AND UNDER MASSIVE ORE)[1]

	Element "Added" to top		Element "Removed" from top		No change
Number of Samples →	≥3	=2	≥3	=2	
SiO_2	5	0	6	0	0
TiO_2	6	0	4	0	1
Al_2O_3	3	0	5	0	3
Fe_2O_3	5	0	4	0	2
MnO	4	0	6	0	1
CaO	6	0	4	0	1
K_2O	8	0	3	0	0
MgO	7	0	4	0	0
Na_2O	1	0	6	0	4
Ag	9	0	2	0	0
Co	5	0	5	0	1
Cr	4	1	3	0	3
Cu	7	0	2	0	2
Ga	3	0	6	0	2
Pb	7	0	3	0	1
Ni	8	0	3	0	0
Sn	8	0	3	0	0
Sr	4	0	7	0	0
Y	7	0	4	0	0
Zn	6	0	5	0	0
Zr	10	0	0	0	1

1. Diamond drill holes 135, 151, 163, 132, 133, 142, 149, 127, 128, 129, 125.

Table E-3

NUMBER OF DIAMOND DRILL HOLES SHOWING SYSTEMATIC VERTICAL VARIATION IN AMULET ANDESITE

(HOLES AWAY FROM ORE)

	Element "Added" to base		Element "Removed" from base		No change
Number of Samples ⟶	≥3	=2	≥3	=2	
SiO_2	22	2	12	0	2
TiO_2	10	2	11	3	11
Al_2O_3	20	0	15	2	0
Fe_2O_3	23	2	9	0	3
MnO	24	1	7	0	5
CaO	12	1	22	1	1
K_2O	24	2	9	0	2
MgO	18	1	16	1	1
Na_2O	13	0	21	1	2
Ag	21	0	15	1	2
Co	9	1	24	1	2
Cr	21	2	14	0	2
Cu	20	1	14	2	2
Ga	13	1	18	2	3
Ni	10	0	20	2	6
Pb	21	1	7	1	6
Sn	17	0	13	2	5
Sr	8	2	25	1	1
Y	17	1	14	2	3
Zn	26	2	5	0	4
Zr	19	2	12	1	3

Table E-4

NUMBER OF DIAMOND DRILL HOLES SHOWING SYSTEMATIC VERTICAL VARIATION IN AMULET ANDESITE

(HOLES NEAR TO AND OVER MASSIVE ORE)[1]

	Element "Added" to base		Element "Removed" from base		No change
Number of Samples ⟶	≧3	=2	≧3	=2	
SiO_2	4	0	7	0	0
TiO_2	4	0	7	0	0
Al_2O_3	4	0	6	0	1
Fe_2O_3	5	0	6	0	0
MnO	8	0	3	0	0
CaO	4	0	6	0	1
K_2O	9	0	1	0	1
MgO	5	0	6	0	0
Na_2O	4	0	6	0	1
Ag	7	0	4	0	0
Co	3	1	7	0	0
Cr	4	1	6	0	0
Cu	7	1	3	0	0
Ga	2	1	7	0	1
Ni	2	1	8	0	0
Pb	9	0	2	0	0
Sn	10	0	1	0	0
Sr	1	0	8	1	1
Y	7	1	3	0	0
Zn	7	0	2	0	2
Zr	6	1	1	0	3

1. Diamond drill holes 135, 151, 163, 132, 133, 142, 149, 127, 128, 129, 125.

APPENDIX F

Use of the I.B.M. 7040 Computer in Handling Data

Values for emulsion calibration curves and relative intensity ratios were obtained using an I.B.M. 7040 computer at the McGill University Computer Center. Programs for these two procedures are described by Lickus (1965).

An additional program was designed to manipulate the analytical results obtained in this report. While it is unlikely that the specific program described here will ever be useful, certain parts of it could be adapted to other projects. Of special interest should be the form in which data were stored and the "format statement" by which the data were removed from storage.

Figure F1 shows the Fortran program which was used in this project. Cards were punched from special data sheets which were filled out according to the example shown in figure F2.[1] Codes and conventions dealing with the use of these data sheets are filed in the Department of Geological Sciences, McGill University.

The Fortran program instructs the computer:

1. To read into storage, the project number (PN), lab sample number (ALN), and analytical results (K) for twenty two elements and J samples per data group[2] (ISN 2, 4, 5, 22).[3]

---

1. The general form was not followed in three places:
    1. Ag, the decimal point is two spaced from the right side of the column,
    2. Zn, there is no decimal point in the column, and
    3. Na_2O and MgO, obtained by a different analytical procedure, were punched on a separate card which was placed last in the group of cards.
2. A data group is all the samples taken from one drill hole for one rock type.
3. ISN, internal statement number, refers to the statements shown in fig. F1.

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2. A data group is all the samples taken from one drill hole for one rock type.
3. ISN, internal statement number, refers to the statements shown in fig. F1.

Fig. F1

```
 SAKRISON  STAT TEST                     FORTRAN SOURCE LIST
      ISN       SOURCE STATEMENT

        0 $IBFTC MAIN
        1        DIMENSION ALN(5),FN(5),XMD(5),DHN(5),EL(5),FT(5),X(5,24),SD(5),
                1PN(5)
        2  4000 READ31,M
        4    31 FORMAT(1I1)
        5       READ 32,((PN(J),ALN(J),(X(J,K),K=1,22)),J=1,M)
       22    32 FORMAT(2X,F6.0,F8.0/27X,4F4.2,4X,F4.2,4X
               1 ,F4.2,4X,F4.2/27X,F5.2,40X,F5.1/27X,F5.1,5X,3F5.1/42X,F5.1,5X,
               2  F5.1/47X,2F5.1/42X,F5.1,F5.0,F5.1/51X,F4.2,4X,F4.2)
       23       L=0
       24    39 DO40K=1,22
       25   310 V=0.
       26       SUMX=0.
       27       XSQS=0.
       30       DO320J=1,M
       31       IF(X(J,K))30,320,30
       32    30 V=V+1.
       33       SUMX=SUMX+X(J,K)
       34       XSQ=X(J,K)**2
       35       XSQS=XSQS+XSQ
       36   320 CONTINUE
       40       IF(V.EQ.0.)GOTO40
       43       XM=SUMX/V
       44       SXSQ=SUMX**2
       45       SDX=(V*XSQS-SXSQ)**.5/V
       46       VARX=SDX**2
       47       CVARX=SDX/XM*100.
       50       SEXM=SDX/(V-1.)**.5
       51       SESDX=SDX/(2.*(V-2.))**.5
       52       IF(V-2.)50,600,50
       53   600 SSEXM=SEXM*12.706
       54       SSESDX=SESDX*12.706
       55       GOTO1200
       56    50 IF(V-3.)60,800,60
       57   800 SSEXM=SEXM*4.303
       60       SSESDX=SESDX*4.303
       61       GOTO1200
       62    60 IF(V-4.)70,900,70
       63   900 SSEXM=SEXM*3.182
       64       SSESDX=SESDX*3.182
       65       GOTO1200
       66    70 IF(V-5.)80,1000,80
       67  1000 SSEXM=SEXM*2.776
       70       SSESDX=SESDX*2.776
       71       GOTO1200
       72    80 CONTINUE
       73  1200 PRINT33
       74    33 FORMAT(1H1,10X,14HLAB SAMPLE NO.)
       75       PRINT35,(ALN(J),J=1,M)
      102    35 FORMAT(1H0,5(/F19.0))
      103       GO TO(51,52,53,54,55,57,59,61,62,63,64,65,66,67,68,69,71,72,
               1  73,74,56,58),K
      104    51 PRINT1
      105     1 FORMAT(1H0,15X,12HSIO2 PERCENT/)
      106       GO TO 140
```

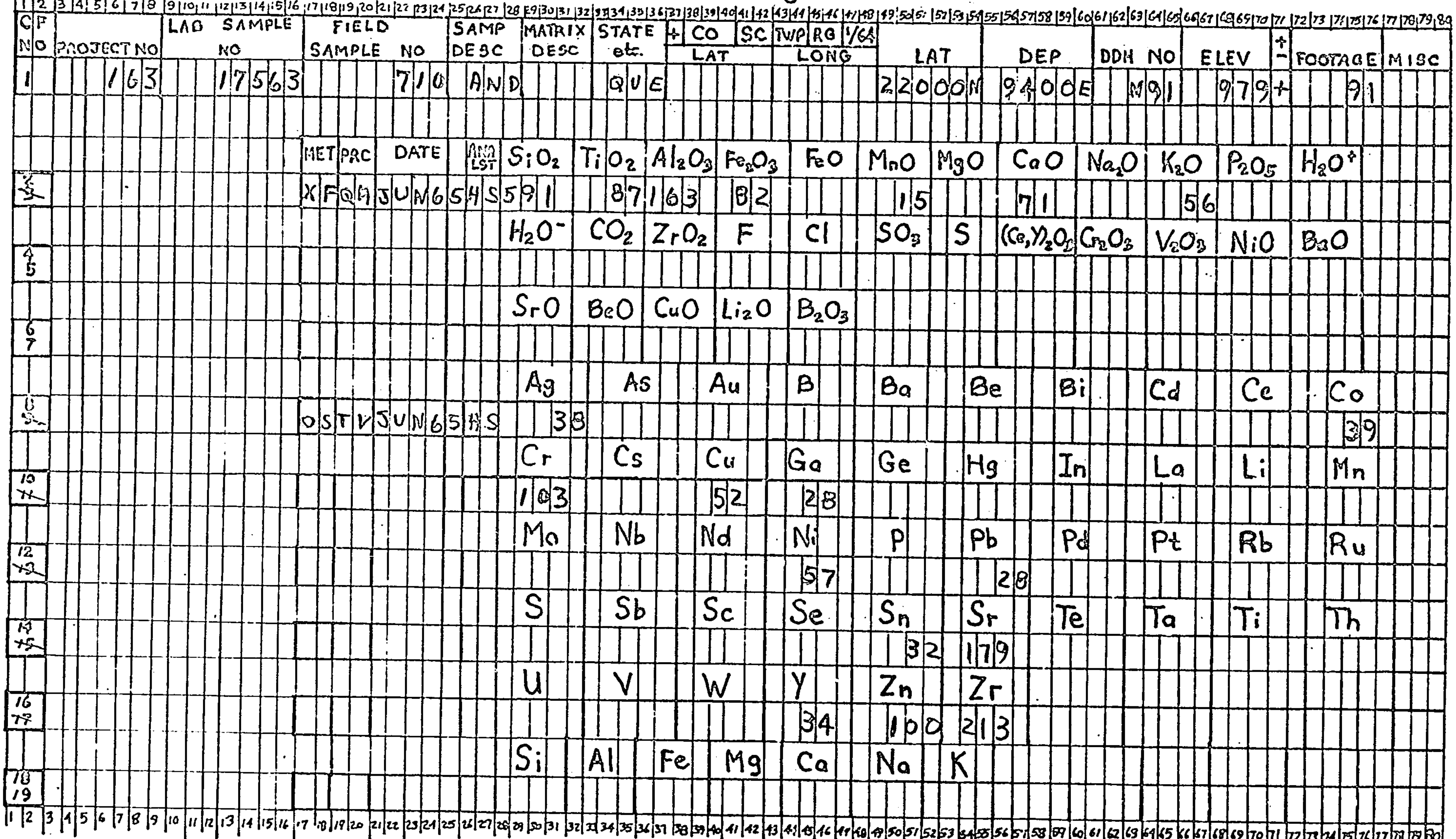
Fig. F1 (continued)

```
SAKRISON  STAT TEST                          FORTRAN SOURCE LIST MAIN
   ISN         SOURCE STATEMENT

           52 PRINT2
            2 FORMAT(1H0,15X,12HTIO2 PERCENT/)
              GO TO 140
           53 PRINT3
            3 FORMAT(1H0,15X,13HAL2O3 PERCENT/)
              GO TO 140
           54 PRINT4
            4 FORMAT(1H0,15X,13HFE2O3 PERCENT/)
              GO TO 140
           55 PRINT5
            5 FORMAT(1H0,15X,11HMNO PERCENT/)
              GO TO 140
           57 PRINT7
            7 FORMAT(1H0,15X,11HCAO PERCENT/)
              GO TO 140
           59 PRINT9
            9 FORMAT(1H0,15X,11HK2O PERCENT/)
              GO TO 140
           61 PRINT10
           10 FORMAT(1H0,15X, 6HAG PPM/)
              GO TO 140
           62 PRINT11
           11 FORMAT(1H0,15X, 6HCO PPM/)
              GO TO 140
           63 PRINT12
           12 FORMAT(1H0,15X, 6HCR PPM/)
              GO TO 140
           64 PRINT13
           13 FORMAT(1H0,15X, 6HCU PPM/)
              GO TO 140
           65 PRINT14
           14 FORMAT(1H0,15X, 6HGA PPM/)
              GO TO 140
           66 PRINT15
           15 FORMAT(1H0,15X, 6HGE PPM/)
              GO TO 140
           67 PRINT16
           16 FORMAT(1H0,15X, 6HNI PPM/)
              GO TO 140
           68 PRINT17
           17 FORMAT(1H0,15X, 6HPB PPM/)
              GO TO 140
           69 PRINT18
           18 FORMAT(1H0,15X, 6HSN PPM/)
              GO TO 140
           71 PRINT19
           19 FORMAT(1H0,15X, 6HSR PPM/)
              GO TO 140
           72 PRINT20
           20 FORMAT(1H0,15X, 5HY PPM/)
              GO TO 140
           73 PRINT21
           21 FORMAT(1H0,15X, 6HZN PPM/)
              GO TO 140
           74 PRINT22
```

Fig. F1 (continued)

```
SAKRISON  STAT TEST                              FORTRAN SOURCE LIST MAIN
     ISN         SOURCE STATEMENT

     176     22 FORMAT(1H0,15X, 6HZR PPM/)
     177        GO TO 140
     200     56 PRINT6
     201      6 FORMAT(1H0,15X,11HMGO PERCENT/)
     202        GO TO 140
     203     58 PRINT8
     204      8 FORMAT(1H0,15X,12HNA2O PERCENT/)
     205    140 CONTINUE
     206        IF(L-1)3000,36,3000
     207     36 PRINT37
     210     37 FORMAT(1H ,15X,42HTHE NATURAL LOGARITHM OF THE CONCENTRATION)
     211   3000 PRINT38,(X(J,K),J=1,M)
     216     38 FORMAT(1H ,F23.2)
     217        PRINT151
     220    151 FORMAT(1H0,25X,3HSUM)
     221        PRINT41,SUMX
     222     41 FORMAT(1H ,F24.4)
     223        PRINT42
     224     42 FORMAT(1H0,15X,15HARITHMETIC MEAN)
     225        PRINT41,XM
     226        PRINT43
     227     43 FORMAT(1H0,15X,25HSAMPLE STANDARD DEVIATION)
     230        PRINT41,SDX
     231        PRINT44
     232     44 FORMAT(1H0,15X,8HVARIANCE)
     233        PRINT41,VARX
     234        PRINT45
     235     45 FORMAT(1H0,15X,24HCOEFFICIENT OF VARIATION)
     236        PRINT41,CVARX
     237        PRINT46
     240     46 FORMAT(1H0,15X,26HSTANDARD ERROR OF THE MEAN)
     241        PRINT41,SEXM
     242        PRINT47
     243     47 FORMAT(1H0,15X,40HSTANDARD ERROR OF THE STANDARD DEVIATION)
     244        PRINT41,SESDX
     245        PRINT48
     246     48 FORMAT(1H0,15X,31HS.E. OF THE MEAN  SMALL SAMPLES)
     247        PRINT41,SSEXM
     250        PRINT49
     251     49 FORMAT(1H0,15X,36HS.E. OF THE STD. DEV.  SMALL SAMPLES)
     252        PRINT41,SSESDX
     253     40 CONTINUE
     255        L=L+1
     256        IF(L.GE.2)GOTO4000
     261        DO5000J=1,M
     262        DO5000K=1,22
     263        IF(X(J,K))5000,5000,6000
     264   6000 X(J,K)=ALOG(X(J,K))
     265   5000 CONTINUE
     270        GOTO39
     271        END
```

Fig. F-2 Special Data Sheets Used in Data Handling.



```
LAB SAMPLE NO.

  35163.
  36863.
  32063.
  35863.

     SIO2 PERCENT

        76.50
        79.00
        63.60
        78.00

                SUM
      297.1000

     ARITHMETIC MEAN
       74.2750

     SAMPLE STANDARD DEVIATION
        6.2271

     VARIANCE
       38.7770

     COEFFICIENT OF VARIATION
        8.3839

     STANDARD ERROR OF THE MEAN
        3.5952

     STANDARD ERROR OF THE STANDARD DEVIATION
        3.1136

     S.E. OF THE MEAN  SMALL SAMPLES
       11.4400

     S.E. OF THE STD. DEV.  SMALL SAMPLES
        9.9073
```

Fig. F3 Example of Output

2. To sum the analytical results (ISN 33).

3. To calculate the arithmetic mean (ISN 43).

4. To calculate the sample standard deviation (ISN 34, 35, 44, 45).

5. To calculate the variance (SN 46).

6. To calculate the coefficient of variance (ISN 47).

7. To calculate the standard error of the mean (ISN 50).

8. To calculate the standard error of the standard deviation (ISN 51).

9. To correct the standard error of the mean for small samples (ISN 52, 53, 56, 57, 62, 63, 66, 67).

10. To correct the standard error of the standard deviation for small samples (ISN 52, 54, 56, 60, 62, 64, 66, 70).

11. To print titles e.g. LAB SAMPLE NO. (ISN 73, 74), SiO_2 PER CENT (ISN 103, 104, 105).

12. To place under the appropriate title those figures which the computer has calculated and stored, e.g., the lab sample number (ISN 75, 102) or per cent SiO_2 (ISN 3000).

13. When all the preceding has been completed for all the elements in all the samples of one data group (J), to convert all the analytical results to natural logarithms and repeat the whole program (ISN 206, 264).

A special card, an "M" card, must be inserted before each data group. This card is punched 2, 3, 4, or 5 in column one in order to tell the computer how many samples there are in one data group (ISN 2, 4). The number of data groups which can be handled in one job is unlimited. The computer will simply stop storing data after the last data card has been read. The number of samples per data group (J) is limited to five but could be increased with minor changes to the program.

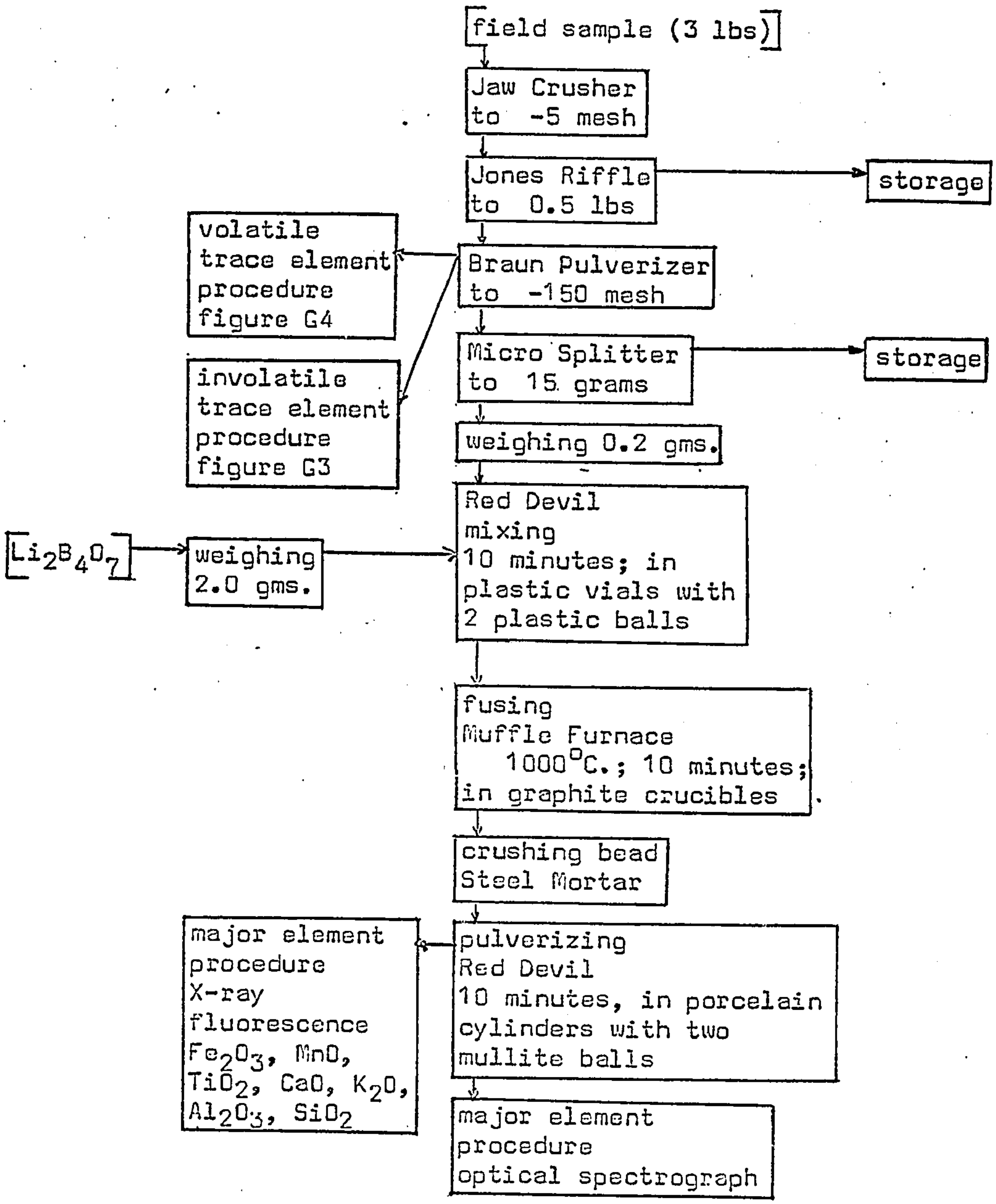
An example of the output of this program for one element in one data group of four samples is given in fig. F3. The program was designed to produce neat pages of figures but it uses up a great deal of paper and computer time and is therefore not at all economical. This fault should be changed before this program is used again.

APPENDIX G

Description of Sample Preparation and Analytical Procedures

Figure G1

SAMPLE REDUCTION AND SAMPLE PREPARATION FOR THE MAJOR ELEMENT PROCEDURE, X-RAY FLUORESCENCE[1]



1. Based on a procedure designed by J. Jellema and G. R. Webber in the Department of Geological Sciences, McGill University.

Figure G2

SAMPLE PREPARATION, MAJOR ELEMENT PROCEDURE
OPTICAL SPECTROGRAPH

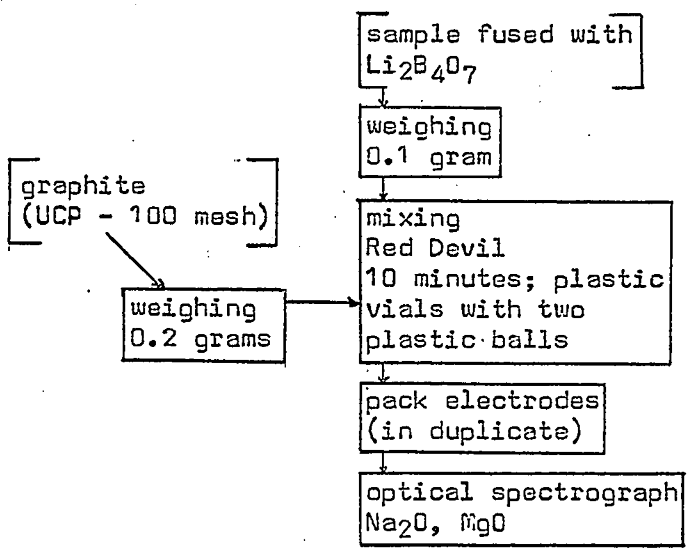


Figure G3

SAMPLE PREPARATION, INVOLATILE TRACE ELEMENT PROCEDURE, OPTICAL SPECTROGRAPH

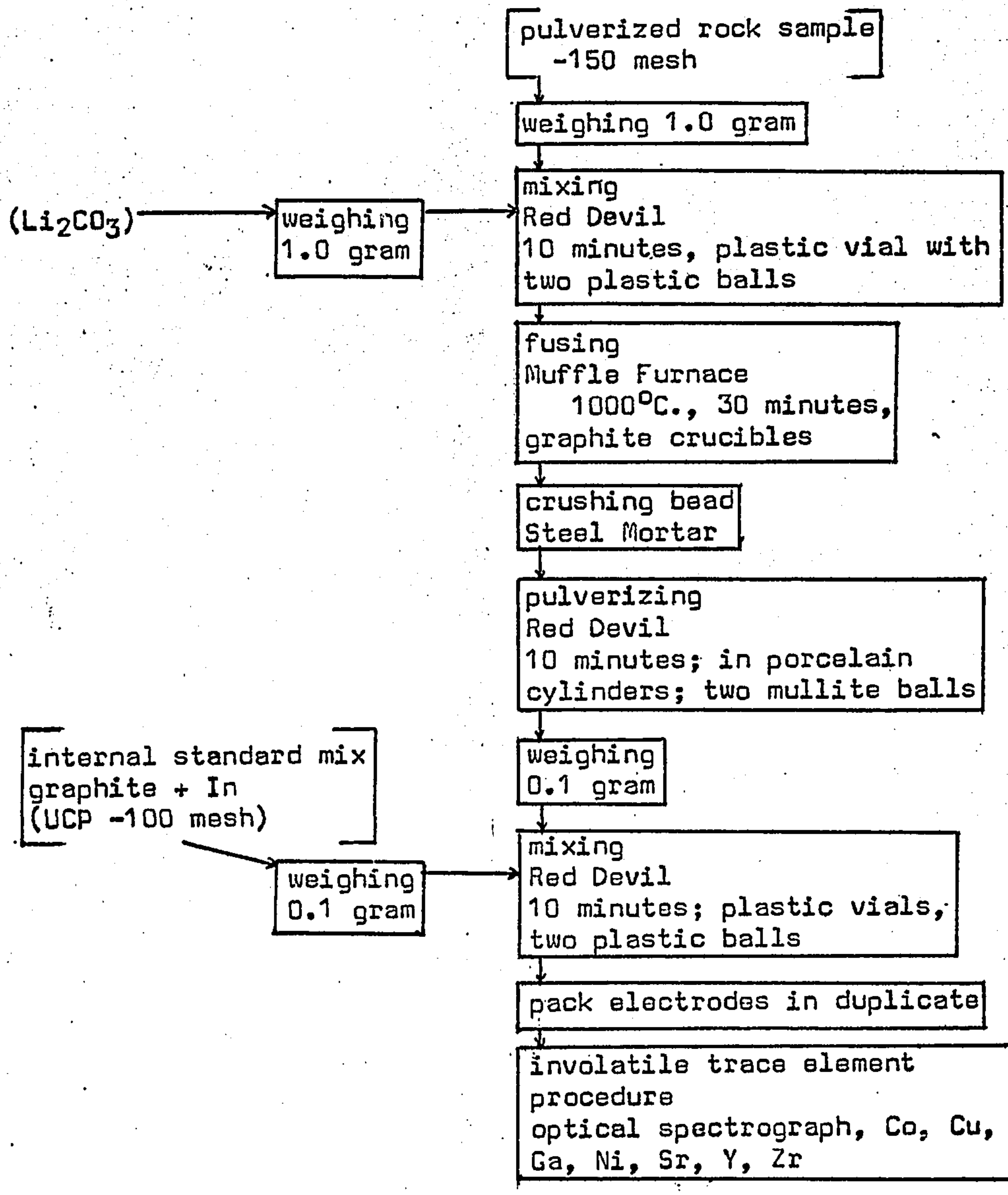


Figure G4

SAMPLE PREPARATION, VOLATILE TRACE ELEMENT PROCEDURE, OPTICAL SPECTROGRAPH

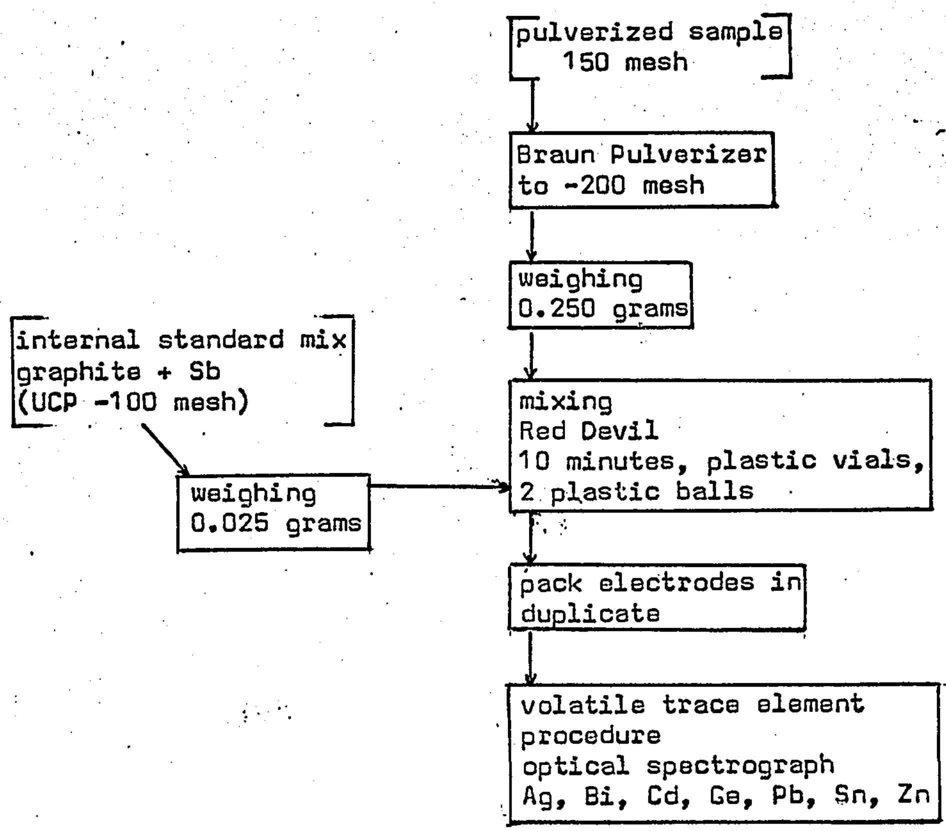


Table G-1

TIME REQUIRED FOR AN INEXPERIENCED TECHNICIAN TO PREPARE APPROXIMATELY SIXTY SAMPLES FOR ALL PROCEDURES

(NOT INCLUDING CRUSHING AND PULVERIZING)

MAJOR ELEMENT PROCEDURES

		HOURS	
1.	Weighing sample	8	
2.	Weighing $Li_2B_4O_7$	9	
3.	Mixing	3	
4.	Fusing	3.5	
5.	Crushing and pulverizing bead	12	
6.	Weighing crushed bead and graphite	9	
7.	Mixing	4	
	Total		48.5 hours

INVOLATILE TRACE ELEMENT PROCEDURE

1.	Weighing sample	9	
2.	Weighing Li_2Co_3	9	
3.	Mixing	3	
4.	Fusing (+ paperwork)	10	
5.	Crushing and pulverizing bead	12	
6.	Weighing crushed bead and graphite	10	
7.	Mixing	5	
	Total		58 hours

VOLATILE TRACE ELEMENT PROCEDURE

1.	Weighing sample and graphite	7.5	
2.	Mixing	3	
	Total		10.5 hours
	Grand Total		117.0 hours

Table G-2

DETAILS OF ANALYTICAL PROCEDURES USING THE OPTICAL SPECTROGRAPH

	I MAJOR ELEMENTS[1] (Na_2O, MgO)	II INVOLATILE TRACE[1] ELEMENTS	III VOLATILE TRACE ELEMENTS
Apparatus (ancillary)	JACO console microphotometer	as I	as I
Standard samples	N.B.S. 1A, 69A, 88, 97, 104 and mixtures of these	prepared by adding compounds of the metals to an artificially prepared base	as II
Flux	$Li_2B_4O_7$ (10 parts flux; 1 part sample)	Li_2Co_3 (1:1)	none
Internal standard	Li added as flux	0.01% In in graphite + 20% NaCl; mix 1:1 with fluxed sample	0.08% Sb_2O_3 in graphite; mix 1 part to 10 parts sample
Electrodes	Cathode 1/8" dia. graphite (ST-40) Anode 3/16" dia. graphite (ST-45) cup in anode, 3 mm x 5 mm	as I	cathode as I anode as I cup; 3 mm x 3/16" boiler caps; 3/16" i.d., graphite, National AGKSPL 3916

1. The major element and involatile trace element procedures were designed by J. Jellema and G. R. Webber in the Department of Geological Sciences, McGill University.

Table G-2 (cont'd)

DETAILS OF ANALYTICAL PROCEDURES USING THE OPTICAL SPECTROGRAPH

	I MAJOR ELEMENTS (Na_2O, MgO)	II INVOLATILE TRACE ELEMENTS	III VOLATILE TRACE ELEMENTS
Excitation and exposure	11 amps to completion; 15 seconds initial burn at 4 amps; preburn ½ second	as II	12 amps for 90 seconds; no preburn
Spectral range control setting	9.87 (second order)	6.10	as II
Slit width	10u	as I	as I
Slit height	5mm	as I	6mm
Filter steps	3,4,5,6	as I	as I
Focus	16	15	as II
Initial racking setting	7	as I	as I
Racking units	5	as I	6
Number of exposures/plate	16	as I	13

Table G-2 (cont'd)

DETAILS OF ANALYTICAL PROCEDURES USING THE OPTICAL SPECTROGRAPH

	I MAJOR ELEMENTS (Na_2O, MgO)	II INVOLATILE TRACE ELEMENTS	III VOLATILE TRACE ELEMENTS
Emulsion	Kodak SA-2, K-33	as I	Kodak K-33
Developing	3 min. at 20°C.; Kodak D-19	as I	as I
Fixing	10 min., Kodak Fixer	as I	as I
Element and internal standard analytical lines (wave length, Å)	Na (3302), Mg (2781); Li (2741)	Co (3453), Cu (3273), Ga (2943), Ni (3414), Sr (3464), Y (3327), Zr (3391), In (3039)	Ag (3381), Bi (3067), Cd (3261), Ge (3039), Pb (2833), Sn (3262), Zn (3345), Sb (2877)

APPENDIX H

Photographs of the Host Rocks

PLATE 1

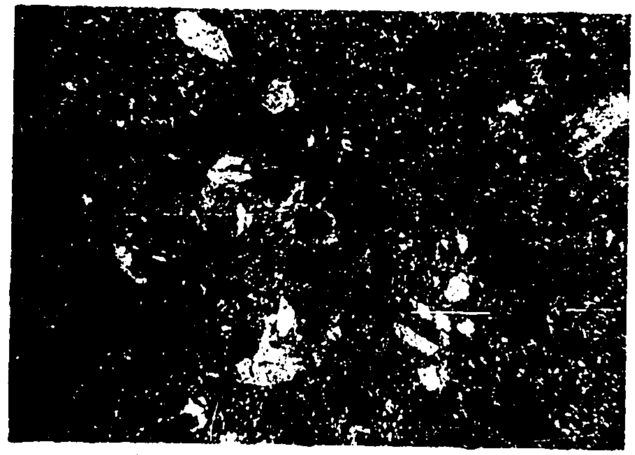


Fig. 1 - Waite Rhyolite, pyroclastic. Note the broken plagioclase crystals in a fine grained matrix. Leucoxene is opaque. The section is from DDH N-115, about 80 feet below the top of the rhyolite. (crossed nicols)

Fig. 2 - Same as Fig. 1. Chlorite and sericite appear gray. (plane polarised light)

PLATE 2

Fig. 1 - Waite Rhyolite, deformed chloritic fragment in dense siliceous matrix. The mineral which appears light gray in the small fragment is epidote. The dark areas are mostly fine grained chlorite and sericite. The specimen is from the same locality as that of Plate 1. (plane polarised light)

PLATE 2

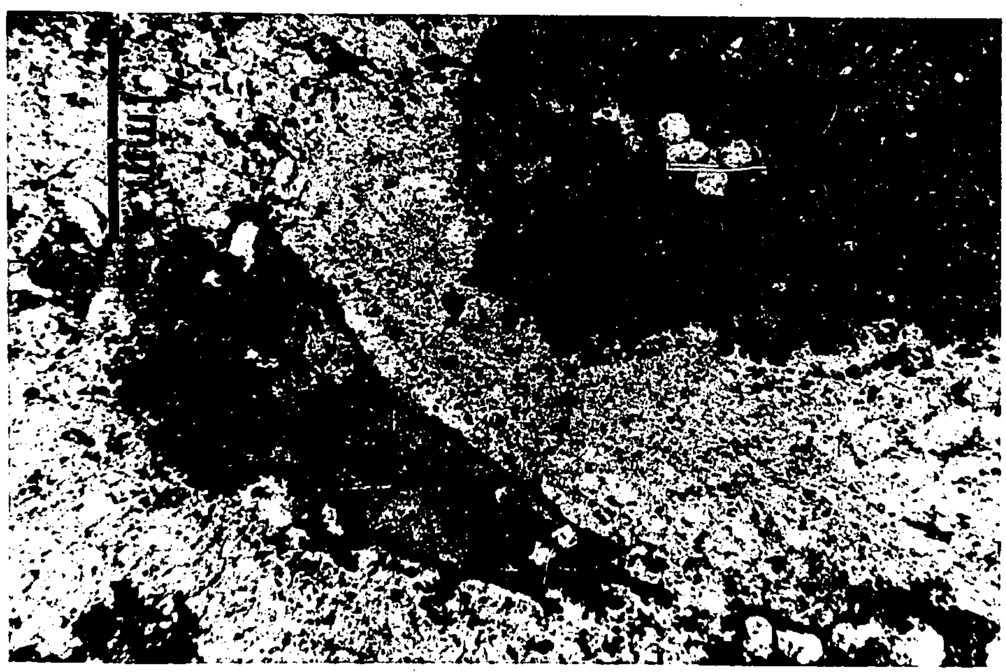


Fig. 1 - Waite Rhyolite, deformed chloritic fragment in dense siliceous matrix. The mineral which appears light gray in the small fragment is epidote. The dark areas are mostly fine grained chlorite and sericite. The specimen is from the same locality as that of Plate 1. (plane polarised light)

PLATE 4

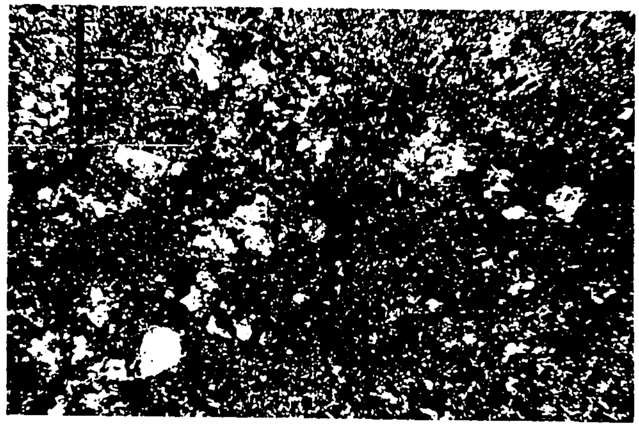


Fig. 1 - Waite Rhyolite, pyroclastic. This photograph is of the same thin section shown in Plate 3. Note the many fragments of plagioclase feldspar. (crossed nicols)

Fig. 2 - Same as Fig. 1. Note the slight suggestion of layering in the alignment of feldspar fragments and leucoxene. (plane polarised light)

PLATE 5

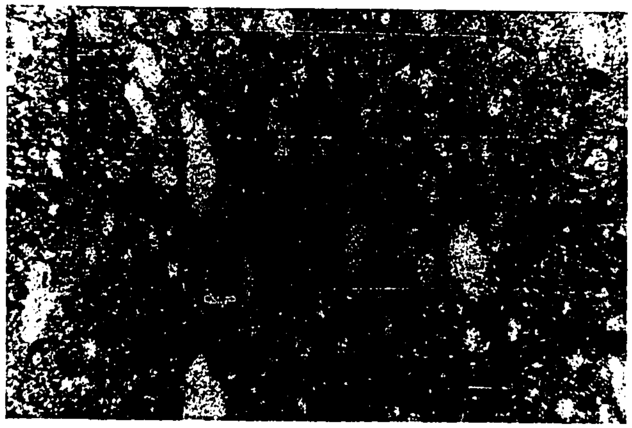


Fig. 1 - Waite Rhyolite, scoriaceous fragment. Note the aligned quartz-filled vesicles. The specimen is from DDH N-114 about 100 feet below the top of the rhyolite. (plane polarised light)

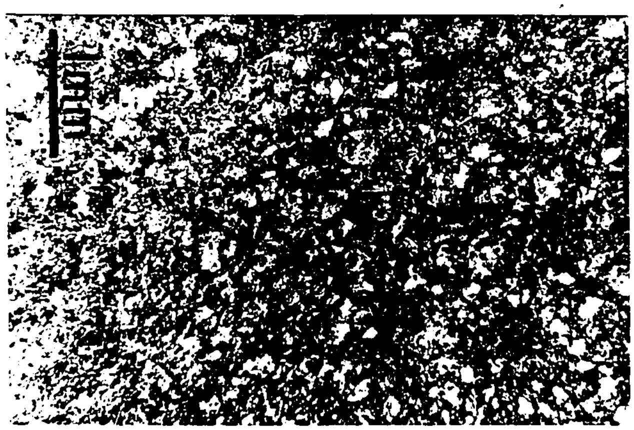


Fig. 2 - Waite Rhyolite, tuffaceous matrix of scoria. Note the irregularly shaped quartz grains in a very fine grained mat of sericite, chlorite and epidote. A faint suggestion of layering is present at 45 degrees across the photograph. The specimen is from the same location as that of Fig. 1. (plane polarised light)

PLATE 6

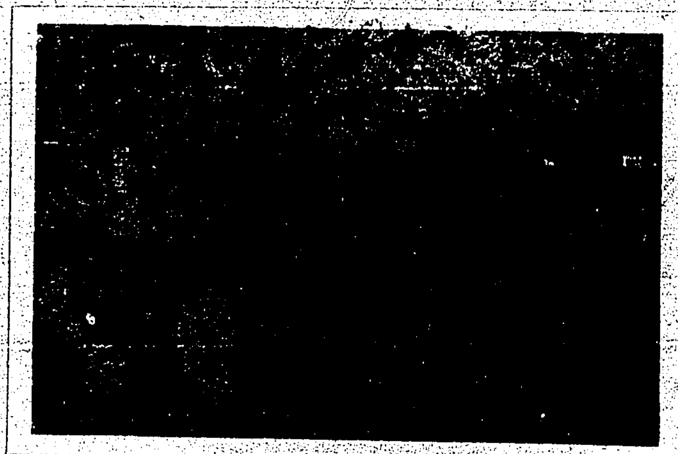


Fig. 1 - Waite Rhyolite, altered, from the fractured and mineralized zone below massive ore. (c, altered cordierite (pinite); b, biotite; ch, chlorite; q, quartz mosaic; a, anthophyllite) The specimen is from DDH N-124 at 1458 feet. (plane polarised light)

Fig. 2 - Same as Fig. 1
Note that the areas of pinite have uniform extinction. (crossed nicols)

PLATE 6

Fig. 1 - Waite Rhyolite, altered, from the fractured and mineralized zone below massive ore. (c, altered cordierite (pinite); b, biotite; ch, chlorite; q, quartz mosaic; a, anthophyllite) The specimen is from DDH N-124 at 1458 feet. (plane polarised light)

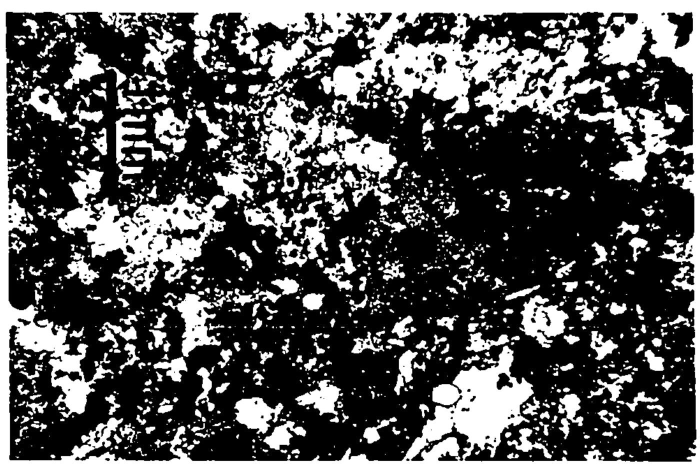


Fig. 2 - Same as Fig. 1
Note that the areas of pinite have uniform extinction. (crossed nicols)

PLATE 7

Fig. 1 - Amulet Andesite
Note the amygdales and the altered laths of plagioclase feldspar. The white rim of the amygdale is actinolite, the dark center is chlorite and sericite. Epidote shows up as dark, 0.2 mm, round patches. The speciman is from DDH N-160 about 75 feet above the base of the andesite. (plane polarised light)

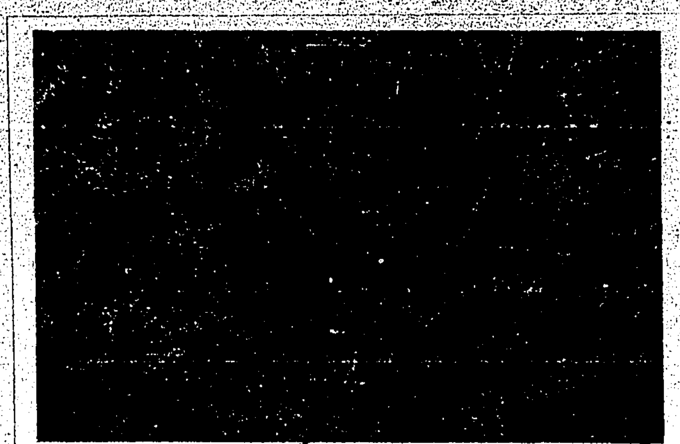


Fig. 2 - Altered Amulet Andesite
The andesite is almost totally converted to a mat of sericite, chlorite, and leucoxene yet the original texture is still slightly apparent. The section is from DDH N-114, about 10 feet from the base of the andesite. (plane polarised light)

PLATE 7

Fig. 1 - Amulet Andesite
Note the amygdales and the altered laths of plagioclase feldspar. The white rim of the amygdale is actinolite, the dark center is chlorite and sericite. Epidote shows up as dark, 0.2 mm, round patches. The speciman is from DDH N-160 about 75 feet above the base of the andesite. (plane polarised light)

Fig. 2 - Altored Amulet Andesite
The andesite is almost totally converted to a mat of sericite, chlorite, and leucoxene yet the original texture is still slightly apparent. The section is from DDH N-114, about 10 feet from the base of the andesite. (plane polarised light)

PLATE 8

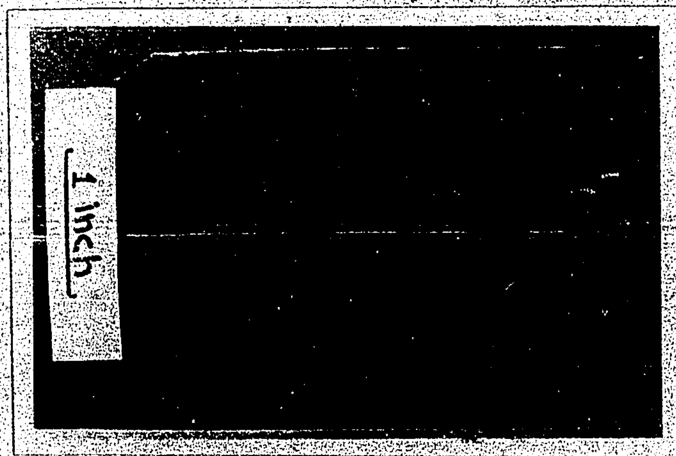


Fig. 1a (above) - Waite Rhyolite, pyroclastic.
Note the one inch long fragment with the narrow bleached rim in the left half of the section of drill core. Numerous grains of pyrrhotite are present in the matrix but the fragment is barren. Some pyrrhotite, but not as much as in the surrounding matrix, is present in the fragment in the right half of the core section. The specimen is from DDH N-97, 15 feet below the top of the rhyolite.

Fig. 1b (below) - Waite Rhyolite, pyroclastic.
Dark fragments with sharp corners, very rarely containing sulphide grains, are poorly sorted in a matrix which contains abundant pyrrhotite and some sphalerite. The specimen is from DDH N-97, 90 feet below the top of the rhyolite.

PLATE 8

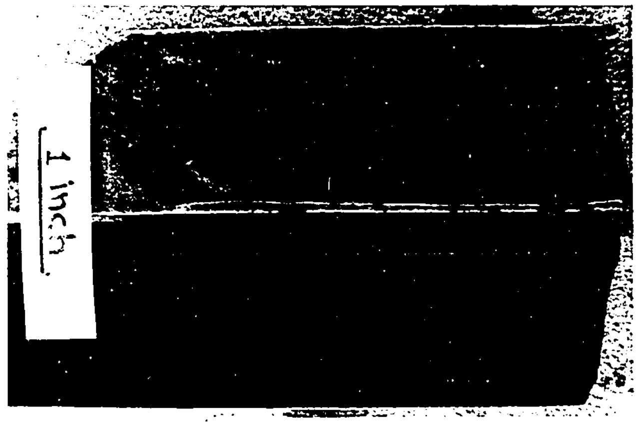


Fig. 1a (above) - Waite Rhyolite, pyroclastic.
Note the one inch long fragment with the narrow bleached rim in the left half of the section of drill core. Numerous grains of pyrrhotite are present in the matrix but the fragment is barren. Some pyrrhotite, but not as much as in the surrounding matrix, is present in the fragment in the right half of the core section. The specimen is from DDH N-97, 15 feet below the top of the rhyolite.

Fig. 1b (below) - Waite Rhyolite, pyroclastic.
Dark fragments with sharp corners, very rarely containing sulphide grains, are poorly sorted in a matrix which contains abundant pyrrhotite and some sphalerite. The specimen is from DDH N-97, 90 feet below the top of the rhyolite.

PLATE 9

Fig. 1a (above) - Waite Rhyolite, finely pyroclastic.
The rhyolite contains about 0.5 per cent of disseminated, 0.1mm, pyrite cubes and is cut by many quartz-carbonate-chlorite veinlets which contain only very rare pyrite grains. The specimen is from DDH N-113, 2 feet below the top of the rhyolite and a 7 foot wide shear zone.

Fig. 1b (below) - Waite Rhyolite, pyroclastic.
White fragments which contain no sulphide grains are scattered in a matrix which contains very small, disseminated grains of pyrrhotite. The specimen is from DDH N-113, 50 feet below the top of the rhyolite.

PLATE 10

Fig. 1a (above) - Waite Rhyolite, finely pyroclastic.
This specimen is typical of much rhyolite in that fragments are not visable although the rhyolite has a mottled appearance. The sample comes from 375 feet below the top of the rhyolite and 150 feet below more obvious breccia. DDH N-121

Fig. 1b (below) - Waite Rhyolite, finely pyroclastic.
This specimen comes from the same locality as that of Fig. 1a but shows one quarter inch diameter, light colored, vesicular fragments concentrated in the right half of the section of core.

PLATE 11

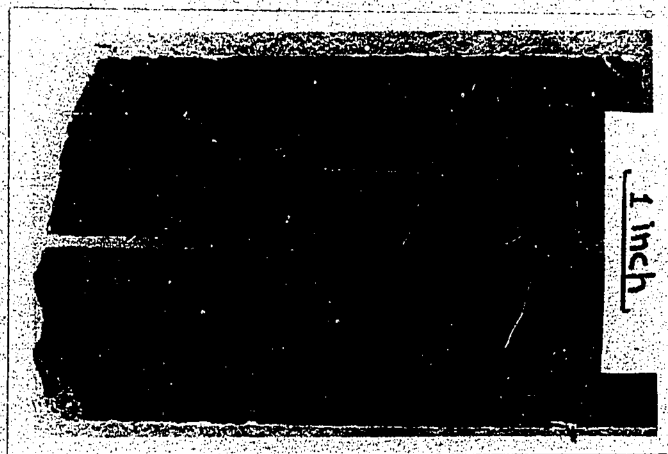


Fig. 1a (above) - Waite Rhyolite, pyroclastic.
This specimen shows dark, deformed fragments in a light colored dense matrix. It is from DDH N-115, 60 feet below the top of the rhyolite.

Fig. 1b (below) - Waite Rhyolite, pyroclastic.
This specimen is from the same locality as that of Fig. 1a. It shows how the same fragmental rhyolite grades into an apparently non-descript, mottled rock. A photograph of a thin section of this material is presented in Plate 2, Fig. 1.

PLATE 11

Fig. 1a (above) - Waite Rhyolite, pyroclastic.
This specimen shows dark, deformed fragments in a light colored dense matrix. It is from DDH N-115, 60 feet below the top of the rhyolite.

Fig. 1b (below) - Waite Rhyolite, pyroclastic.
This specimen is from the same locality as that of Fig. 1a. It shows how the same fragmental rhyolite grades into an apparently non-descript, mottled rock. A photograph of a thin section of this material is presented in Plate 2, Fig. 1.

PLATE 12

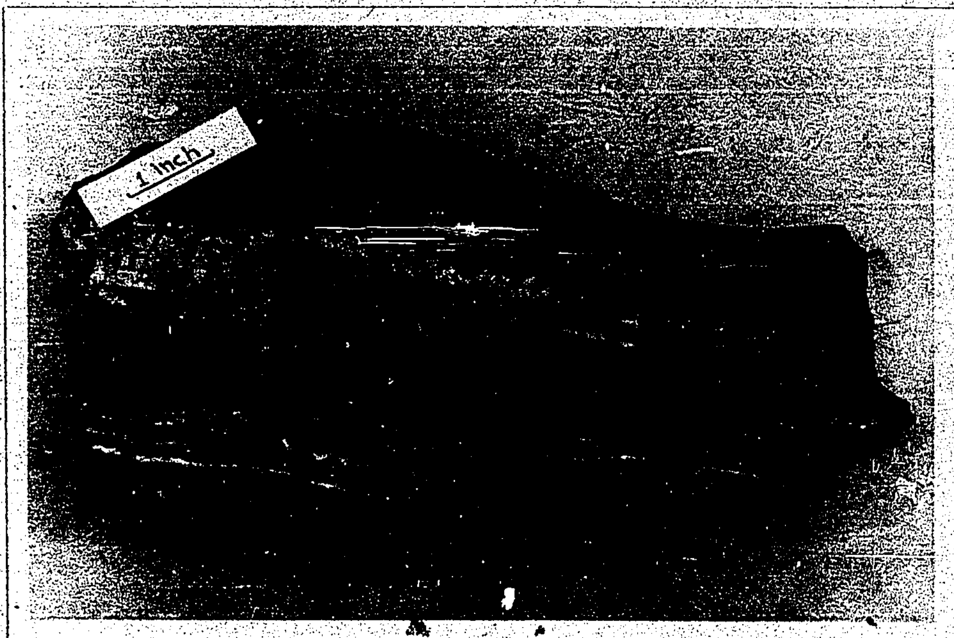


Fig. 1 - Amulet Andesite in contact with Bedded, Cherty Tuff. Relatively fresh andesite is dark and is altered only in a one inch wide zone at the tuff contact. The white bleaching in the andesite is caused by the development of sericite.
(403 drive, station 417 + 20 feet north, west wall)

PLATE 12

Fig. 1 - Amulet Andesite in contact with Bedded, Cherty Tuff. Relatively fresh andesite is dark and is altered only in a one inch wide zone at the tuff contact. The white bleaching in the andesite is caused by the development of sericite.
(403 drive, station 417 + 20 feet north, west wall)

APPENDIX I

Sample Locations

Table I-1

APPENDIX I

SAMPLE LOCATIONS

(See diamond drill hole plans for drill hole locations.)

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type[1]
N-91 1070	710	17563	75-107	A
	711	17263	125-150	A
	712	15963	150-168.7	A
	713	15763	180.5-211	A
	714	32663	212-225	A
	715	18163	225-250	A
	716	16463	250-267.5	A
N-92 1050	717	18463	100-125	A
	718	15863	125-150	A
	719	16163	150-175	A
	720	20163	175-207.5	A
	721	24963	259-275	R
	722	16563	275-300	R
	723	15463	300-325	R
	724	15663	325-350	R
N-93 1050	725	24463	195-200	A
	726	17363	200-225	A
	727	26163	225-250	A
	728	17663	250-275	A
	729	18163	275-296	A
	730	26563	298-325	R
	731	13063	325-357.5	R
N-94A 1070	732	55963	225-250	A
	733	22263	250-275	A
	734	26463	275-300	A
	735	25963	300-331	A
	736	20863	333-350	R
	737	39163	350-375	R

1. R: Rhyolite; A: Andesite; T: Tuff

Table I-1cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-96 (1154)	738	13463	150-167	A
	739	18063	180-200	A
	740	26263	200-225	A
	741	26063	225-251	A
	742	20663	279-300	R
	743	16363	300-336	R
N-97 (1169)	744	20763	450-475	A
	745	17763	475-494	A
	746	7763	502-532	A
	747	25463	532-548	R[1]
	748	25063	548-575	A[1]
	749	20363	575-607	A[1]
	750	33263	607-632	R
	751	16663	632-650	R
N-98 (1079)	752	23063	332-425	A
	753	14263	425-450	A
	754	14563	450-468	A
	755	13363	471-486	R
	756	15263	486-524	R
N-110 (1216)	757	22563	1200-1223	A
	758	21863	1245-1251 1261-1273	A
	759	8363	1288-1319	A
	760	8263	1458-1489	R
	761	7863	1489-1525	R
	762	22063	1550-1575	R
N-111 (1170)	935	25263	800-825	A
	936	28463	825-840.5	A
	937	30163	856.5-888	A
	938	30463	888-925	R
	939	36763	925-950	R
	940	29163	950-975	R
	941	36063	975-1000	R

1. rock type questionable; these samples sere not included in the compilation.

Table Il cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-112 (1153)	763	13563	925-947	A
	764	21763	954-975	A
	765	14463	975-1000	A
	766	18363	1000-1029	A
	767	19663	1029-1044	R
	768	22463	1044-1093	R
	769	21463	1093-1125	R
N-113 (1150)	942	37863	1325-1350	A
	943	37763	1350-1375	A
	944	37463	1375-1410	A
	945	31163	1410-1418	A
	946	36963	1425-1441	R
	947	9863	1441-1475	R
	948	29663	1475-1500	R
	949	39263	1500-1525	R
N-114 (1163)	950	32763	1150-1175	A
	951	25863-	1175-1200	A
	952	28063	1200-1225	R
	953	28363	1225-1250	R
	954	7363	1250-1275	R
	955A	20063	1275-1300	R
N-116 (1115)	770	22663	550-575	A
	771	8563	575-600	A
	772	19763	600-625	A
	773	22363	625-658	A
	1343	51563	660.5-662.5	T
	774	7663	662-700	R
	775	29363	700-725	R
	776	6363	725-750	R
N-117 (1191)	777	23863	1150-1175	A
	778	20463	1175-1200	A
	779	8763	1200-1225	A
	780	21563	1225-1257.5	A
	781	20963	1257.5-1272	R
	782	30863	1282-1300	R
	783	15563	1300-1325	R
	784	29763	1325-1350	R

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-118 (1130)	785	28963	450-475	A
	786	26363	475-491.5	A
			497.5-500	
	787	28563	500-525	A
	788A	20563	525-557	A
	1342	51463	556.5-560	T
	788	31563	558.5-576	R
	789	29063	576-600	R
	790	30563	600-625	R
N-119 (1018)	791	22763	900-925	A
	792	22463	925-950	A
	793	27763	950-975	A
	794	30363	975-992	A
	1341	51364	992-994.5	T
	795	31763	994-1025	R
	796	24863	1025-1050	R
	797	29263	1050-1075	R
	798	55963	1075-1100	R
N-120 (1232)	799	33663	800-825	A
	800	29463	825-850	A
	801	27663	850-875	A
	802	6563	875-897	A
	803	26963	898.5-925	R
	804	27563	925-950	R
	805	27463	950-975	R
	806	(lost)	975-1000	R
N-121 (1029)	807	28763	675-700	A
	808	16263	700-725	A
	809	24563	725-750	A
	810	14963	750-772.5	A
	1340A	51063	773-774	T
	1340B	51163	786-787.5	T
	1340C	51263	798.5-799.5	T
	811	23663	794.5-825	R
	812	7463	825-850	R
	813	19563	850-875	R
	814	16963	875-900	R

Table Il cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-122	815	21063	925-950	A
(1315)	816	19963	950-975	A
	817	26863	975-1000	A
	818	16763	1000-1019	A
	819	32563	1030-1050	R
	820	34063	1050-1075	R
	821	33163	1075-1097	R
N-123	822	24263	409-439	A
(1107)	823	24163	444-475	R
	824	23563	475-500	R
	825	23963	500-516	R
N-125	1022	39063	1250-1275	A
(1169)	1023	35963	1275-1325	A
	1024	11563	1325-1335 1344-1366	A
	1025	10463	1335-1344	A
	1026	37963	1366-1409	R
	1027	35563	1409-1425	R
	1028	37563	1425-1450	R
N-127	997	11263	1000-1025	A
(1146)	998	9563	1025-1050	A
	999	9263	1050-1075	A
	1000	9363	1075-1100	A
	1001	34263	1100-1116	A
	1002	3063	1273-1300	R
	1003	35463	1300-1325	R
	1004	35763	1325-1350	R
	1005	34363	1350-1375	R
N-128	1006	9963	1050-1075	A
(1178)	1007	10263	1075-1100	A
	1008	9163	1100-1125	A
	1009	10663	1125-1155	A
	1010	34463	1248-1277	R
	1011	38963	1277-1303	R
	1012	36463	1303-1325	R
	1013	37663	1325-1350	R

Table Il cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-129	1014	11363	1075-1100	A
(1157)	1015	9763	1100-1124.5	A
	1016	8863	1169-1200	A
	1017	9663	1200-1225	A
	1018	34163	1305-1323	R
	1019	10163	1346-1375	R
	1020	33763	1375-1406	R
	1021	27263	1406-1425	R
N-132	962	10963	1250-1276	A
(1162)	963	10063	1302.5-1325	A
	964	11663	1325-1347	A
	965	40363	1352-1362.5	R
	966	11063	1362.5-1396	R
	967	56063	1396-1425	R
	968	10363	1425-1450	R
N-133	969	27863	1050-1075	A
(1185)	970	12363	1075-1093	A
	971	37063	1110-1125	A
	972	35663	1125-1157	A
	973	9463	1199-1225	R
	974	34863	1400-1425	R
	975	31063	1425-1450	R
N-134	927	32963	1000-1025	A
(1107)	928	30263	1025-1050	A
	929	32163	1050-1075	A
	930		1075-1098	A
	931	35163	1111.5-1132	R
	932	36863	1132-1162.5	R
	933	32063	1162.5-1177	R
	934	35863	1177-1200	R
N-135	826	36363	1000-1023	A
(1143)	827	36563	1023-1050	A
	828	37263	1050-1083	A
	829	36263	1083-1114	A
	1339	50963	1091-1092	T
	830	15063	1114-1150	R
	831	12163	1150-1175	R
	832	15363	1175-1200	R

Table Il cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-139 (1128)	833	19863	950-969	A
	834	17063	969-988	A
	835	6763	988-1025	A
	836	22863	1025-1046	A
	1338	50863	1046-1047	T
	837	24663	1047-1075	R
	838	13863	1075-1100	R
	839	25363	1100-1125	R
	840	7163	1125-1150	R
N-142 (1177)	976	20263	1025-1050	A
	977	38363	1050-1067 1081-1096	A
	978	18963	1096-1109	A
	979	19163	1121-1144.5	A
	980	17863	1144.5-1175	R
	981	21363	1175-1200	R
	982	25663	1200-1225	R
N-144 (1112)	841	30063	925-950	A
	842	19063	950-975	A
	843	38263	975-1000	A
	844	38163	1000-1023.5	A
	1335	50563	1081-1082 1091.5-1093	T
	845	21663	1036-1050	R
	846	38863	1050-1075	R
	847	(lost)	1075-1100	R
	848	(lost)	1100-1125	R
N-149 (1147)	983	11863	1300-1325	A
	984	14163	1325-1345	A
	985	13263	1348-1375	A
	986	13163	1375-1391	A
	987	6963	1412.5-1425	R
	988	12063	1425-1450	R
	989	34963	1450-1475	R
	990	18863	1475-1496	R
N-150 (1198)	849	26763	1014-1050	A
	850	28863	1050-1075	A
	851	31263	1075-1094	A
	852	28663	1193.5-1234	A
	1336	50663	1233.5-1235 1237.5-1243	T
	853	33863	1240-1275	R

Table II cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-151 (1190)	859	32363	1050-1075	A
	860	24763	1075-1100	A
	861	8063	1100-1122	A
	862	33363	1123-1150	R
	863	13663	1150-1175	R
	864	14663	1175-1200	R
	865	24063	1200-1225	R
N-152 (1140)	866	19463	1300-1325	A
	867	7263	1325-1350	A
	868	33463	1350-1375	A
	869	16063	1375-1398.5	A
	870	15163	1405-1425	R
	871	30663	1425-1465	R
N-153 (1122)	991	10563	1089-1130	A
	992	11763	1130-1139	T
	993	10763	1139-1175	R
	994	9063	1175-1200	R
	995	8963	1200-1225	R
	996	11163	1225-1250	R
N-155 (1180)	872	16863	1000-1025	A
	873	17963	1025-1055	A
	874	23263	1055-1075	A
	875	23363	1076-1090	A
	1335	50563	1081-1082 1091.5-1093	T
	876	25563	1094-1125	R
	877	23463	1125-1150	R
	878	8163	1150-1168	R
N-157 (1198)	879	23163	1175-1200	A
	880	25763	1200-1234	A
	1334	50463	1257-1260	T
	881	30763	1266-1300	R
	882	29863	1300-1325	R
	883	25163	1325-1350	R
N-158 (1080)	884	19363	1075-1100	A
	885	13763	1100-1125	A
	886	31863	1125-1150	A
	887	21263	1150-1175	A
	1333	50363	1180-1185	T
	888	21963	1185-1199	R

Table Il cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-159 (1119)	889	12863	950-988	A
	890	14363	988-1025	A
	891	17163	1025-1050	A
	892	11263	1050-1066	A
	1132	50263	1061-1066	T
	893	18563	1067-1086	R
	894	38363	1086-1100	R
	895	38063	1100-1125	R
	896	18763	1125-1150	R
N-160 (1112)	955B	32863	975-1000	A
	956	33963	1000-1025	A
	957	27963	1025-1057.5	A
	958	32463	1070-1100	R
	959	22163	1100-1125	R
	960	28163	1125-1150	R
	961	29563	1150-1175	R
N-161 (1026)	897	31363	950-975	A
	898	31963	975-1000	A
	899	32263	1000-1025	A
	900	26663	1025-1044.5	A
	901	28263	1052.5-1075	R
	902	9663	1075-1100	R
	903	29963	1100-1113 1140-1144	R
N-162	904	36663	1050-1075	A
	905	35263	1075-1100	A
	906	34763	1100-1125	A
	907	24363	1125-1152.5	A
	908	35363	1157-1175	R
	910	34563	1175-1200	R
	911	14763	1200-1225	R
	912	12563	1225-1250	
N-163	913	27163	975-1000	A
	914	33563	1000-1026.5	A
	915	17463	1026.5-1050	A
	916	23763	1050-1080.5	A
	1131	50163	1080-1087	T
	917	27363	1088.5-1125	R
	918	31663	1125-1150	R
	919	33063	1150-1175	R

Table II cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-164 (1136)	920	36163	1300-1332.5	A
	921	34663	1346.5-1375	A
	922	37163	1375-1398	A
	1130	50063	1404-1407.5	T
	923	14863	1412-1425	R
	924	12463	1425-1450	R
	925	21163	1450-1475	R
	926	11963	1475-1500	R
N-174 (1157)	1088	51663	800-825	A
	1089	51763	825-850	A
	1090	51863	850-875	A
	1091	51963	875-890 894-912	A
	1092	52063	942.8-943.4	T
	1093	52163	954-975	R
	1094	52263	975-1000	R
	1095	52363	1000-1025	R
	1096	52463	1025-1050	R
N-181 (1119)	1097	52563	925-950	A
	1098	52663	950-975	A
	1099	52763	975-1000	A
	1100	52863	1000-1023	A
	1101	52963	1028.5-1034.5	T
	1102	53063	1034-1060	R
	1103	53163	1060-1085	R
	1104	53263	1085-1109	R
	1105	53363	1109-1134	R
N-190 (1151)	1106	53463	925-950	A
	1107	53563	950-975	A
	1108	53663	975-1000	A
	1109	53763	1000-1023	A
	1110	53863	1041-1049	T
	1111	53963	1049-1075	R
	1112	54063	1075-1100	R
	1113	54163	1100-1125	R
	1114	54263	1125-1150	R

Table II cont'd

DDH (elev. at collar, feet)	Field Sample Number	Lab. Sample Number	Footage (feet)	Rock Type
N-199 (1110)	1115	54363	1325-1350	A
	1116	54463	1350-1375	A
	1117	54563	1375-1400	A
	1118	54663	1400-1431	A
	1119	54763	1502-1525	R
	1120	54863	1525-1550	R
	1121	54963	1550-1575	R
	1122	55063	1575-1600	R
N-204 (1110)	1123	55263	1025-1050	A
	1124	55363	1128-1150	A
	1125	55463	1150-1168	A
	1126	55563	1200-1225	R
	1127	55663	1225-1250	R
	1128	55763	1250-1275	R
	1129	55863	1275-1300	R