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The syngenetic U-deposit at Gayot lake, New Quebec

THE SYNGENETIC U-DEPOSIT AT
GAYOT LAKE, NEW QUEBEC

by

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ABSTRACT

The discovery of a syngenetic stratabound uranium deposit within the Sakami Formation in northern Quebec is the first discovery of this kind, at least in Canada, in unmetamorphosed Precambrian (Aphebian) sediments. Similar deposits in younger formations, e.g. Cambrian (Ranstaad) and Permian (Lodève) are known in Europe. This paper emphasizes the genetic aspects of the Gayot Lake deposit, i.e. the favourable combination of several controlling factors at the time and site of deposition of the uraniferous horizon. Also the sympathetic behaviour of accompanying trace elements both horizontally and vertically will be discussed. For the vertical distribution of major, minor and trace elements within the mineralized horizon, drill core of four diamond drill holes in various environments were sampled in intervals of 10 cm and assayed. The geochemical data was then subjected to a mathematical factor analysis and interpreted afterwards. This method enabled us to confirm and refine the geological interpretation as far as the genetic aspects are concerned. The ore horizon could thus be defined as a particular sedimentary environment in gyttja facies, acting as metallotect at the time of sedimentation, while climatic conditions favoured the formation of evaporates, especially in isolated restricted basins. The deposit is contained in a subhorizontal tectonically dissected sheet of low grade ore from 0.2 to 3m thickness, and its discovery disproves the general view that the Superior Province has very little U-potential. Implications of the Gayot Lake discovery may be that in the future, Aphebian sediments might deserve more attention as potential targets for uranium exploration in areas without Helikian cover (the areas of Aphebian metasediments with unconformable Helikian sandstone cover are sites for unconformity-type uranium deposits). On the other hand, the significant syngenetic uranium enrichment within the Aphebian Sakami sediments might give more substance to the protore hypothesis to explain the Precambrian unconformity-type uranium deposits of northern Saskatchewan and northern Australia.

TABLE OF CONTENTS

FIGURES:

...iii

FIGURES: (cont'd)

TABLES:

PLATES:

INTRODUCTION

The U-deposit described here and named Gayot Lake Deposit is located in the Superior Structural Province in northern Quebec, west of the Labrador Trough (Figure I). The nearest towns are Schefferville and Fort Chimo, both located at a distance of 275 km from the deposit, to the southeast and north-northeast respectively. The first indications of this deposit were found in 1976 by UEM (Uranerz Exploration and Mining Limited, the Operator of the Joint Venture (50-50) with SDBJ (Société de développement de la Baie James). Geological information was gained through surface mapping and 145 diamond drill holes drilled in the area from 1978 to 1980.

REGIONAL GEOLOGY (Figure I)

A brief description of the geological framework of the stratiform deposit shows it unconformably overlying the Archean basement rocks of the Superior Structural Province (granite gneisses, migmatites, gneisses and metavolcanics; intruded by pegmatites and diorite dikes).

The Aphebian sedimentary Sakami Formation occurs as local outliers in northern Quebec, forming two roughly ENE-WSW trending discontinuous belts between the Labrador Trough to the east and James Bay to the west. The two belts are approximately 300 Km long each and N-S distance from one belt to the other is about 200 Km.

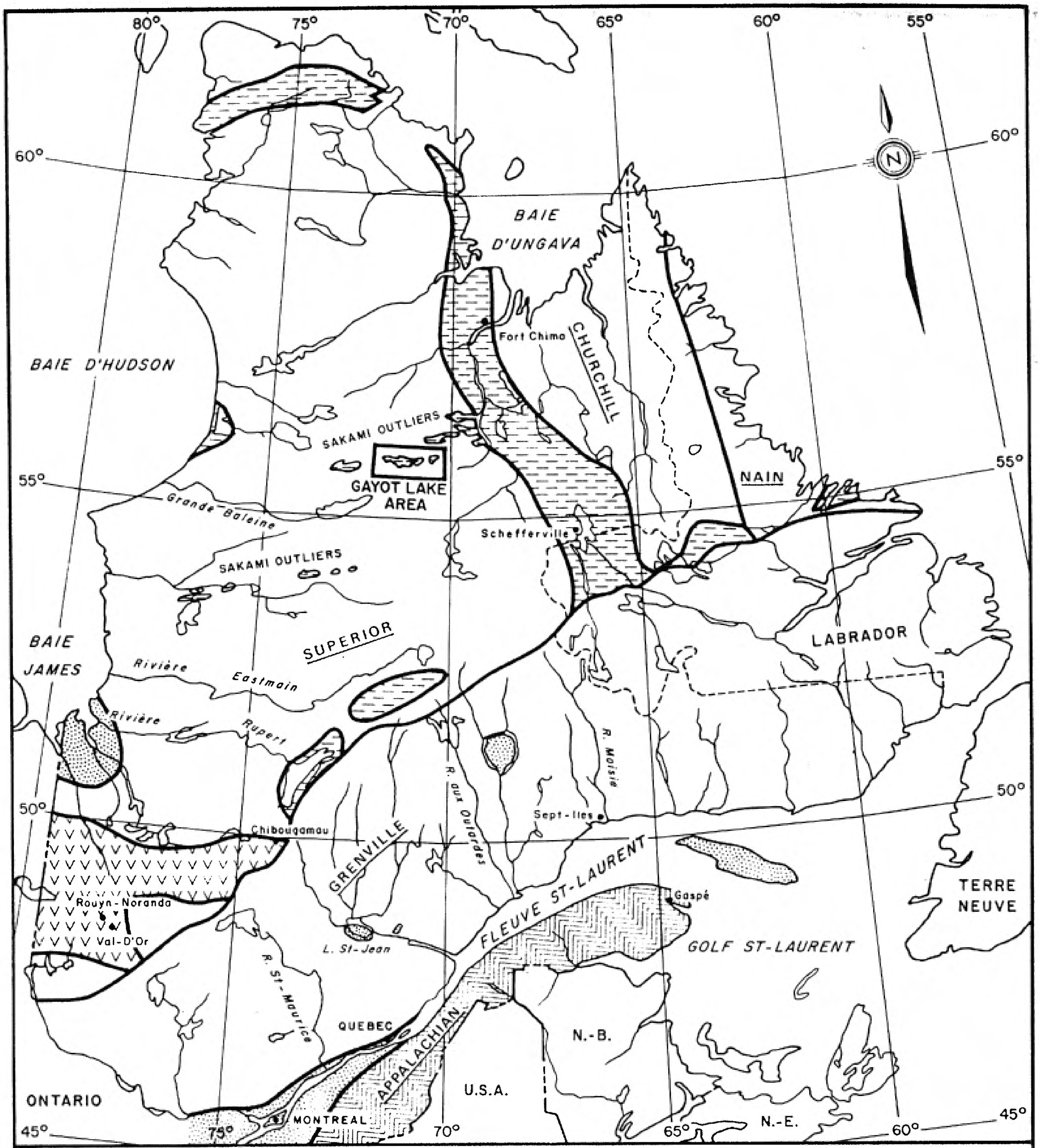
The Kenoran Orogeny (2480 Ma) resulted in the folding, faulting and metamorphism of the Archean sedimentary and volcanic rocks. Anatexis and plutonism is widespread.

The Hudsonian Orogeny (1735 Ma), which gave rise to the Labrador Trough to the east, and which affected all of the Churchill Province, did not have any appreciable impact on the Superior Province except for faulting and perhaps the intrusion of some diabase dikes of uncertain age. Thus, the Aphebian Sakami Formation is unmetamorphosed.

The Sakami Formation is divided into a lower continental sequence of red beds, conglomerates, mudstones and siltstones and an upper, epicontinental sequence of quartzitic sandstones (Eade, 1966).

The U-mineralization, which has been dated (Pb-Pb) at 1.85 billion years (Robbins 1980), is stratabound and occurs within sediments of the Lower Sakami Formation of the Gayot Lake outlier. As the mineralization can be interpreted as syngenetic (see furhter below), the age of 1.85 billion years for the mineralization provides us also with an approximate minimum age for the Lower Sakami Formation.

Tectonics within the Sakami outliers has been mainly restricted to syn- and post-depositional block faulting and the tilting of the sediments towards the south.



Gayot Lake, Québec

GENERAL LOCATION MAP
AND REGIONAL GEOLOGY

FIG.-I

THE SAKAMI FORMATION AND ITS RELATION TO THE LABRADOR TROUGH (Figure II)

Although it is not the purpose of this paper to dwell upon the stratigraphic position of the Sakami Formation, we will elaborate on the possible correlation between it and the earliest sediments of the Labrador Trough.

Figure II shows three Sakami outliers (Gayot Lake, Lac Pons and Lac Gerzine) in conjunction with the Labrador Trough embayments to the west of Cambrian Lake.

Literature studies (Eldorado Nuclear Limited, 1977 Assessment File Report; Denison Mines Limited, 1970 Assessment File Report; E. Dimroth, 1978; W.F. Fahrig, 1969) suggest that the Sakami sediments are time equivalent to the sediments of the two northern Labrador Trough embayments. T. Clark (personal communication, 1982) confirms this hypothesis. Dimroth (1978) classifies the embayment sediments at the base of the Labrador Trough as part of the Chakonipau Formation (red arkose, grit, conglomerate, intercalated argillite), which is overlain by the Portage Formation (red arkosic sandstone with intercalated pink dolomite and dolomitic sandstone).

T. Clark (personal communication, 1982) does not agree with this classification. He argues that the difference in thicknesses of Chakonipau Formation just east of Cambrian Lake (perhaps 50-60 m) and the embayment sediments (~500-600 m) would be difficult to explain if both were time equivalents. Furthermore paleocurrent directions indicate that the source area for the embayment sediments was from the east of Cambrian Lake. Consequently, he argues, there was no trough at that time east of Cambrian Lake and the Chakonipau could not then have been deposited simultaneously. Therefore, the Sakami Formation should be older than the Chakonipau Formation. The problem then is: why don't we find Sakami sediments at the base of the Chakonipau Formation? Even though, for the purpose of this paper, it does not make any difference; we still feel that the essentially continental sequences of the Sakami and Chakonipau Formations should be grouped together.

We adopt the view, that the northern belt of Sakami outliers represents the remnants of an early intracontinental rift system, perpendicular to the later Labrador Trough. At this time, the western side of the Labrador Trough was the site of an intracontinental shallow basin. This also explains the difference in thickness between the Sakami (more than 1000 m at Gayot Lake) and the Chakonipau Formation (approx. 60 m). A modified illustration (Figure III) from Dimroth (1978) shows the inferred Cambrian Otelnuk Fault on the southern limit of the suggested rift system, so that the Cambrian Lake area represents the triple junction of the east-west "failed arm" and the NW-SE trending Labrador Trough. The halt of subsidence within the rift system at an early stage, resulted in the lack of deposition of marine sediments there.

Findings by Seguin et al (1981) support the idea of time equivalence between the Sakami Formation and the Chakonipau Formation. Paleomagnetic studies on the Lac Tilly outlier, Sakami sediments in the Rivière La Grande area led them to propose a depositional age for the Sakami Formation of at least 2060 Ma. This age correlates very well with the lower Labrador Trough sediments (Dimroth 1970, 1978). Seguin obtained an age of magnetization of the Sakami sediments of 1.85 billion years, which is the same age as that obtained for the U-mineralization at the Gayot Lake outlier.

GEOLOGY OF THE GAYOT LAKE AREA (Figure IV)

The Sakami outlier, which contains the Gayot Lake U-deposit is approximately 52 Km long (E-W) and 12 Km wide (N-S). Geological surface mapping of this sedimentary basin and the adjacent basement was done by Uranerz and Eldorado (Assessment Report No. GM-34924) on their respective concessions. A compilation of the geology of this outlier is included (Figure IV).

BASEMENT GEOLOGY

Approximately 30% of the Archean basement lithologies in the immediate vicinity of the Gayot Lake outlier consist of rock types with granitic affinities: pink leucogranite, hornblende granite, biotite granite and pegmatites. Approximately 65% of the lithologies are gneisses: hornblende gneisses, biotite gneisses, banded gneisses. The remaining 5% or so are amphibolites and schists.

The general trend of foliation in the basement rocks is NNE, with considerable local deviation from this general trend indicating faulting and folding. The faulting also follows the general NNE direction except at the southern rim of the sedimentary basin, where E-W trends prevail.

At the unconformity with the Sakami sediments, the basement is usually chloritized and sericitized (alteration under reducing conditions). In places, hematization prevails over other alteration products. At the southern rim of the Gayot Lake outlier, regolithic basement was observed at the unconformity.

STRATIGRAPHY OF THE SAKAMI FORMATION

At the northern rim of the Gayot Lake sedimentary basin Lower Sakami sediments unconformably overlie the Archean basement. In contrast to the Upper Sakami, the lower member has a wider range of lithologies and grain size. It can be subdivided into 4 units (from older to younger).

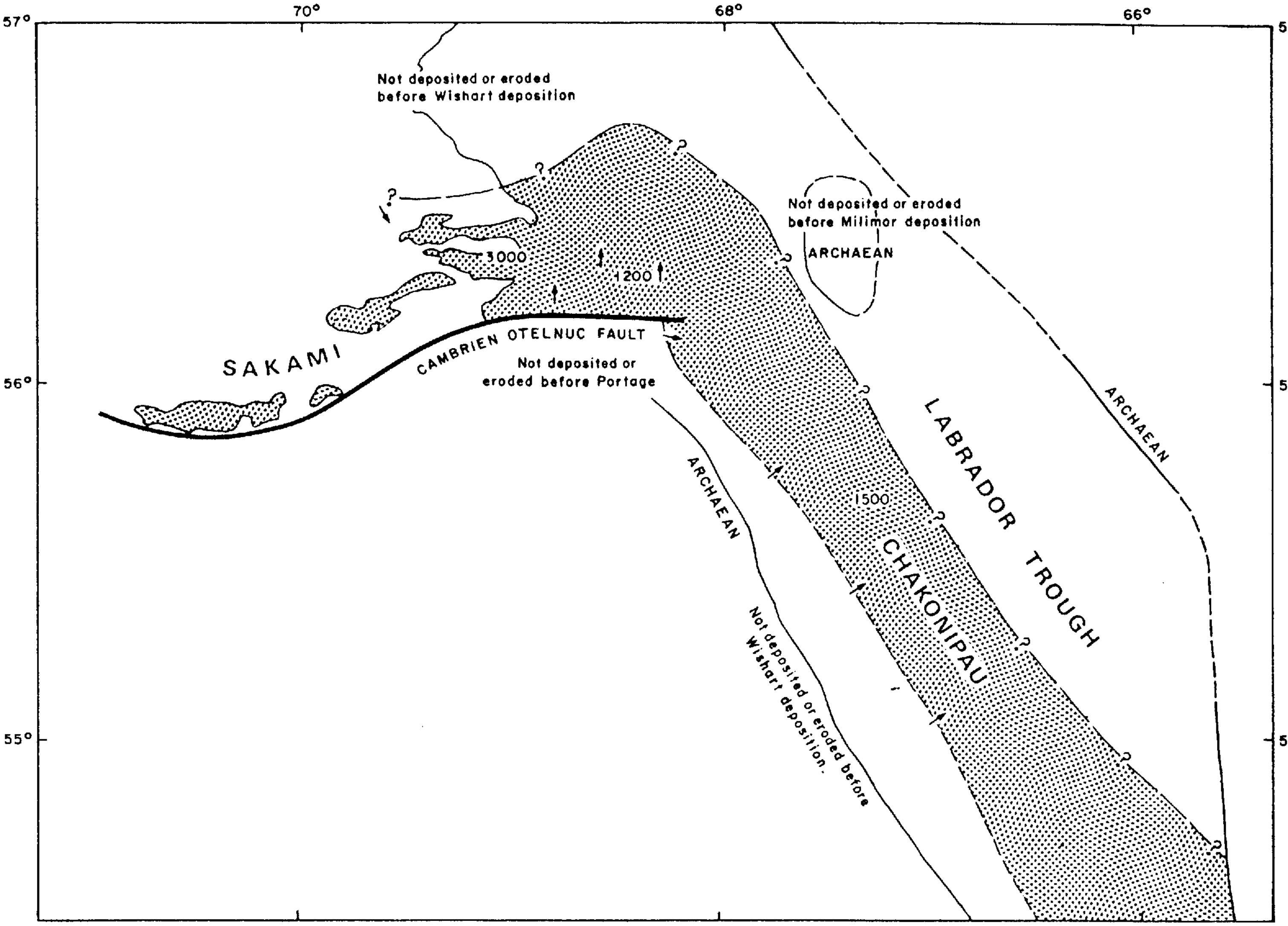
1) basal conglomerate (0-10 m), overlying the basement.

2) laminated argillites (red and green) with a few mm thick carbonate beds, siltstone and sandy argillites (9-80 m), with the uranium mineralization at the contact with the above unit.

3) red and green sandy to arkosic argillites with intraformational conglomerates and microconglomerates, with lateral facies changes to argillitic sandstones and subarkosic sandstones (80 m).

4) argillites and siltstones - red and green)
   sandstones - pink to buff) cyclic deposition (200 m)
   argillites and siltstones - red and green)

The thickest sections of typical argillitic lower Sakami outcrop in the western half of the Uranerz concession is to the west of Dieter Lake. From this area, a lateral facies change to coarser grained material (subarkosic sandstone) occurs both to the east and to the west.



LEGEND

Chakonipau and Sakami Formation

▨	Arkose, grit, pebble conglomerate, locally boulder conglomerate and pyroclasties.
━	Inferred faulting during or shortly after Chakonipau deposition.
→	Inferred provenance.
1500	Estimated thickness of the formation, in meter.

Km. 0 16 32 48 Km.

Modified after Dimroth (1978).

Distribution of Sakami and Chakonipau Formation in the Vicinity of Cambrian Lake.

FIG. - III

Microfilm

PAGE DE DIMENSION HORS STANDARD
MICROFILMÉE SUR 35 MM ET
POSITIONNÉE À LA SUITE DES
PRÉSENTES PAGES STANDARDS

Numérique

PAGE DE DIMENSION HORS STANDARD
NUMÉRISÉE ET POSITIONNÉE À LA
SUITE DES PRÉSENTES PAGES STANDARDS

The No. 3 unit can be subdivided into an upper, mainly red sandy argillite (3a), and a lower, mainly green sandy argillite (3b), with a gradual lateral facies change to the ENE, to a red variety.

The Upper Sakami member is mainly a white to pink sandstone. At the base, this unit is interbedded with siltstones (red and green), and passes conformably from the lower member.

At the southern rim of the sedimentary outlier, no Lower Sakami sediments could be traced. This may be partly due to faulting, but even in areas without faulting, Lower Sakami lithologies are not present, suggesting that either the lower units have not been deposited in the south (the Upper Sakami would then be transgressive upon the Lower Sakami and the whole basin was later tilted towards the south, as indicated by the ± uniform southerly dip of sedimentary strata) or we have again a facies change. The former possibility is favoured by the author, since the paleocurrents indicate a N→S direction for transportation and deposition of the sediments and a coarsening of sediments downstream can hardly be expected.

LITHOLOGICAL DESCRIPTION OF LOWER SAKAMI SEDIMENTS (from older to younger)

The Basal Conglomerate (Unit 1)

This rock type was deposited in local depressions and should be more adequately described as a basal breccia. The rock is very poorly sorted. The quartz, feldspar and rock fragments, which constitute 10-50% of the rock, are angular to subrounded and range in size from a few mm to 10 cm. The matrix reflects the poor sorting of the rock, being very inhomogenous and varying from fine to medium grained. The colour is usually grayish green to green, and sometimes reddish.

The Laminated Red and Green Argillites (Unit 2)

Very fine rhythmical layering characterizes this rock type and gives it occasionally a varved appearance. The laminae range in thickness from fractions of a millimeter to 0.5 cm. The grain size of the finest fractions is about 5μ; coarser fractions attain 0.25 mm, consisting of angular grains of quartz, plagioclase (albite) and minor potash feldspar, floating in the fine-grained matrix. The matrix minerals are mainly sericite, chlorite, albite and (in the red varieties) iron hydroxides and hematite. Carbonate material is unevenly distributed and often is found recrystallized into larger grains or laths. Biotite is a minor constituent and occurs as partly chloritized flakes parallel to the bedding. Occasionally, a few mm thick layers of a carbonate precipitate alternate with the shale layers.

The Red and Green Sandy to Arkosic Argillite (Unit 3)

This rock type is generally a massive wacke and represents a turbidite. The fine grained matrix usually comprises more than 50% of the rock, but varies from 15 to 90%. The fragments are angular to subrounded and consist of, in order of abundance: quartz, microcline, plagioclase, minor granitic and schistose rock fragments, all varying in size between 0.05 and 3 mm. The matrix minerals are: sericite, chlorite and chloritized biotite, albite and (in the red varieties) limonite and/or hematite. Some varieties, especially at the base of the unit, are moderately (5-10%)to very rich (50-80%)in carbonate, which tends to have recrystallized; others are rich in coarser clasts, forming intraformational conglomerates.

The Cyclic Deposits of Argillites/Siltstones and Sandstones (Unit 4)

Lithologically the argillites and/or siltstones are similar to Unit 2 except that the grain size is generally coarser and quartz makes up a higher portion of the rock constituents. Also, depositional structures such as cross bedding are often present. The sandstones are generally greenish white, fine grained and quartzitic to subarkosic.

UPPER SAKAMI SEDIMENTS

The Upper Sakami, above Unit 4 of the Lower Sakami is mainly a white to pink quartz sandstone. As this rock type was not studied in detail, no further description will be given here. At the base, this unit is interbedded with minor siltstones (red and white).

TECTONICS

The Gayot Lake sedimentary basin was probably controlled by NE-SW longitudinal faults. These faults produced a graben-like structure. The Unit 2 of the Lower Sakami sediments, deposited into this depression, attained its greatest thickness where the graben was deepest. During and subsequent to this sedimentation, especially in the Dieter Lake-Lake Vivian area, the NE-SW faults were reactivated, producing large offsets within the sediments (Figure IV and VI) and minor drag folding. The last tectonic event was a tilting of the sedimentary basin to the south, resulting in the general SSE 25° dip of the sediments. This tectonism may have to be seen in conjunction with the initial evolution of the Labrador Trough geosyncline (e.g. early continental rifting?).

MODE OF SEDIMENTATION

The very first sediments deposited (unit 1) on the partly regolithic Archean surface were accumulations of both locally and non-locally derived debris and pebbles of diverse composition situated in depressions produced by the above described tectonics. These accumulations rarely exceed a thickness of a few meters. After this, a typical lake deposit, under mostly reducing conditions, (Unit 2 - argillites interbedded with carbonate horizons) was formed within the graben structure (thicknesses of up to 80 m), blanketing the relief of the Archean basement. Mud cracks and ripple marks within red varieties indicate a periodically shallow environment. The source for the argillites was the adjacent weathered Archean land surface. The close of this sedimentary cycle was marked by a period of retarded sedimentation, with an accumulation 0-3 m of silt, mud and partly pisolitic carbonate beds, in a more turbid environment (turbation, pene-contemporaneous deformations, (see Plates 1, 2, 3)),but still under mostly reducing conditions. At the end of sedimentation of Unit 2, the graben was probably deepened through a reactivation of the NE-SW faults.
The following semi-pelitic (Unit 3) Lower Sakami sediments were then deposited in an essentially lacustrine environment, but at the front of psammitic deltaic deposits or an alluvial fan terminating in a "lake". Thus there was a distinct increase in the rate of sedimentation. At that time, the energy of the depositional environment was increasing to the NE; the sediments deposited to the NE were laid down in a high energy environment and sorting was poor (arkoses, micro-conglomerates), whereas further to the SW (in the area of Dieter Lake) much of the energy was already lost (the rivers having entered the lacustrine environment) and accordingly the percentage of fine-grained material increased gradually from NE to SW: micro-conglomerate→arkose→argillitic sandstone→ sandy argillite).

In the deeper parts of the basin, Unit 3b (green sandy argillite) was deposited in a reducing environment, but this changed gradually to an oxidizing environment both laterally (closer to the basin margins) and with time (to give way to Unit 3a - the red sandy argillite), whereas for unit 3a the environment was continuously oxidizing.

After deposition of Unit 3, a cyclic sedimentation of argillitic, silty and sandy deposits began to reflect different stages of subsidence and quiessence in the sedimentary basin, with an accumulation of 50 to 80 m of sediments in each semi-cycle, attaining a total of 200 m. The Lower Sakami attains a total thickness of ~370 m.

The essentially uniform orthoquartzites of the Upper Sakami are assumed to represent an epicontinental sandstone deposit.

THE U-MINERALIZATION

This mineralization can most adequately be compared with the syngenetic part of the Permian (Autunian) U-deposit of Lodève, Herault (France), Herbosch,A.1974 and the upper Cambrian sedimentary U-deposit of Ranstaad (Sweden), Armangs,G.1968. At Lodève, the very fine-grained uranium mineralization (pitchblende and coffinite) close to the present surface (open pit) is stratabound and related to lacustrine carbonaceous pyrite-rich fine grained horizons at the interface of the lower grey (reduced) Autunian and the upper red (oxidized) Autunian (P. Moureau et C. Caleix, 1980; M.J. Wyart, 1970; A. Herbosch, 1974). At the Ranstaad deposit, most of the uranium is concentrated in a 2-4 m thick zone of carbonaceous and pyrite-rich marine shale (Uranium Resources, Production and Demand, 1977). A recent example of this type of environment is in the Black Sea, where the upper 90 cm of the basin sediment is enriched in uranium (E.T. Degens, 1977).

The bulk of the U-mineralization of the Gayot Lake deposit occurs within a highly uranium enriched lake-bottom sediment (low energy) at the interface of Unit 2 (laminated argillite) and Unit 3 (sandy to arkosic argillites).

The mineralization consists of very fine grained (2-5μ) sooty pitchblende and pitchblende together with <1% sulfides (mostly chalcopyrite, bornite, pyrite, chalcocite and molybdenite) and minor organic material (<1%). The U-oxides are disseminated within the fine grained calcitic sediments, clearly following the sedimentary features. Occasionally a few mm thick massive bands of pitchblende do occur. Microscopic investigations have led to the conclusion that the mineralization is syngenetic-synsedimentary. In some cases, it has been diagenetically remobilized and enriched (E.V. Pechmann 1978, unpublished).

Characteristically, the stronger mineralization is found when Unit 2 is fully reduced at the top and Unit 3 is slightly oxidized at the base. In this case, the interface of both units is marked by a layer of recrystallized carbonates, and it is about 0.6 m below this layer that the mineralization occurs within an olive green to brown silty mudstone. Obviously the fixing of uranium occurred during a period when the rate of sedimentation was very low.

In the deepest parts of the basin (down dip from Dieter Lake area), the transition of Unit 2 to Unit 3 is very smooth, both units having been deposited in a reducing environment, subsequently no substantial amounts of uranium were fixed at the poorly defined interface. In the shallow parts of the basin (~6-7 km east of Dieter Lake area) Unit 3 underwent a facies change from green sandy argillite to highly oxidized red sandstone with only a few meters of silty material left at the base. Again no substantial amounts of uranium were fixed at the interface of both units.

It is suggested, that evaporation balanced out and periodically exceeded the influx of water into the basin as in places the overlying sequence contains mud cracks in the shallower parts of the basin. At the same time, some tectonic adjustments in the area surrounding the basin probably occurred, exposing fresh basement rock to weathering and liberating U-saturated groundwaters which ultimately found their way into the basin. The uranium was then fixed in the bottom muds (lake bottom sediment), which were in the form of a gyttja (transition between fully reduced sapropelite and fully oxidized red bed), whereas the water overlying the sediment was still oxygen-rich. The sediment was in a transition between a poorly oxidized upper layer of 10-30 cm and a reduced layer below with thiobacteria reducing the oxidized components of the circulating waters or pore solutions of the upper 20 cm or so. In this way, both sulfides and uranium were fixed within the mud. A second mechanism of fixing the uranium was probably the adsorption of uranium cations by clay minerals. The actual thickness of the mineralized horizon is from 20 cm to 2m and contains from a few hundred up to 5000 ppm U_3O_8 per meter thickness. Figure V shows the basement immediately north of the Gayot Lake mineralization still producing modern lake bottom sediments with high uranium contents.

The transitional character between oxidizing and reducing environment is still reflected in the overlying sub-unit 3b where in the area of underlying uranium mineralization it is in a state of semi-oxidation and the colour is a mixture of green, gray and red (lit de vin).

In the area of Dieter Lake (deepest part of the basin), where sub-unit 3b is green only (fully reduced), this unit itself contains disseminated U-mineralization at different stratigraphic levels, but due to the high rate of sediment accumulation, the grade is very low (100-300 ppm), but the mineralized thicknesses increase considerably.

FACTORS CONTROLLING THE U-MINERALIZATION

As outlined above, the U-mineralization is restricted to a well-defined environment both temporarily and spatially. Which are the factors controlling this environment?

Figure VI shows the distribution of the U-mineralization. Figure VII shows a vertical section across the mineralized area.

These figures suggest a relationship between the basin bottom topography, thickness of sediments and U-mineralization. Generally the mineralized horizon is well developed and well mineralized in the areas of depressions with thick accumulations of Unit 2, whereas on rises, this horizon usually is poorly developed and contains little U-mineralization. This suggests: 1) the fine-grained sediment, containing the U-mineralization (comparable with an actual lake-bottom sediment, or the modern sediments of the Black Sea, apart from their organic content) could accumulate more easily in depressions than on rises; 2) the fixation of U was favoured within the more quiet and reducing environment of the depressions as opposed to the higher energy and probably less reducing environment of the rises (layered water body).

Furthermore, it seems evident that the general trend of individual mineralized areas, separated by the rises of the basin bottom, follows the direction of the NE-SW faults. It thus seems clear that the NE-SW faults predated sedimentation of the Lower Sakami even though they offset these sediments through later reactivation. Through preferential weathering and erosion of the basement along these tectonic lines prior to the sedimentation of the Sakami, NE-SW elongated troughs and rises were created. The trends of these depressions and rises (paleotopography) of the bottom of the future sedimentary basin predetermined the distribution of the U-mineralization.

Detailed drilling within mineralized areas revealed that in addition to the above described controls there may also be channel-like features, since in some areas (Lake Vivian) the mineralization is very irregular and seems to follow very narrow trends. Also, thicker accumulations of uranium-rich sediments may, at least in part, be due to the down slope slumping of unconsolidated mud from the rises into the depressions. On the other hand, the mineralized sediments may be completely flushed away from the top of the rises.

The mineralizing environment as a whole, is in turn controlled 1) by the distance from the shoreline (near shore environment) at the time of sedimentation and 2) the depth of the basin bottom with respect to the water level. At a particular distance and depth, the optimum conditions for sedimentation of very fine particles in a semi-euxenic environment (oxy-redox inversion boundary) during a period of very low erosion were met. In order to maintain a high level of U-concentration in the water body of the basin, it is suggested that the water level within the basin was regulated only through influx of water and evaporation (with no outflux of water from the system). The U extracted from the water and adsorbed by the bottom sediments (mud) through circulating pore solutions was thus replenished continuously.

HORIZONTAL DISTRIBUTION OF TRACE ELEMENTS WITH RESPECT TO U_3O_8 DISTRIBUTION WITHIN THE MINERALIZED HORIZON

Figure VIII shows the horizontal distribution of U_3O_8 over the investigated area, averaged over one meter thickness of mineralized horizon. Figures IX, X and XI show the horizontal distribution of Mo, V and Cu respectively superimposed upon U_3O_8 distribution.

Mathematically, the best correlation is found between U_3O_8 and Mo (Figure VI) with a correlation factor of 0.66. The second best correlation is between U_3O_8 and V (Figure VII) with a correlation factor of 0.55, followed by U_3O_8 and Cu (Figure VIII) with a correlation factor of 0.35.

VERTICAL DISTRIBUTION OF MAJOR, MINOR AND TRACE ELEMENTS OVER THE MINERALIZED HORIZON FROM FOUR DRILLHOLE INTERSECTIONS, A FACTOR ANALYSIS

To further substantiate the genetic model for the Gayot Lake mineralization, 371 core samples in 10 cm intervals were taken from four mineralized diamond drill holes (DDH-99, -111, -119 and -135) and analyzed for 22 elements. The statistical evaluation of the data was done by factor analysis. For location of drill holes see Figure VI.

The elements Al, Be, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, N, P, Pb, Sr, Th, Ti, V, Zn and Zr were all analyzed by I.C.A.P. (Inductively Coupled Argon Plasma) emission spectroscopy. The technique involves the total dissolution with hydrofluoric acid of the rock samples and quantitative analysis of the above 21 major, minor and trace element constituents by induction coupled argon plasma spectrometry. This system was chosen because of its low cost and its ability to provide major, minor and trace element data simultaneously. U was analyzed by X.R.F. from the same solution. Analysis for Si, S and organic carbon would have been extremely useful, but considering the substantial extra cost and the low levels of sulfur and organic carbon within the samples, it was decided to do without them.

VARIMAX ROTATED FACTOR MATRIX FOR DDH-99

	Ore Horizon; 38 cases					Wall Rock & Ore Horizon: 88 cases					
FACTOR:	1a	2a	3a	4a	5a	1b	2b	3b	4b	5b	
ELEMENT											
U	-.20	.89		.33		-.24	.77		.56		U
Pb	.26	.71	-.28	.38	.22	-.29	.58	-.21	.59	.25	Pb
Cu				.73					.72		Cu
Mo					.94					.92	Mo
V		.22		.76					.70		V
Mn	-.93					-.95					Mn
P	.44	.71				.41	.40		.24		P
Ca	-.95		-.21			-.97					Ca
Na	.94					.82				.20	Na
Be	.54	.57		.49	.27	.60	.42		.60	.20	Be
Al	.95					.97					Al
Fe	.74		.62			.77		.56			Fe
Mg		-.25	.86			.29	-.23	.80			Mg
Ti	.94			.23		.97			.20		Ti
K	.97					.97					K
Cr	.93	-.31				.92	-.26				Cr
Co	.43	.43			.63	.45	.35			.45	Co
Ni	.20	.53	.51	.30	.38		.47	.55	.31	.36	Ni
Sr	-.82		.25	.24		-.80			.33		Sr
Th	-.25	-.83				-.22	-76				Th
Zr	.86	.35		.25		.81			.31		Zr
Zn			.86					.82	-.20		Zn
% of Variation	54.8	22.0	10.9	6.5	5.8	54.7	10.4	5.8	24.2	5.0	

TABLE I

The factor analysis establishes correlations between elements of similar behaviour under specific conditions and groups them together in "factors". In a sedimentary environment for example, the various factors would characterize certain facies as e.g. various detrital facies versus a number of differing chemical facies with their respective specific element associations. A detrital facies would be characterized by a factor being highly saturated, with Al, K, Na, (Mg, Fe), Zr, etc., i.e. these elements correlate well within this group, whereas a chemical facies like the carbonate facies would be characterized by a factor highly saturated with the elements Ca, (Mg, Fe in the proper environment), Mn and Sr. Certain detrital minerals would preserve a characteristic element combination of their source rock etc. Certainly there are no rules established as to how we have to interpret these factors and thus we are left with an embarassing freedom of interpretation of the data obtained through the factor analysis. But generally the geological and mineralogical investigations and the results of the factor analysis are so well in accordance, that the possibility of misinterpretation is very slim.

The factor analysis was performed as a subprogram to the SPSS - package (Normann, H.N. et al, SPSS - Statistical package for the social sciences, McGraw-Hill, 2nd ed., 1970) on a CDC - CYBER 170-760 computer.

The varimax rotated factor matrix was finally used for interpretation of the data. For more detailed information about this topic, we refer to Herbosch, 1974, and other authors (see refence, Herbosch.A.1974), The four holes from which the cores were analyzed were selected so that we had a broad variation of sedimentary environments from very shallow to very deep. Thus the emphasis is not to be seen in the factor analysis of all 371 samples together, but rather in the factor analysis of the approximately 90 samples from each hole. Again for the set of samples from each hole, two sets of factor analysis were affected: one over the whole 9-10 m interval sampled, and one over only the Uranium-mineralized interval of 1.5 to 4 m, which henceforth we will call the "ore horizon". The photos of plates 1, 2 and 3 show various macroscopic textural aspects of the ore horizon.

In tables 1, 2, 3 and 4 the factor analysis for each hole compares the results for the ore horizon on the left side of each table with the results for the entire 9-10 m of sampled thickness on the right side of each table. Table 5 shows the results of the factor analysis for only the ore horizon of all four holes together.

FACTOR ANALYSIS DDH-99, TABLE 1

The diamond drill hole number 99 intersected one of the best mineralizations at Gayot Lake. The mineralized zone in the drill hole is interpreted as being located at the flank of a local depression at the lake bottom, where a transitional environment from oxigenated to euxenic conditions prevailed and in which the facies could most appropriately be described as a gyttja.

A) Factor analysis for 3.8 m of ore horizon

Factor 1a: Bipolar, this factor opposes detritral and chemical environments: Al, Fe, Na, K, Cr, Zr and Be are all positively correlated to this factor and represent the detrital or clastic facies of the sediment. On the other hand Ca, Sr, Mn, belonging to the carbonate facies (inorganic chemical precipitation of carbonates), have a strongly negative correlation to this factor. As U and Pb are also negatively correlated to factor 1a, there may be an overlap between the carbonate facies and the facies or environment favourable for U- precipitation. Mg is not characterized as belonging to either of the two facies, Mg-chlorites being found in both environments.

Factor 2a expresses the high correlation between U and Pb due to the fact that most of the Pb is radiogenic. The association of U and P within this factor may indicate a correlation between organic matter and uranium fixation insofar as a reducing environment was produced by decaying organic matter (reduction of oxidized U-complexes). We assume that unlike in modern lakes, life probably developed preferentially near and at the lake bottom and possibly within the lake bottom mud. As Nickel correlates well with U too, a reducing environment is again a likely explanation. The correlation of Be within this factor could either be explained by adsorption of Be in the original clay fraction of the reducing organic-rich lake bottom mud or by resorption of Be by living organism. Characteristically, Th has a highly negative correlation within this factor, ruling out any detrital contribution for U - accumulation. A gyttja is the most likely environment for this element association. Unfortunately diagenesis of the sediments has so thoroughly altered the original mineralogical composition of the sediments, that very little mineralogical evidence can be found to further demonstrate the validity of this interpretation. The photos of Plate 1, 2 and 3 do however deliver some evidence for such an interpretation.

Factor 3a groups Fe, Mg, Ni and Zn together, strongly suggesting the reflectance of a basic source rock for some of the detrital material, as all of the elements are most concentrated in basic igneous rock types. This reflectance is possible by inheritance through Mg/Fe clays and chlorites from basic terrain via weathering, erosion and finally sedimentation. This might reflect a relatively low O_2 level of the atmosphere in Aphebian times, because otherwise the Mg-Fe association typical for amphiboles, pyroxenes and chlorites would have been destroyed in a warm subtropical environment (lateritization), that is needed to explain the evaporite (see Factor 3, Table 4, DDH-135) encountered elsewhere. Or else, with a higher degree of probability, we would have a gradual change from a moderate to a subtropical climate with time, which would very well explain the gradual increase of hematite above the ore horizon. But more important yet, this association reflects the absence of vegetation on land, which could act as a filter for the very fine grained weathering products of basic igneous rocks. The basement rocks encountered beneath the unconformity with the sediments, show only little oxidation (hematization).

Factor 4a: A strong correlation between Cu and V would be expected in a sedimentary environment under slightly reducing conditions. Probably Cu and V were precipitated under slightly different Eh/Ph conditions than U, thus reflecting slightly differing environments, U needing slightly more reducing conditions than Cu/V.

In fact the maximum Cu and V contents are found only slightly shifted towards the hanging wall with respect to the maximum U-contents. A comparison with the U-Cu mineralization of Zambia (Africa) (L. Meneghel, 1979) reveals a very similar relationship, the U being enriched in the probably more reducing environment below the Cu-mineralizations. If the pH in the lake water was between 6 and 7, then chalocite (Cu_2S) would already precipitate at higher Eh values than tolerable for U-reduction (R.M. Garrels and C.L. Christ,1965,p.319).

Factor 5a: This factor is strongly saturated only by Mo and somewhat less by Co. As a basement source for Mo (Molybdenite vein) occurs in the immediate vicinity of hole No. 99, reaching the unconformity and cropping out at the present surface north of the sediments, this factor is probably more reflecting the proximity of the Mo-source than the depositional environment. This factor is so dominated by the Mo-saturation, that no information about the depositional environment is available.

B) Comparison of the right and left side of Table 1 (thickness of the ore horizon is 3.8 m) with the right side of the Table (8.8 m total sampling thickness) reveals no major differences, except for factor 4, where the correlation of U-Pb with Cu-V is much stronger on the right side of the table, thus enhancing the importance of a reducing environment for metal fixation within the sediments, as the number of analyzed samples increases.

SUMMARY OF RESULTS

Uranium as well as lead have a slightly negative correlation with elements representing the detrital facies (factor 1a,b) a slightly positive correlation with elements representing the carbonate facies. Both elements are negatively correlated to factor 1a,b, and show a distinct positive correlation with elements representing a reducing environment. The positive correlation with phosphorous (factor 2a,b) is indicative of an originally organic rich environment. The strong negative correlation of uranium with thorium rules out any direct detrital contribution to uranium accumulation within the sediments. The sedimentary facies best uniting all these requirements would be a gyttja. Such a sediment would originally be organic rich, partial oxidation in situ shortly after sedimentation would however destroy much of the organic matter and only phosphorous would remain in the sediment. We also have to consider the possibility of a lower level of oxygen concentration in the aqueous environment during Aphebian times - thus decay of much less organic matter than in modern aqueous environments would probably produce a reducing environment. Finally the progressive change of a moderate climate towards a subtropical climate was probably responsible for the progressive availability of first U and then Cu and V and other metals. This progressive climate change is also reflected in the sediments: the moderate climate produced shales beneath the ore horizon, the transitional climate the transition zone between shale and wacke with the ore horizon, and the subtropical climate after erosion of the soil, the wackes above the ore horizon. In the shallow environments, the sediments were, shortly after sedimentation, diagenetically oxidized.

VARIMAX ROTATED FACTOR MATRIX FOR DDH-119

	Ore Horizon: 15 cases				Wall Rock & Ore Horizon: 84 cases				
FACTOR:	1a	2a	3a	4a	1b	2b	3b	4b	
ELEMENT									
U	-.21	.87	.29			.92			U
Pb		.94	.24			.93	.22		Pb
Cu		.60	.44			.76			Cu
Mo		.93			-.29	.78	.23		Mo
V	.24		.89		.58	.56	-.33		V
Mn	-.92	.35			-.91		-.26		Mn
P	.53	.69			.50	.31	.36		P
Ca	-.98				-.91		-.37		Ca
Na	.90	.27	.32				.79	-.48	Na
Be	.34	.71	.55		.68	.60			Be
Al	.98				.97			.21	Al
Fe	.81	.43			.39			.89	Fe
Mg	-.45	-.27	-.57					.70	Mg
Ti	.98				.94			.27	Ti
K	.95	-.27			.86		-.35	.29	K
Cr	.84	-.51			.82		-.43	.26	Cr
Co		1.00			-.24	.35	.69		Co
Ni	.59	.76			.25	.20	-.23	.63	Ni
Sr	-.97				-.86	.24			Sr
Th	.35	-.77	-.31			-.28	-.48		Th
Zr	.96				.45		.59		Zr
Zn			.79			.53			Zn
% of Variation	52.7	38.6	8.8		47.6	27.3	19.2	6.0	

TABLE II

FACTOR ANALYSIS DDH-119, Table 2

The diamond drill hole 119 intersected again an excellent mineralization, but the thickness was considerably reduced with respect to DDH-99 and the mineralization is believed to occur within a slightly shallower environment of deposition.

A) Factor analysis for 1.5 m of ore horizon

This small group of 15 samples rendered only 3 factors:

Factor 1a: The bipolarity between carbonate facies and detrital facies is again quite strong. Even though Mg is negatively saturated within this factor, it does not correlate with the carbonate facies.

Factor 2a: The strong saturation of U, Pb, Cu, Mo, Co and Ni is indicative of a reducing environment being the main controlling factor for metal fixation within this 1.5 m thickness of sediment, Cu and V being again slightly shifted towards the hanging wall. Phosphorous is again interpreted as being representative of organic material and Be as being indicative of the fine grained nature of the sediment.

Factor 3a: In the same way, Cu and V concentrations are shifted upwards with respect to the U-mineralization, also Zn concentrations are shifted. Therefore Zn is found together with Cu and V in the third factor with only low saturation for U and Pb.

B) Comparison of the right and left side of Table 2

With increasing number of samples and inclusion of wall rock, the factors are increased by one and are saturated in a different manner.

Factor 1b: For an unidentified reason, V now correlates well with the elements of the detrital facies of factor 1b. Na is no longer saturated in the first factor, but in the third - high sodium contents (albite) are encountered in the shales below the mineralized horizon together with Co and Zr.

Factor 2b: The major change here is that now V and Zn appear together with the other metals even further emphasizing the reducing character of the environment during metal fixation in the sediments. On the other hand Co and Ni now characterize other assemblages in the 3rd and 4th factor respectively.

Factor 3b: This factor reflects a sodium (average of 4.2% Na_2O over 1.3 m) zirconium and cobalt enrichment within shales below the ore horizon. This may indicate an early period of evaporation - (see also interpretation of factor 1 for DDH 135). Microscopic thin section examination indicates albitization of U-feldspar within a calcareous siltstone to very fine grained calcareous sandstone. J. Wyart,(1970) describes albitization of potassium feldspars in the Permian sediments of Lodève and explains it by diagenetic replacement from sodium rich lagoonal waters.

Factor 4b: The association of highly saturated Fe, Mg and Ni is again indicative of a mineral assemblage deriving from a basic source rock.

VARIMAX ROTATED FACTOR MATRIX FOR DDH-111

	Ore Horizon: 39 cases					Wall Rock & Ore Horizon: 100 cases						
FACTOR:	1a	2a	3a	4a	5a	1b	2b	3b	4b	5b	6b	
ELEMENT												
U		.81					.86					U
Pb	-.40	.69				-.27	.74					Pb
Cu			-.86					.75				Cu
Mo					.69					.45		Mo
V	.27	.87				.30	.81					V
Mn	-.93					-.93						Mn
P	.44		.83			.37		-.63	.24			P
Ca	-.98					-.97						Ca
Na	.78	-.40				.68				.29	.58	Na
Be	.86	.30				.88	.29					Be
Al	.99					.96						Al
Fe				.92					.89			Fe
Mg	-.89	.20	-.22			-.85						Mg
Ti	.99					.92			.23			Ti
K	.96					.97						K
Cr	.97					.94						Cr
Co	.50			.32		.32	.21		.41			Co
Ni				.41					.61			Ni
Sr	-.91		-.22			-.84						Sr
Th	.27	-.21	.29		.67	.22		-.23	.31	.29	.42	Th
Zr	.92				.22	.82				.26		Zr
Zn				-.21	-.32							Zn
% of Variation	62.7	14.9	9.2	7.9	5.2	60.2	16.1	6.6	9.1	4.5	3.4	

TABLE III

SUMMARY OF RESULTS

Probably because of the reduced thickness of the ore horizon, less variability of element distribution within this horizon occurred and thus a smaller number of factors resulted. On the right hand of Table 2, the ore horizon is clearly defined in factor 2b, regrouping all the elements requiring a reducing environment for fixation or precipitation within a sedimentary sequence except for Co and Ni. Ni-concentrations in solution in the lake water were probably too low, so that the affinity of Ni to factor 2a is obscurred in factor 2b by the much greater affinity to the detrital assemblage of factor 4b, which reflects a basic source rock. For Co the affinity to factor 2a is obscurred in factor 2b by the much greater, though unexplained affinity to the horizon of sodium enrichment, reflected in factor 3b. This affinity will again be found in DDH 135. The only evidence for a shallower environment of ore metal precipitation with respect to DDH 99 is this albite rich horizon below the ore horizon which may represent an early evaporitic environment.

FACTOR ANALYSIS DDH-111, Table 3

The diamond drill hole 111 intersected 4 m of low grade U-mineralization. The geological interpretation led us to the conclusion that the depositional environment was deeper and further offshore than at the sites of DDH 99 and 119 and hence below the oxy-redox boundary of the stratified water body of the lake.

A) Factor analysis for 4 m of ore horizon

Factor 1a: Interestingly this time magnesium is grouped together with the carbonate facies instead of the detrital facies as previously (DDH-99 and 119). A comparison of the ratio of CaO/MgO in the carbonate facies of DDH-99 (CaO/MgO of 9.5) and DDH-111 (CaO/MgO of 2.2) indicates that the carbonate facies in DDH-111 is considerably richer in MgO.

Consequently, we may conclude that either a Mg-rich carbonate precipitated directly (dolomite precurser)from a Mg-rich heavy brine of a stratified lake at depth or that incomplete dolomitization occurred diagenetically within the same environment. At these depths we would expect a completely euxenic environment. Such an environment would be expected in the more central part of a deep lake without exit and sufficient evaporation! Under such conditions, very little uranium in solution would occur at such depths and so far away from the shoreline of the lake to be fixed within the lake bottom. Uranium would have been precipitated already in a somewhat less reducing environment (close to the shoreline), where the oxy-redox boundary is closer to the lake bottom. And in fact, there is relatively little uranium within the ore horizon at this locality.

Factor 2a: U and Pb show a significantly positive correlation with V only, the other metals showing up in other associations within other factors. Hence reduction of oxidized uranium complexes is still the governing factor for U-fixation. But availability of U and base metals is so limited, that no clear patterns emerge from the factor analysis: U and base metals were precipitated already in shallower environments.

Factor 3a: Cu and P show a strong negative correlation. This is probably overemphasized because of one sample which at the same time rendered the highest Cu assay (3280 ppm) and the lowest P_3O_5 assay ($<0.01\%$) of the entire hole right at the top of the ore horizon. At the same time the high Mg-contents are no longer found above this sample interval, indicating a shallowing of the environment, favouring the Cu-producing facies to migrate further towards the centre of the depositional basin.

Factor 4a: As we find Fe and Ni within this factor, we would also expect Mg here, to explain this factor again by inheritance of material from basic source rock. Probably this positive relation still exists, but it is totally masked by the strong positive correlation of Mg with the elements of the carbonate facies!

Factor 5a is only saturated with respect to Mo and Th. Unfortunately very few values for Mo above the detection limit of 30 ppm were obtained and thus this factor may be of no significance.

B) Comparison of the right and left side of Table 3

With respect to the left side, very few differences occur on the right side. In factor 3b, Cu and P are reversed, but this has no practical meaning. Factor 6b is an additional factor and reflects a slightly higher sodium level at the central third (the ore horizon) of the sampled interval. This may again be due to the deeper environment, where a brine not only rich in Mg but also rich in Na could accumulate. Possibly some of the Na ions were incorporated in silicate minerals or even more albite was formed diagenetically from sodium rich precursers.

SUMMARY OF RESULTS

The most important information resulting from the factor analysis of the sampled interval from DDH-111 is that "dolomitization" of the carbonate facies occurred to some extent and that the Na-level in the vicinity of the ore horizon is slightly elevated with respect to sediments both below and above the ore horizon. The dolomitization as well as the sodium enrichment could be explained as occurring in a deeper further offshore environment of sedimentation, where brines are sufficiently concentrated with respect to Mg^{++} and Na^+ ions (layered water body) so that Mg replaces Ca, and Na is incorporated in the detrital facies in order to form albite at a later stage. This environment is not very favourable for U-accumulation in the lake bottom mud.

VARIMAX ROTATED FACTOR MATRIX FOR DDH-135

	Ore Horizon: 28 cases					Wall Rock & Ore Horizon: 99 cases				
Factor:	1a	2a	3a	4a	5a	1b	2b	3b	4b	
ELEMENT										
U	-.58	.65	.20	-.36			.99			U
Pb	-.50	.50	.26	-.49	.26		.89			Pb
Cu	-.29	.82	.29		-.20		.77	.23		Cu
Mo	-.36	.67					.64	.20	.30	Mo
V		.95	-.22			.34	.38	.24	.68	V
Mn	-.71	.63					.50	.76		Mn
P	-.23	.71	-.30			.60	.43	.38		P
Ca	-.84	.49					.55	.74		Ca
Na	-.70	-.40	.50			-.84		-.30	-.25	Na
Bc	.83		-.37	-.27		.82			.26	Be
Al	.89	-.42				.77	-.24	-.48		Al
Fe	.92					.82			.30	Fe
Mg	.97					.97				Mg
Ti	.87	-.26	.27			.99				Ti
K	.93	-.26				.92		-.24		K
Cr	.86	-.21		.35		.92				Cr
Co				-.33		-.79		-.27		Co
Ni					.91	.45				Ni
Sr			.41				.21			Sr
Th	-.27			.63		.36	.25	.35		Th
Zr	.45		.80	.27		.87				Zr
Zn	.53		.55	.53		.66		.49		Zn
% of Variation	59.6	16.1	12.4	7.7	4.2	56.5	32.7	6.8	4.0	

TABLE IV

FACTOR ANALYSIS DDH-135, Table 4

The diamond drill hole No. 135 intersected 1 m ore grade U-mineralization within 2.8 m high background sediments. Geologically the mineralization was explained as occurring within sediments deposited at quite shallow depth above the oxy-redox boundary of the lake water within an evaporitic environment. Dessication mud cracks within red mudstone were found in one of the drill holes in the vicinity.

A) Factor analysis for 2.8 m of ore horizon

Factor 1a: Mg is again positively correlated with the group of elements representing the detrital facies. Sr does not show a correlation with either the detrital or the carbonate facies, nor does Na, as can be seen by comparing factor 1a with factor 2a. As Na is positively correlated with Sr in factor 3a, we have to conclude that it is part of an evaporate facies, which explains the negative saturation in factor 1a, where chemical facies are opposed to detrital facies.

Factor 2a: U, Pb, Cu, Mo, V, Mn, P and even Ca are all positively correlated within this factor; therefore there has to be a considerable overlap of the carbonate facies with the facies responsible for ore metal precipitation. We then have to assume, that during evaporation, these elements were so concentrated in the highly saline lake water, that they all precipitated together under slightly reducing conditions with later diagenetic oxidation of the sediments. Thin section studies revealed intergranular and lense shaped pitchblende accumulations concentrate in areas with still preserved though partly diagenetically oxidized dissiminated sulfide mineralization, mainly pyrite. A barrier probably separated this part of the depositional environment at least temporarily from the rest of the lake at the time of metal fixation within the ore horizon. Drillhole interpretation confirms this hypothesis. Another argument in favour of such a model is the lack of positive correlation between the forementioned metals and Be, the latter normally being adsorbed onto clay minerals deposited in a deeper and therefore quiet environment. In this factor a negative correlation between Na and the ore metals is apparent, whereas in factor 3a a slight positive correlation between U, Pb, Cu on one hand and Na, Sr on the other hand can be observed. This is due to a slight shift of the zone of maximum Na-content with respect to the zone of maximum U-content: 1 m zone of sediment averaging 3% Na_2O begins 0.4 m below the lower limit of the 1 m zone of sediment containing 0.22% U_3O_8.

Factor 3a: As already mentioned, the positive saturation of Na and Sr within this factor together with a strong negative saturation of Na within factor 1a suggests an evaporitic environment. The slight positive correlation with U, Pb, Cu and Zn does not contradict this interpretation, as evaporation was probably the driving force for metal fixation in the sediment. The correlation with Zr is probably meaningless and disappears completely on the right side of the table.

Factor 4a: opposes again Th and U.

Factor 5a: Probably because of the generally oxidizing conditions, the generally well correlating group of elements: Fe, Mg, Ni and less so Zn, was broken up, possibly through diagenesis, and only Ni remained within this group, thus representing the basic source rock association.

B) Comparison of the right and left side of Table 4

Factor 1b: The right side of table 4 (10 m of sampled thickness) shows a substantially different picture as compared to the left side, because of inclusion of 4 m sedimentary albitite - a totally different facies with 5.8% Na_2O in the hanging wall of the ore horizon. This corresponds to >50% Albite. The rest being quartz, potassium feldspar and minor amounts of carbonate. This albitite is also distinctly enriched in Co. As this facies is now so dominant over the carbonate facies, Na and Co replace Ca, Mn and Sr as the representatives of the carbonate facies in factor 1b with a strong negative saturation. We interpret the albitite as an excellent example of an evaporite facies. The ratio Na_2O/K_2O is 2.4. On a microscopic scale, detrital textures are rare in this section, the albite being authigenic.

Factor 2b: is very similar to factor 2a except for V and P, which show a somewhat lower saturation in factor 2b, and Na, which now no longer influence this factor because of the true albitite facies being above the ore horizon.

Factor 3b: instead of the factor 1b, factor 3b is now saturated with Ca and Mn the elements of the carbonate facies.

Factor 4b is probably of no significance, being only saturated with V.

Factor 5b disappeared, Ni being represented in factor 1b.

SUMMARY OF RESULTS

The factor analysis indicates the environment of sedimentation and metal fixation in the vicinity of DDH-135 is directly opposite to the environment encountered at the locality of DDH-111. In DDH-111 we find a deep euxenic environment with a heavy, Mg and Na enriched brine as a bottom water layer, whereas in DDH-135 an evaporitic, temporarily oxidizing shallow environment was encountered. What both diamond drill holes have in common is the evidence for an isolated environment from the rest of the water body; in the case of DDH 135 because of a barrier between the main lake and a restricted shallow basin, and in the case of DDH-111 because of a heavy brine accumulating at the lake bottom, preventing water circulation.

VARIMAX ROTATED FACTOR MATRIX FOR ORE HORIZON OF DDH-99, 111, 119, 135, 120 CASES

FACTOR:	1p	2p	3p	4p	5p	6p	
ELEMENT							
U	-.20	.83			.20		U
Pb	-.25	.79					Pb
Cu		.22			.59		Cu
Mo		.47					Mo
V		.49			.21	.24	V
Mn	-.91			-.20			Mn
P	.23	.59			-.41		P
Ca	-.93			-.25			Ca
Na	.32			.89			Na
Be	.64	.56					Be
Al	.96			.24			Al
Fe	.42		.71				Fe
Mg	-.31	-.21	.77	-.20	.22		Mg
Ti	.95			.21			Ti
K	.97						K
Cr	.93	-.25					Cr
Co	.20	.33	.29	.48			Co
Ni			.34	.23			Ni
Sr	-.56		.28		.27	.28	Sr
Th		-.37	-.47			.49	Th
Zr	.77			.47			Zr
Zn							Zn
% of Variation	52.4	20.0	13.1	7.6	3.8	3.0	

TABLE V

FACTOR ANALYSIS ORE HORIZON, DDH-99, -111, -119 AND -135, 120 SAMPLES, TABLE 5

The factor analysis for each hole individually resulted in the characterization of specific environments for each intersection of the ore horizon. The same factor analysis, regrouping the sample intervals of the ore horizon of all four holes together, should summarize the various environments. In fact, most of the information obtained from the individual factor analysis of each hole is still contained in Table 5, but without the knowledge of the above described results from every single hole, a correct interpretation of the data would be very difficult, if not impossible.

In factor 1 for example, we would probably see Mg as part of the carbonate facies, which is incorrect for 3 holes out of 4. On the other hand, factor 2 would fairly well reproduce the average element association of the ore horizon and factor 3 would well reproduce the Fe-Mg-Ni association of the basic source rock assemblage, even though this association is not represented completely in each hole. The factor 4, reflecting the association Na-Co, was represented on the right side of Table 3 and 4 (DDH-119 and -135), where it stood for the evaporitic environment. This association was not produced in DDH-99 and -111, where on the contrary we encountered a deeper environment with a tendency towards euxenic conditions in DDH-99 and completely euxenic conditions in DDH-111. Factor 5 expresses the bimodality between a more reducing environment with preservation of organic material and a less reducing environment sufficient for Cu-precipitation, but not sufficiently reducing for preservation of organic material. This factor was best developed in the intersection of DDH-111. Factor 6 essentially tells us, that Th does not fit into any of the previously described environments. Further interpretation is impossible because Th is the only element of a significant saturation within this factor. On the other hand, no more information for Th is available from the Tables 1, 2, 3 and 4, because no specific pattern for Th is developed there either..

DISCUSSION OF RESULTS

The geological interpretation of an area encompassing several Km^2 of stratabound uranium mineralization at Gayot Lake, resulted in the development of a syngenetic to early diagenetic model for the uranium concentration in the sediments.

The factor analysis was very useful in establishing a more detailed picture of the factors controlling the sedimentary environment during ore metal entrapment in the ore horizon.

The factor analysis enhanced local difference in the depositional environment at various depths below lake level, implying differences in the distance from the lake shore.

At the time the geological interpretation was done, we were aware neither of the evaporite intersected in DDH-135 nor of the dolomitization encountered in DDH-111. These findings are thus exclusively due to the factor analysis, and if further exploration drilling should be done in the area at some time in the future, recognition of these two facies might be a powerful tool in outlining the favourable area for mineralization.

The factor analysis defined the ore horizon as a fine grained facies with very low sedimentation rates, high carbonate contents, deposited during a time of evaporation in the vicinity of the oxy-redox boundary of a stratified lake. High P contents attest to the role of decomposition of organic material in order to maintain reducing conditions within the lake bottom mud and the association with Be is indicative of the fine grained nature of the sediments. These characteristics form part of the definition of the gyttja facies. The ore horizon with its high contents of entrapped metals is thus clearly defined as a metallotect. Consequently, no doubt remains as to the syngenetic to very early diagenetic nature of the mineralization.

SUMMARY AND CONCLUSION

The geological and genetical aspects of the Gayot Lake uranium deposit have been discussed. The interplay of tectonics, rate of sedimentation, climatic conditions, oxy-redox potential of the depositional environment, depth of deposition, distance from the shoreline, availability of uranium and the paleotopography of the basin bottoms resulted in the accumulation and entrapment of uranium within a carbonate rich, fine grained stratigraphically well defined horizon in gyttja facies, where reducing conditions prevailed below the sediment - lake water interface and slightly oxidizing conditions prevailed above this interface.

The mathematical factor analysis was very helpful in defining this environment and its local variations. The interpretation of the data delivered by the factor analysis does not require a profound understanding of the mathematical background, and thus the factor analysis can be a powerful instrument for the exploration geologist who does not want to be too deeply involved in complicated mathematics.

The Gayot Lake uranium deposit is the first known syngenetic stratabound uranium accumulation of possible ecnomic importance within non-metamorphic Precambrian sediments. The same or similar processes which led to uranium enrichment in younger sediments in other parts of the world were already active in Precambrian (Aphebian) times. Non-metamorphic as well as metamorphic Aphebian sediments should therefore be considered as a possible source for future uranium supply. An additional aspect of the Gayot Lake uranium discovery is that the unconformity-type deposits of northern Saskatchewan and Northern Australia could now more easily be explained by the Aphebian protore hypothesis, since syngenetic U-enrichment in Aphebian sediments can be quite substantial.

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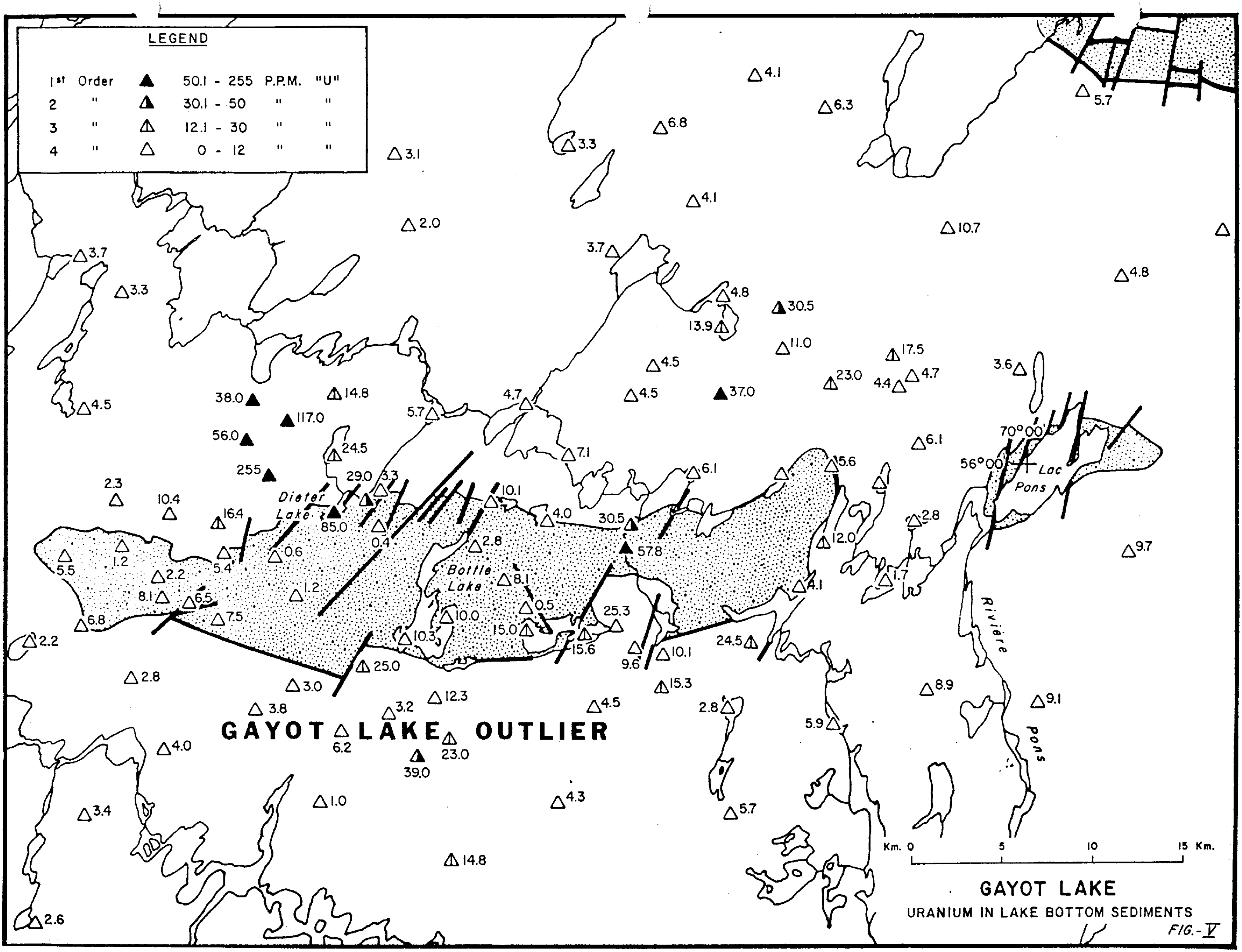
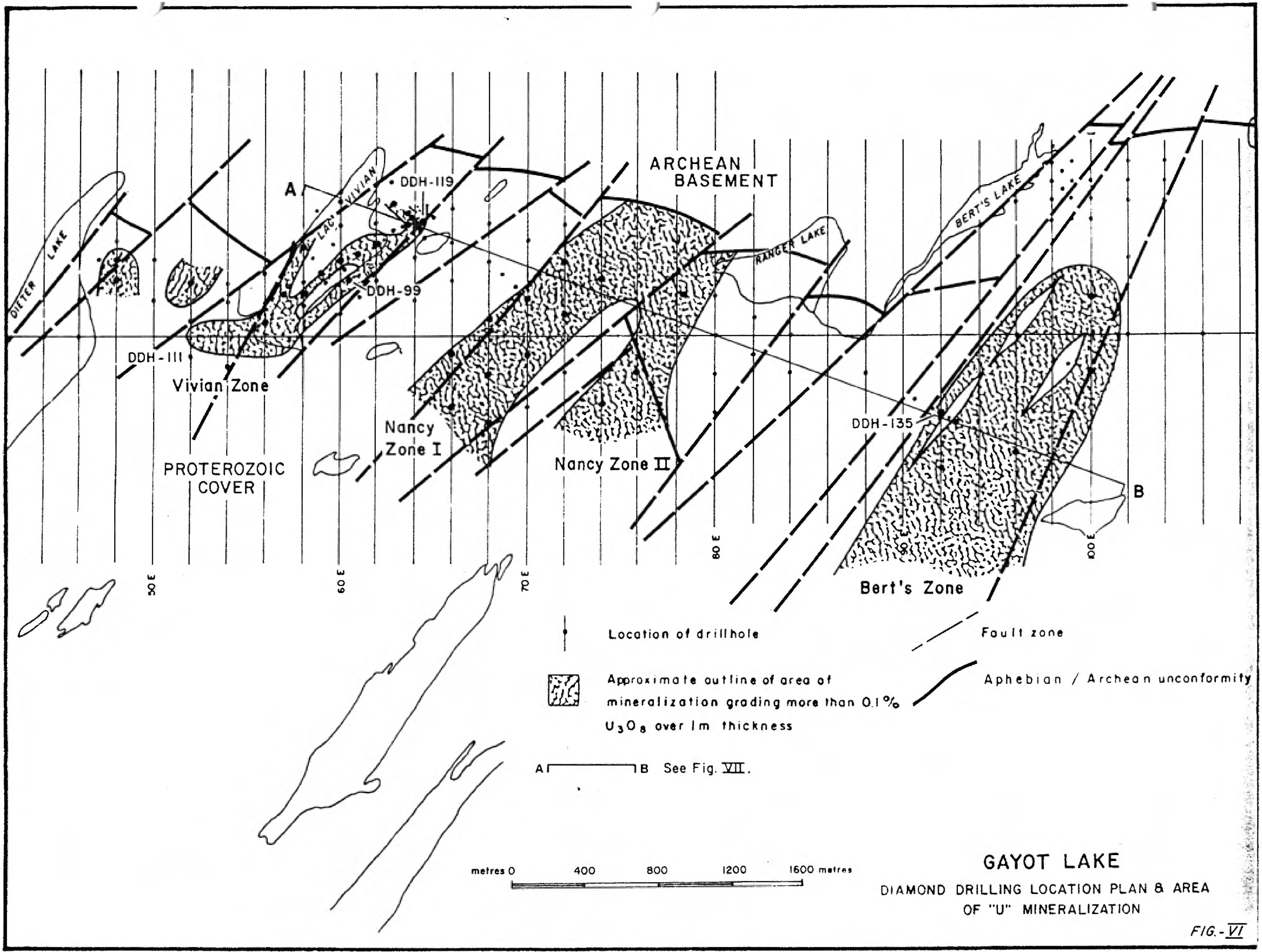


GAYOT LAKE

URANIUM IN LAKE BOTTOM SEDIMENTS

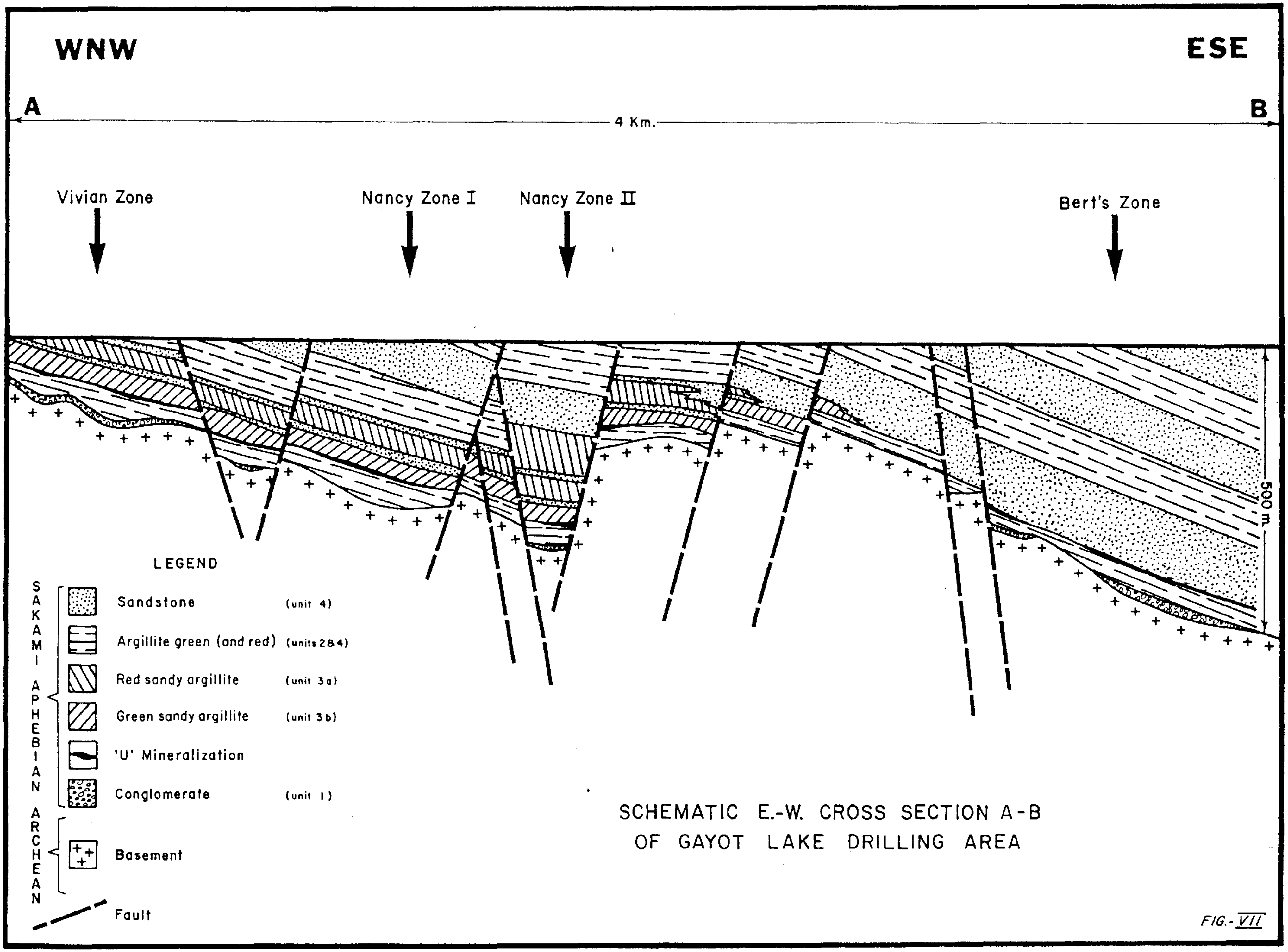
FIG.-V



GAYOT LAKE

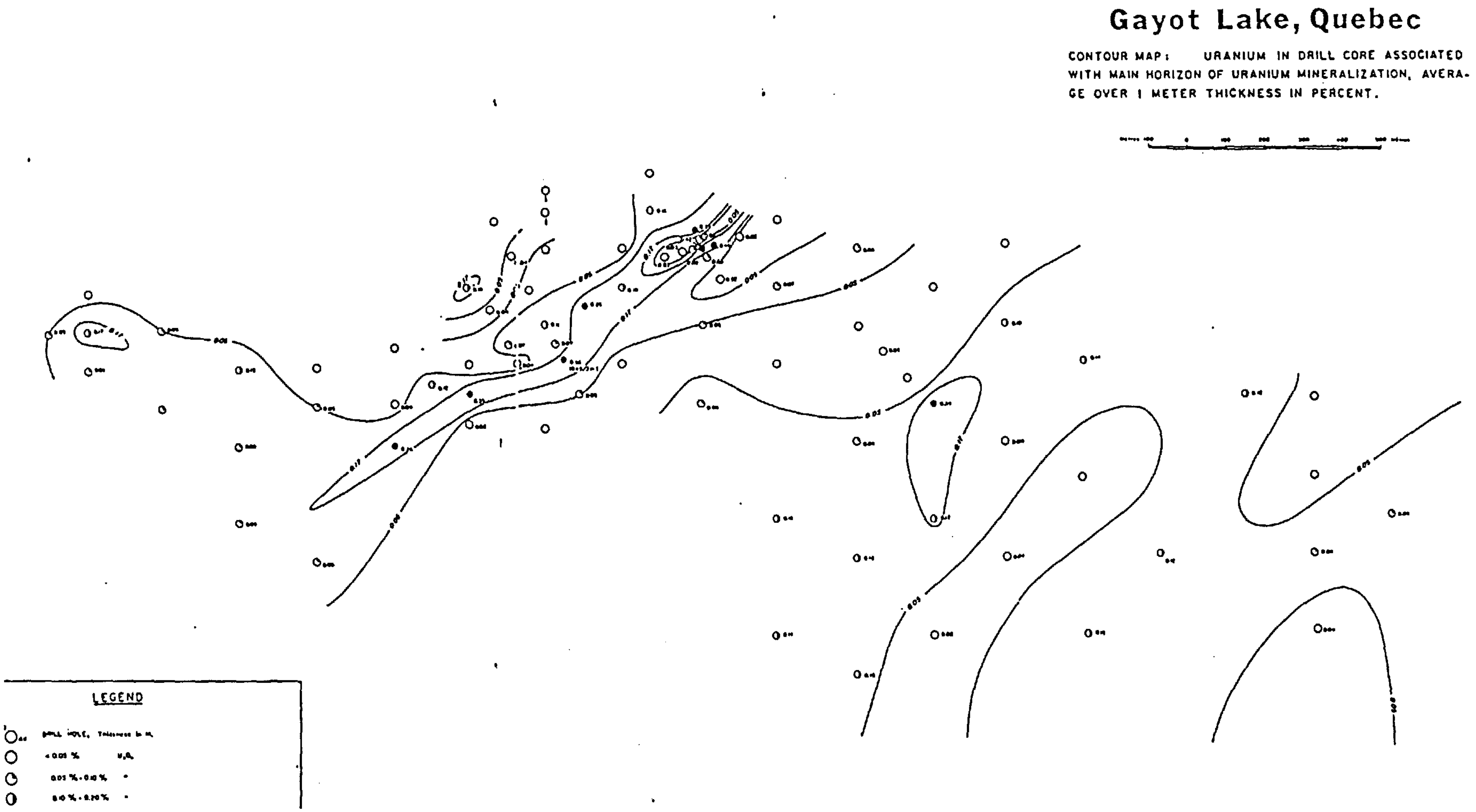
DIAMOND DRILLING LOCATION PLAN & AREA OF "U" MINERALIZATION

FIG.-VI



SCHEMATIC E.-W. CROSS SECTION A-B OF GAYOT LAKE DRILLING AREA

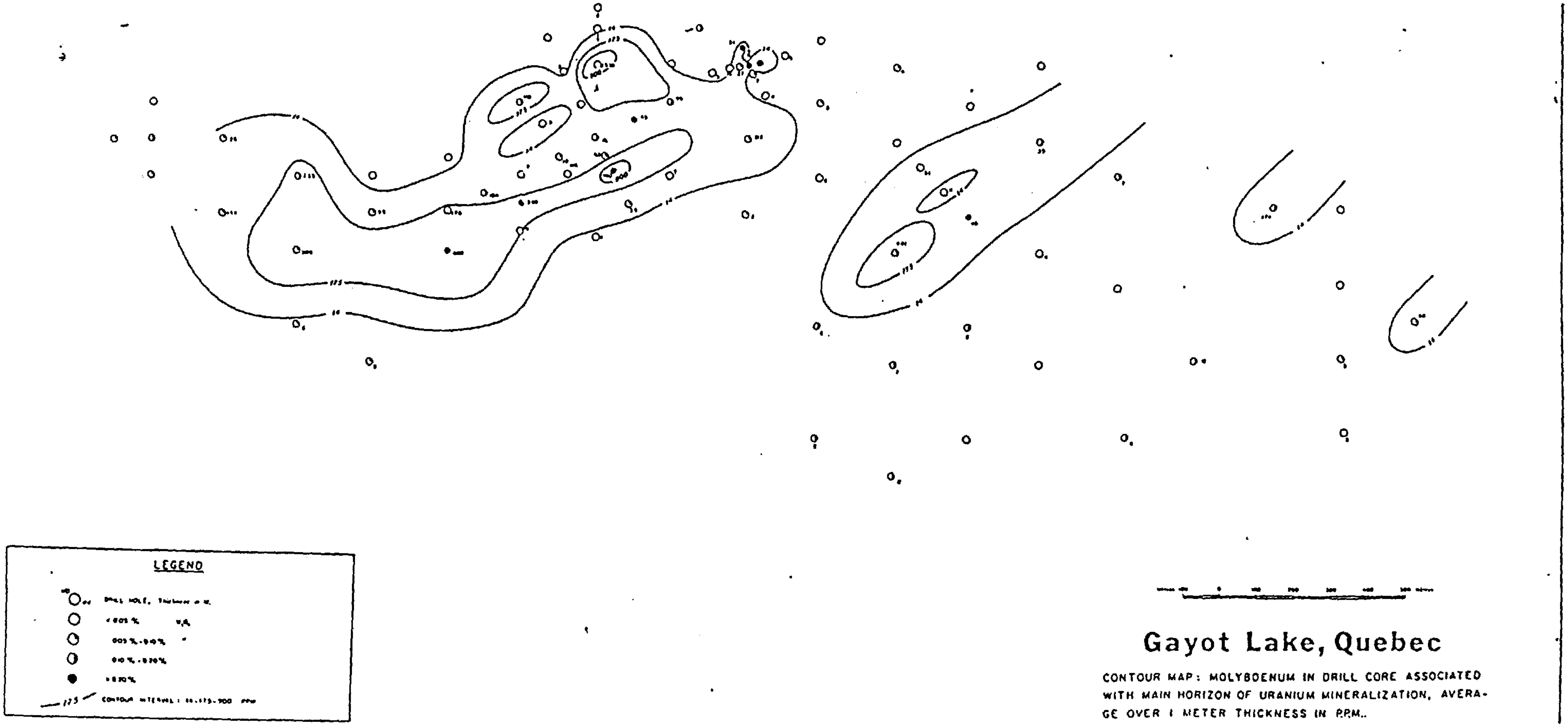
FIG.-VII



Gayot Lake, Quebec

CONTOUR MAP: URANIUM IN DRILL CORE ASSOCIATED WITH MAIN HORIZON OF URANIUM MINERALIZATION, AVERAGE OVER 1 METER THICKNESS IN PERCENT.

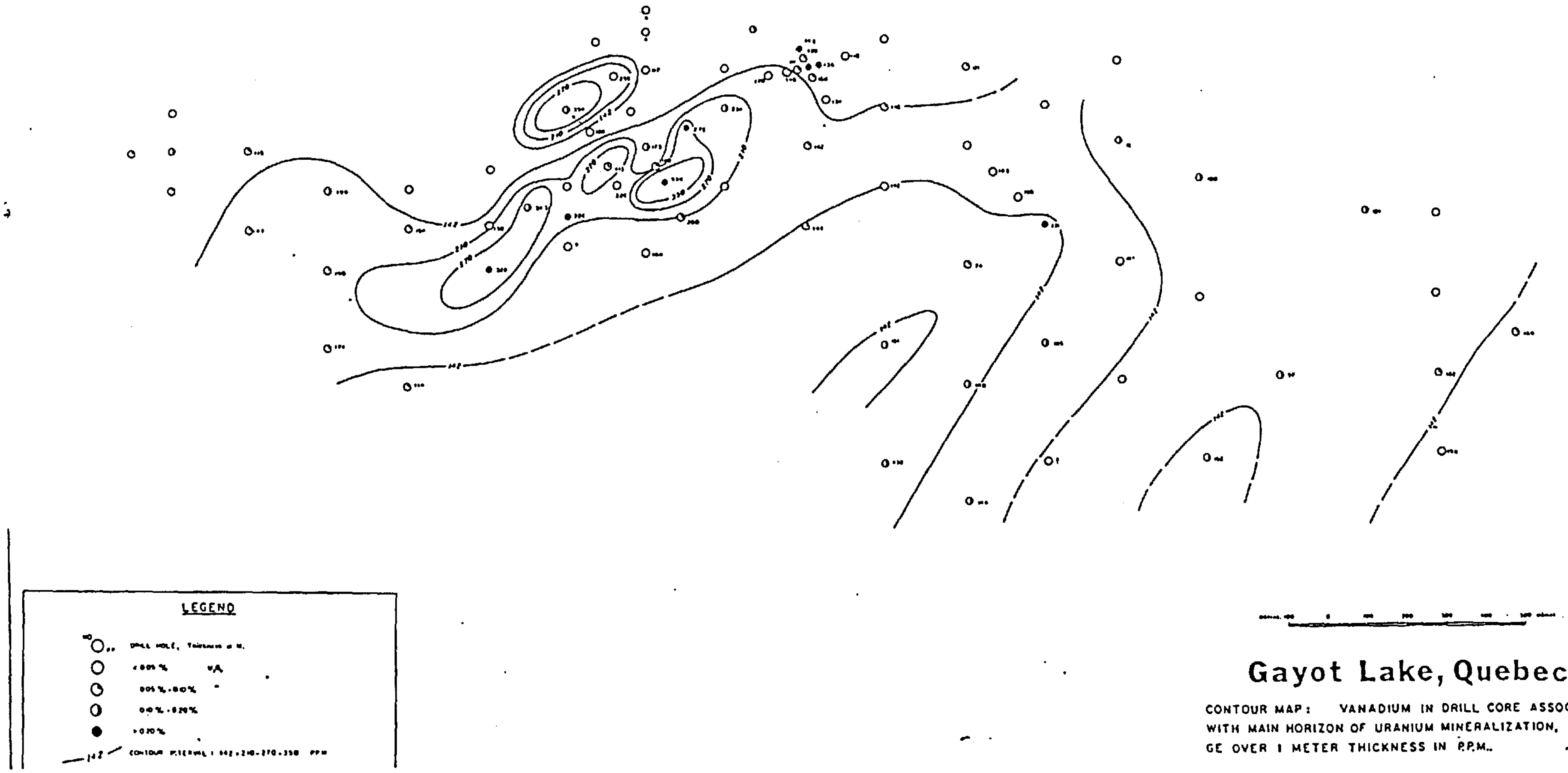
FIGURE VIII



Gayot Lake, Quebec

CONTOUR MAP: MOLYBDENUM IN DRILL CORE ASSOCIATED WITH MAIN HORIZON OF URANIUM MINERALIZATION, AVERAGE OVER 1 METER THICKNESS IN PPM.

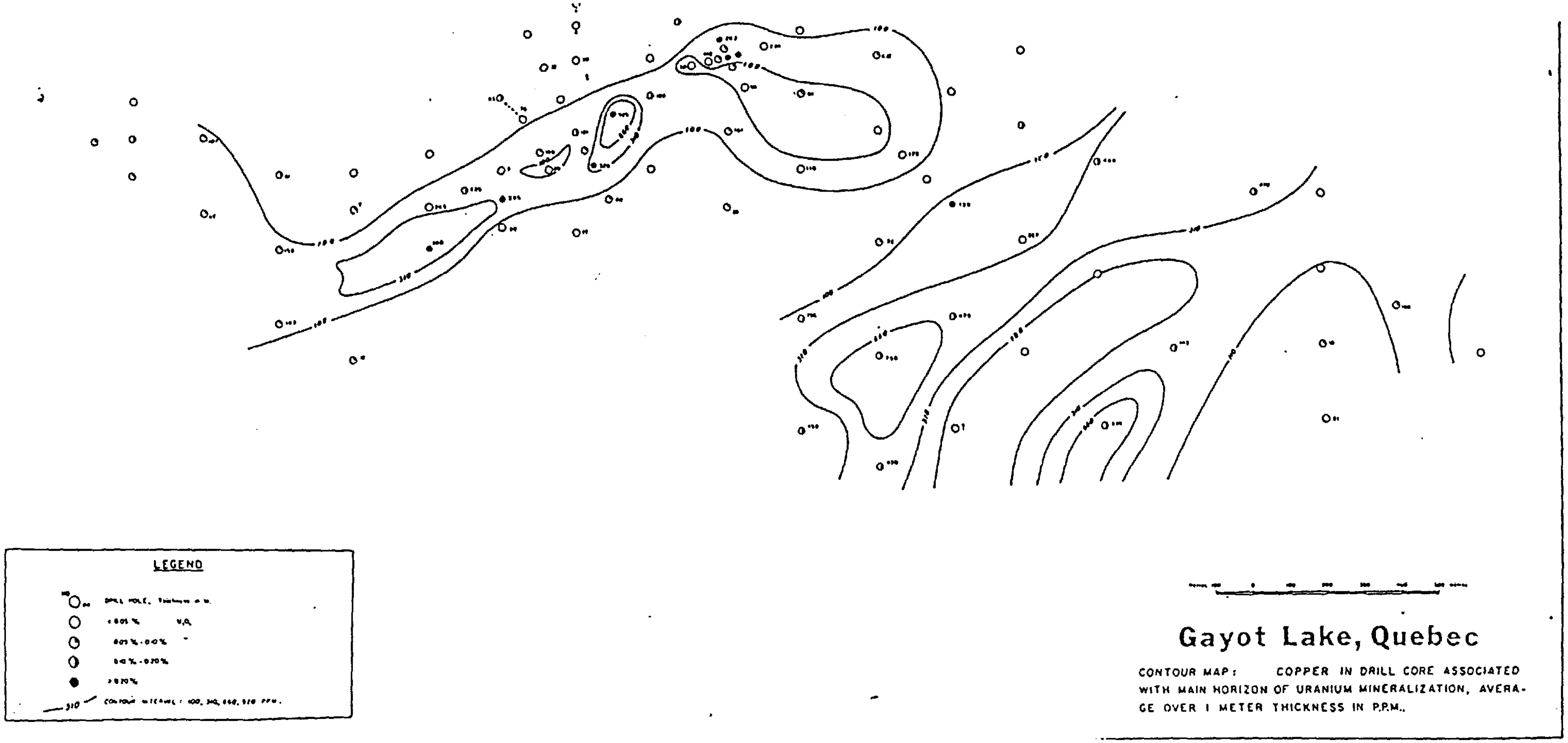
FIGURE IX



Gayot Lake, Quebec

CONTOUR MAP: VANADIUM IN DRILL CORE ASSOCIATED WITH MAIN HORIZON OF URANIUM MINERALIZATION, AVERAGE OVER 1 METER THICKNESS IN P.P.M..

FIGURE X



Gayot Lake, Quebec

CONTOUR MAP: COPPER IN DRILL CORE ASSOCIATED WITH MAIN HORIZON OF URANIUM MINERALIZATION, AVERAGE OVER 1 METER THICKNESS IN P.P.M..

FIGURE XI

FIGURE 1

FIGURE 2

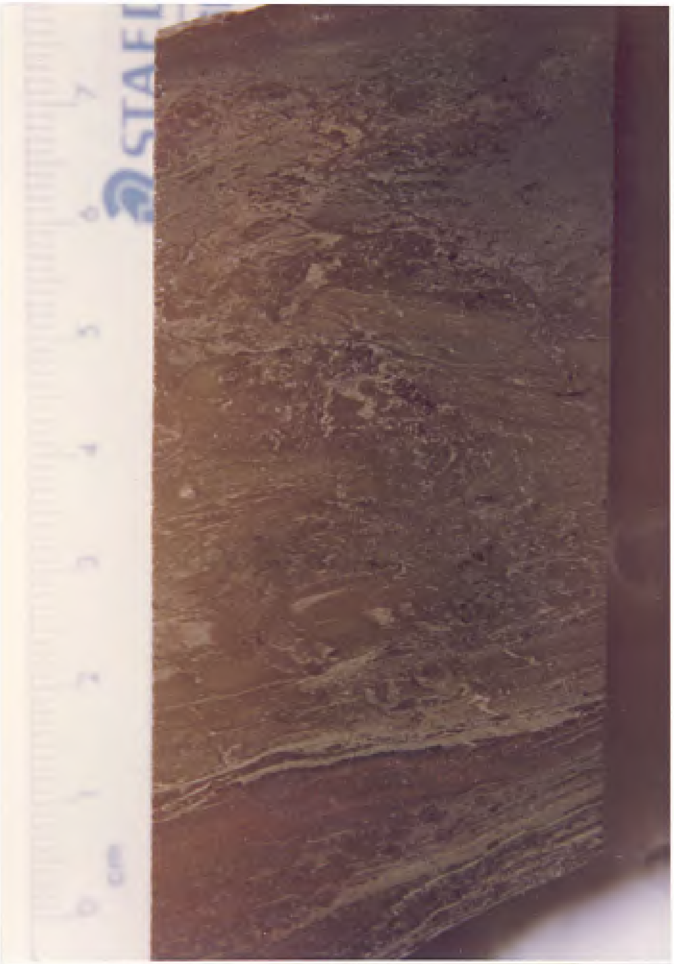


FIGURE 3

FIGURE 4

PLATE I

FIGURE 5

PLATE I, DDH 99: SEDIMENTARY STRUCTURE WITHIN AND JUST BELOW THE ORE HORIZON

Figure 1: Depth: 126.7 m. Slightly mineralized (1000 ppm U_3O_8) siltstone from centre of ore horizon with penecontemporaneous deformation.

Figure 2: Depth: 126.8 m. Well mineralized (6500 ppm U_3O_8) calcareous mudstone in gyttja facies. Internal features reveal paracontemporaneous alteration and deformation. The calcite vein contains pitchblende and is a diagenetic feature. At the very bottom calcite pisoliths have developed.

Figure 3: Depth: 126.9 m. Well mineralized (6000 ppm U_3O_8) calcareous mudstone in gyttja facies (similar to Figure 2).

Figure 4: Depth: 127.1 m. Well mineralized (7000 ppm U_3O_8) limestone.

Figure 5: Depth 127.7 m. Slightly mineralized (850 ppm U_3O_8) pisolitic (calcite) mudstone.

FIGURE 1

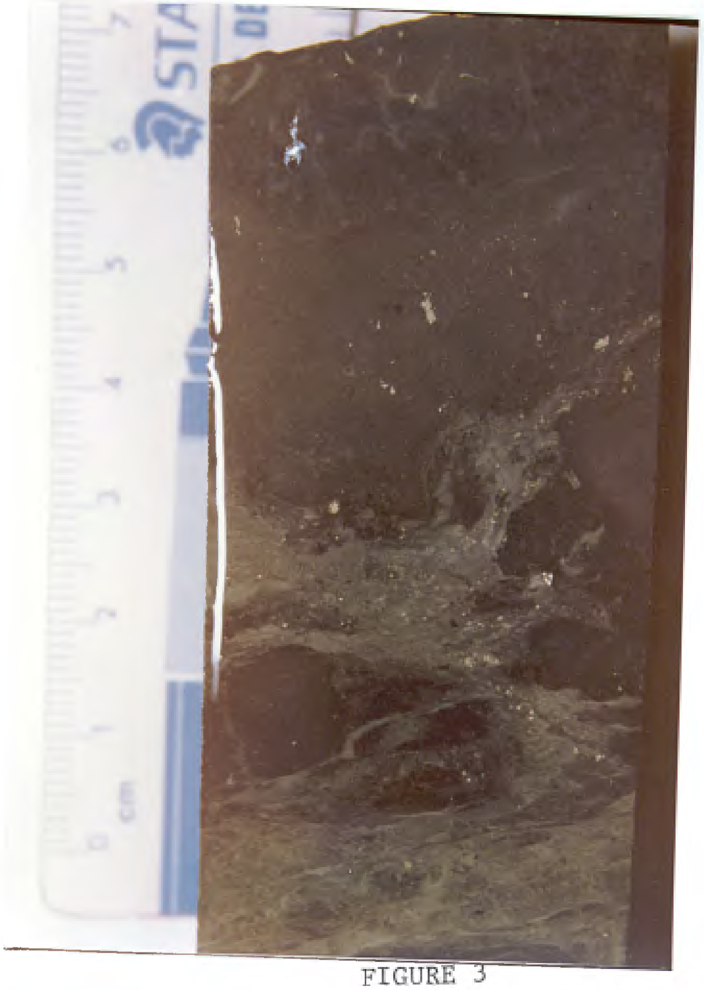


FIGURE 3

FIGURE 2

FIGURE 4

PLATE II

PLATE II, DDH 119 AND 111: SEDIMENTARY STRUCTURES IN VICINITY OF THE ORE HORIZON

Figure 1:	DDH 119, depth: 55.2 m. Non-mineralized limestone, bed above ore horizon. Partly pisolitic.
Figure 2:	DDH 119, depth: 55.8 m. Very well mineralized (32000 ppm U_3O_8) calcareous mudstone in gyttja facies. Penecontemporaneous alteration and deformation. Fractures are diagenetic and contain pitchblende.
Figure 3:	DDH 111, depth: 198.2 m. Non-mineralized mudstone in sapropelite facies. Penecontemporaneous deformation. Bright spots are sulfides, mainly pyrite.
Figure 4:	DDH 111, depth: 199 m. Slightly mineralized (1350 ppm U_3O_8) in transitional facies in between gyttja and sapropelite. The circular structures may be indications of former organic substance, since this sample yielded one of the highest P_2O_5 values of the drill hole.

FIGURE 1

FIGURE 3

FIGURE 2

FIGURE 4

PLATE III

PLATE III: DDH 135 and 113: SEDIMENTARY STRUCTURES

Figure 1:	DDH 135, depth: 279.9 m. Slightly mineralized (1050 ppm U_3O_8) sequence of siltstone, sandstone, mudstone and limestone showing reworking shortly after sedimentation, probably downslope transport. The red coloration is most probably due to diagenetic oxidation.
Figure 2:	DDH 135, depth: 280 m. Well mineralized (5500 ppm U_3O_8) calcareous very fine grained sandstone to siltstone. Red colour is due to diagenetic oxidation - remnants of pyrite associated with pitchblende are still present.
Figure 3:	DDH 135, depth: 280.8 m. Non-mineralized siltstone just beneath ore horizon with soft sediment deformation. Diagenetic jointing does not penetrate coarser grained siltstone layers and has different angles in different material.
Figure 4:	DDH 113, depth: 250.3 m. This sediment layer can be correlated with that of Figure 3. The core sample is again from just beneath the ore horizon. Soft sediment deformation resulted in irregular fractures with offsets of up to 1 cm.