MANITOBA
DEPARTMENT OF ENERGY AND MINES

HON. DONALD W. CRAIK
Minister

PAUL E. JARVIS
Deputy Minister

MINERAL RESOURCES DIVISION
IAN HAUGH
Executive Director

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HELICOPTER-SCINTILLOMETER AND LAKE-SEDIMENT SURVEYS KASMERE-MUNROE LAKE AREA, NORTHWEST MANITOBA

By
N.M. Soonawala

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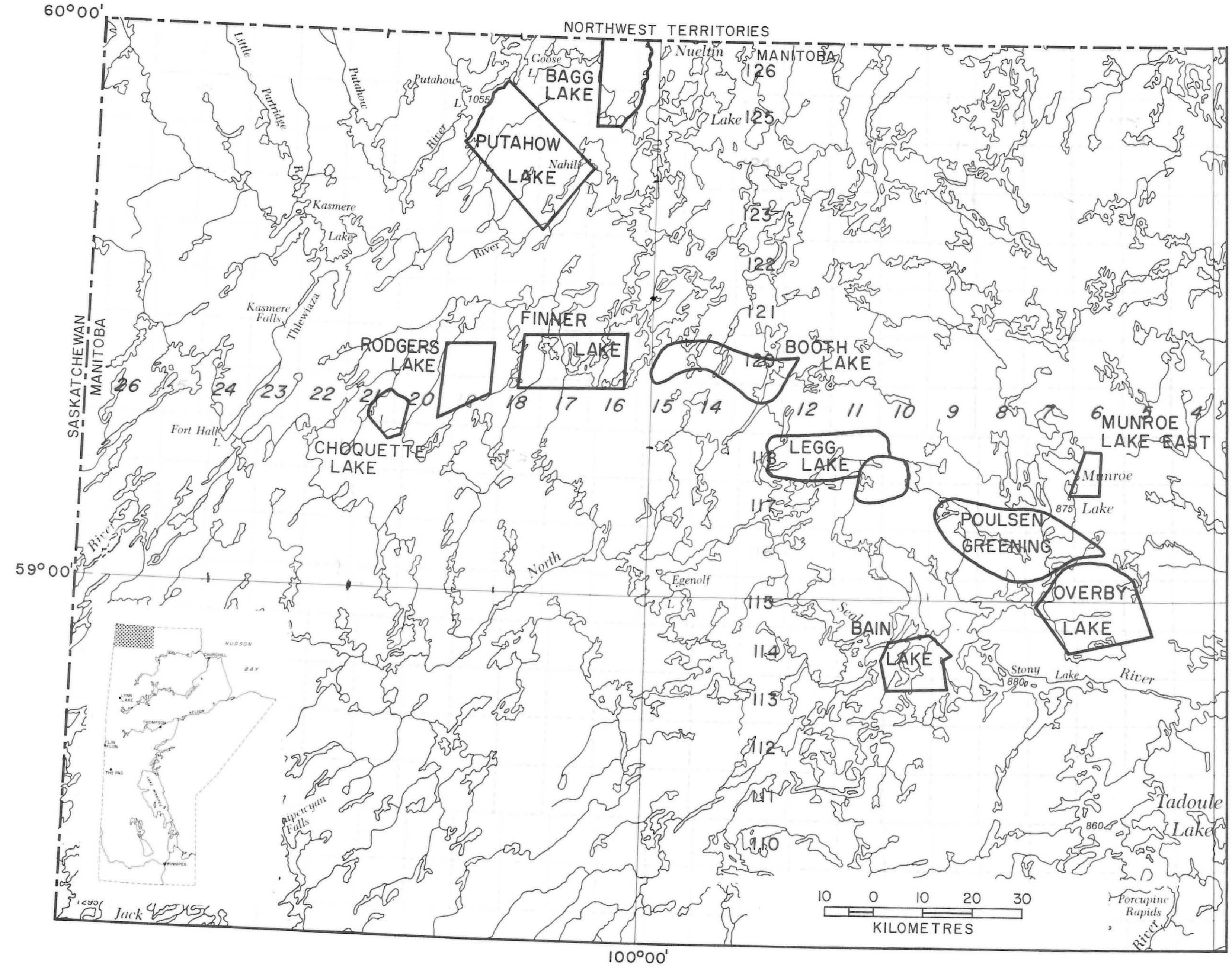


FIGURE 1: Index Map

INTRODUCTION

During the 1976 and 1977 field seasons helicopter-borne scintillometer and lake-sediment uranium surveys were implemented over parts of the Kasmere Lake and Munroe Lake map sheets (NTS areas 64N and 64 0) which are bounded by latitudes 58° N and 60° N, and longitudes 100° W and 102° W. In the eastern part of this area there was a limited overlap into the Tadoule Lake area (NTS 64J), and about five percent of the work described in this report has been done in that area. 5 685 line kilometres of helicopter-borne scintillometer surveys were implemented over eleven areas totalling 1 640 km². 591 lakes were sampled over eight different areas (a total of 1 440 km²) which were more or less coincident with the areas surveyed by the helicopter-borne scintillometer (refer to Figure 1 and Table 1). Access to the area was by float plane from Lynn Lake, about 380 km to the south. The area is totally uninhabited, the nearest settlements being Brochet, Churchill and Lynn Lake.

The surveys were implemented under the auspices of the Canada-Manitoba Subsidiary Agreement on Mineral Exploration and Development which was a part of the General Development Agreement, and were cost shared equally by the Governments of Manitoba and Canada. Overall monitoring of the Project was the responsibility of a Management Committee, with both Federal and Provincial representation, but the field operations were managed by Provincial personnel.

ACKNOWLEDGEMENTS

The work described in this report was carried out under the direction of J.F. Stephenson. The field supervision was the responsibility of R.A. Whitworth and R.J. Garber, both of whom also made major contributions to the geological aspects of this report. G.C. Sharpe and numerous seasonal employees helped in all aspects of the work.

Much of the helicopter flying was done with great expertise by the late Dan Renny.

The geochemical analyses were the responsibility of J. Gregorchuk; and J. Macek identified several minerals.

W.D. McRitchie edited, and generally polished, the several successive manuscripts with great care.

THE EXPLORATION SEQUENCE

The purpose of the operation can be described as follows. The results of regional airborne gamma-spectrometer and lake-sediment surveys, along with 1:250 000 — scale geological maps were used as the initial data-base, to delineate areas likely to contain uranium mineralization; the ultimate objective being to locate such mineralization. This called for a process which would successively reduce the area of investigation from tens of thousands of square kilometres to drill targets. Figure 2 illustrates a suitable exploration sequence consisting of the following four tiers: regional, follow-up regional, site-specific and detailed sampling surveys, followed by drilling and gamma logging. The follow-up regional stage for the Kasmere-Munroe area is the subject of this report.

REGIONAL SURVEYS:

The regional geophysical and geochemical surveys in the Kasmere-Munroe area were implemented in 1975 as a part of the Federal/Provincial Uranium Reconnaissance Program (URP). The survey unit comprised individual 1:250 000 NTS sheets, i.e., an area of about 13 000 km². The investigations entailed a high-sensitivity aerial gamma-ray spectrometer survey at 5 km line spacing, and lake-sediment geochemistry at a density of one sample per thirteen square kilometres. Parameters, such as these provide rapid coverage at low cost per square kilometre surveyed, but are fraught with several limitations.

The gamma-spectrometer survey altitude of 120 m results in a single digital measurement on the record for a sample area of approximately 350 m by 500 m on the ground (Allan and Richardson, 1974). Features of economic interest would be only a small fraction of this area e.g., a mineralized zone 200 m by 1 m is about a thousand times smaller. Consequently, the contribution of such a mineralized zone to the aerial spectrometer trace is diluted drastically by the contribution of the non-mineralized area. On the other hand, features of dimensions comparable to or larger than 350 m by 500 m would produce the most prominent signals. However, anomalously radioactive features of this size, such as granitic bodies, are seldom of direct economic interest.

Another limitation of the technique is that due to the wide line spacing, only a small fraction of the survey area is actually sampled. The survey lines are 5 km apart, but it has been estimated that this system samples a strip of ground with an approximate width of 350 m centered under the survey aircraft; therefore only 7% of the survey area is sampled. Generally, if the line spacing of an airborne scintillometer survey is less than the expected strike length of the target sought, and if the flight direction is perpendicular to the expected strike, there is a theoretical 100% probability of detecting the target. The probability thereafter decreases with increasing line spacing. Therefore it can be concluded that regional surveys, i.e., the top tier of Figure 2, can be usefully employed to define areas of the order of a few hundred square kilometres, but greater precision should not be expected. Thus they are unsuitable for locating targets for ground surveys, and for that purpose follow-up regional surveys should be implemented over the areas defined by the regional surveys.

FOLLOW-UP REGIONAL SURVEYS:

The regional surveys are used to delineate smaller areas (~ 100 km²) in which an intensification of coverage appears warranted. These areas become the focus of the helicopter-scintillometer "follow-up regional surveys" in which the basic line interval of 250 m ensures that mineralized features of that strike length or greater, are detected. The accompanying lake-sediment surveys at an average density of one sample per three km² are also suited for targets of similar dimensions. Results from the follow-up surveys are precise enough to define ground follow-up targets in the order of one square kilometre. It should be recalled that this discussion applies only to exposed uranium mineralization, as a few centimetres of overburden is sufficient to shield all natural gamma radiation.

The main results of the helicopter-scintillometer surveys were available a few hours after the termination of each flight, the radium lake-sediment results were ready four days after the lakes were sampled and the lake sediment uranium results were obtained within a couple of weeks.

The decision to provide a rapid turn-around between data acquisition and release, to facilitate immediate ground follow-up, restricted the sophistication of the surveys. For example, the helicopter-scintillometer was operated in the broad-band mode precluding radioelement discrimination, and the lake sediments were not sampled for their organic content (see Methods and Procedures). However these shortcomings were more than offset by the advantages of being able to mount an immediate follow-up on the ground, a process which in any case, supplied all the additional data which would have been obtained if more sophisticated methods had been initially used for the follow-up regional surveys.

In the case of the helicopter-scintillometer surveys, a complication was introduced by the presence of extensive boulder fields in the Kasmere-Munroe area, a legacy of the now-departed glaciers. Boulders, because of their large surface area, and because they are usually stripped clean of overburden, are strong sources of gamma radiation, which swamps the gamma signal from outcrops of comparable areas. Thus in the survey area helicopter-scintillometer anomalies were almost invariably caused by boulder fields. However, it was soon determined that most of the boulders were of local derivation and reflected the make-up of the sub-outcrop, and thus could be used as useful indicators of mineralization.

Additional lake-sediment surveys of the 'follow-up regional' nature were also implemented in the 1977 field season, their objective being to locate anomalous concentrations of base metals. These results will be published separately.

REGIONAL GEOLOGY

The rocks of the Kasmere-Munroe-Tadoule area are Precambrian in age and form part of the Churchill structural province of the Canadian Shield. Weber et al. (1975) and Schledewitz (1976) provide the most recent and comprehensive accounts of the geology of this region. Figure 3 is a simplified geological map based on their data. The oldest unit comprises Archean foliated granitoid bodies, which have been referred to as basement. They range in composition from quartz diorite to alaskite-granite, some containing hypersthene. The Archean age of these rocks has been determined by the Rb-Sr whole rock isochron method (Weber et al, 1975a). A sequence of Aphebian rocks unconformably overlies the Archean rocks. This supracrustal sequence consists of metasediments and derived migmatites and paragneisses. In the southern part of the Kasmere area (64N), these rocks form an extension of the Wollaston Fold Belt, and to the north, they are contiguous with the Hurwitz group. The Aphebian metasedimentary rocks comprise pelitic, psammitic, rudaceous and calcareous strata suggesting geosynclinal, platform and continental sedimentation. The Aphebian age has been determined on the basis of stratigraphic considerations and Rb-Sr whole rock isochron data for a pelitic biotite gneiss from the sequence. A white anatectic granite from within the Aphebian sequence is thought to result from partial anatexis of the pelitic biotite gneisses. It commonly hosts low-grade uranium mineralization and has been found to be responsible for several regional airborne gamma-ray spectrometer anomalies.

Massive homogeneous Hudsonian intrusive granites are a prominent feature of the geology. Some are fluorite bearing and have been referred to as Nueltin Lake granites.

The fifth unit on Figure 3 is a grey granodioritic gneiss which strikes northeast across the northwestern part of the area. The gneiss is of uncertain origin, the massive phases suggesting an igneous derivation, whereas the well foliated weakly layered portions may be paragneisses.

Further details regarding the geology of the Kasmere-Munroe-Tadoule area may be obtained from Weber et al. (1975b) and Schledewitz (1976).

NOTES ON URANIUM GEOLOGY

The survey area has historically been considered attractive for uranium mineralization. The following five environments for possible uranium concentration have been identified by Stewart (1977):

- unconformities between Archean granitoids and adjacent Aphebian metasediments;
- unconformities between metasedimentary units;
- certain metasedimentary horizons, particularly calc-silicate-rich layers;
- anatectic leucocratic granite derived by partial anatexis of metasediments and;
- faults, structural traps, shear zones, graphite and sulphide zones and other alteration zones.

Unconformities have been considered highly significant for uranium exploration where the genetic model calls for the transport of uranium in ground waters from 'source' or 'fertile' rocks to a geochemical barrier where the dissolved uranium is precipitated in economically significant amounts. In such a model, the unconformity provides a channel for the transport of the solutions, together with local reducing geochemical environments for the deposition of the metal. In the survey area the Archean or Hudsonian granitoids could well constitute the source rocks, and the Archean-Aphebian unconformity the other essential component of the model. Layers containing graphite, carbonate or sulphides, or fault planes along certain horizons in the metasediments can provide the reducing environments for uranium deposition. The unconformities (or disconformities) within the metasediments as shown by Weber et al. (1975b, Table 1) could also be significant, provided there was depositional hiatus and the formation of a regolith. The postulated unconformity between the Daly Lake Group and the Hurwitz group may be of interest in this respect.

The Aphebian age (2.0 — 1.6 Ga) of the metasediments corresponds to one of the four distinct intervals identified by Robertson and Tilsley (1977) as being favourable for the formation of uranium deposits.

Perhaps the most spectacular example of unconformity type deposits is the series of major uranium deposits along the rim of the Athabasca sandstone in Saskatchewan. However, all these deposits are confined to a unique situation, i.e., the Helikian-Aphebian unconformity and no such situation exists in Manitoba. However in Saskatchewan, (e.g. at Burbidge Lake), several lower grade occurrences have been located in Aphebian calc-silicate rocks very similar to those in Manitoba, and at a great distance from the Aphebian sandstone contact (Munday, 1979).

Another favourable environment for uranium mineralization in the Kasmere-Munroe-Tadoule area is the pegmatite-alaskite-gneiss uranium association described by Nishimori et al. (1977). They list the following eight factors as being diagnostic of such an association:

- a gneissic terrane;
- a Proterozoic age;
- occurrence in mobile belts, e.g. an area affected by the Hudsonian orogeny;
- moderate to high-grade metamorphic terrane;
- injection of uraniferous granites into surrounding country rock to form migmatites;
- variation of composition and texture;
- uraninite as the primary mineral, and
- anatexis of uranium-rich metasediments as the main process responsible for uranium concentration.

Most of these criteria are met with in the survey area.

THE URANIUM RECONNAISSANCE PROGRAM

BACKGROUND

Manitoba participated in the Uranium Reconnaissance Program (URP) from 1975, when the Kasmere-Munroe area was surveyed, to 1979 when the Program was terminated. The URP was a nation-wide program which was first presented at a Provincial Mines Ministers Conference in 1974 (Darnley et al., 1975). Its overall objectives were to indicate those areas where there is the greatest probability of finding new uranium deposits, and to provide nationwide, systematic and consistent data to serve as a basis for uranium resource appraisal. The URP program was funded and administered jointly by the Provincial and Federal Governments but the responsibility for technical management was assigned to the Geological Survey of Canada.

The Program was intended strictly as a reconnaissance program based on the concept that most uranium deposits occur within or on the margins of regions of the crust containing higher than average amounts of uranium. It was designed to identify all areas of primary uranium enrichment. High sensitivity airborne gamma-ray spectrometry, lake sediment geochemistry and sampling of subsurface aquifers were selected as the three main techniques for the Program. In Manitoba surveys of only the first two types were employed.

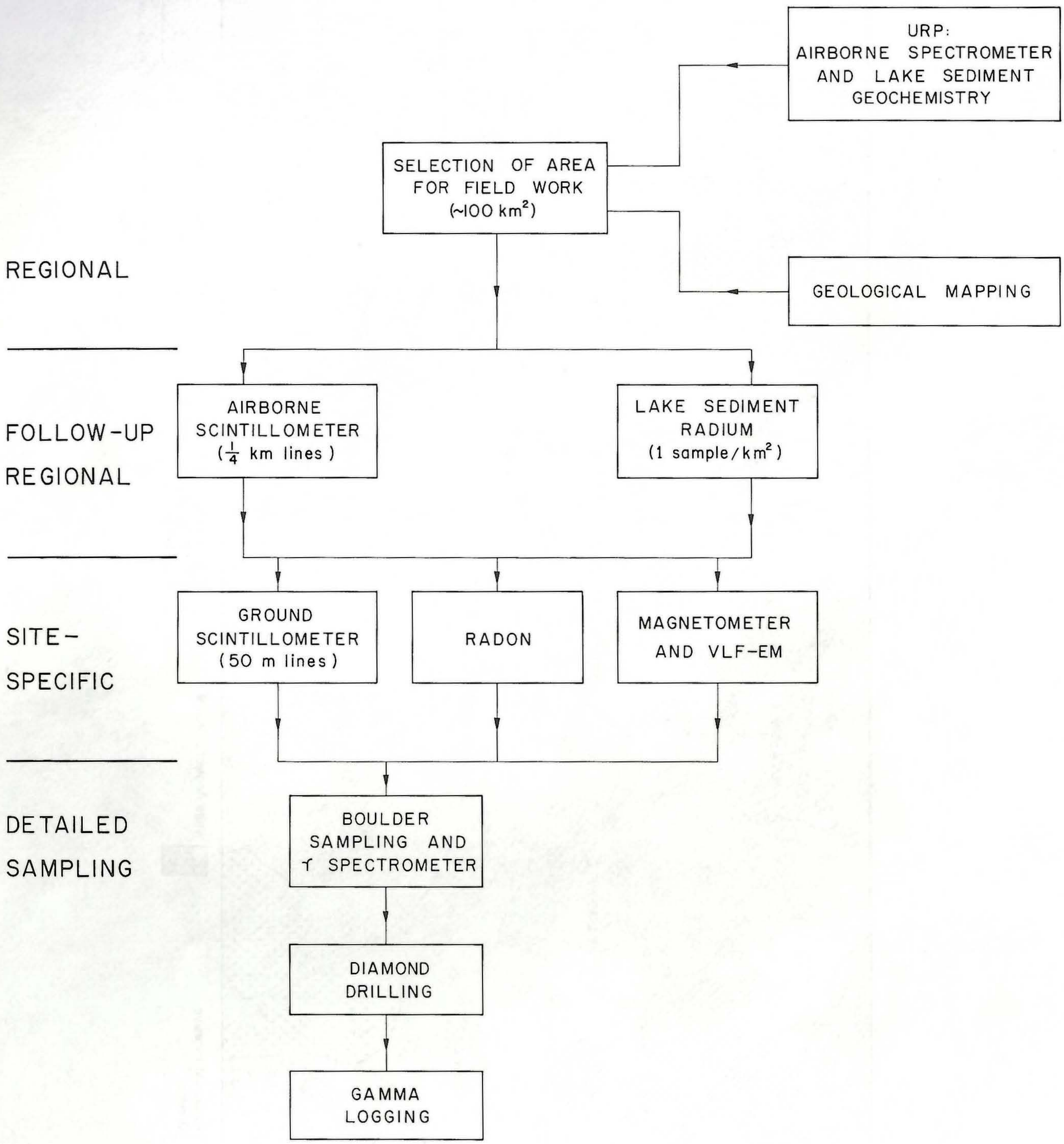


FIGURE 2: The exploration sequence for uranium

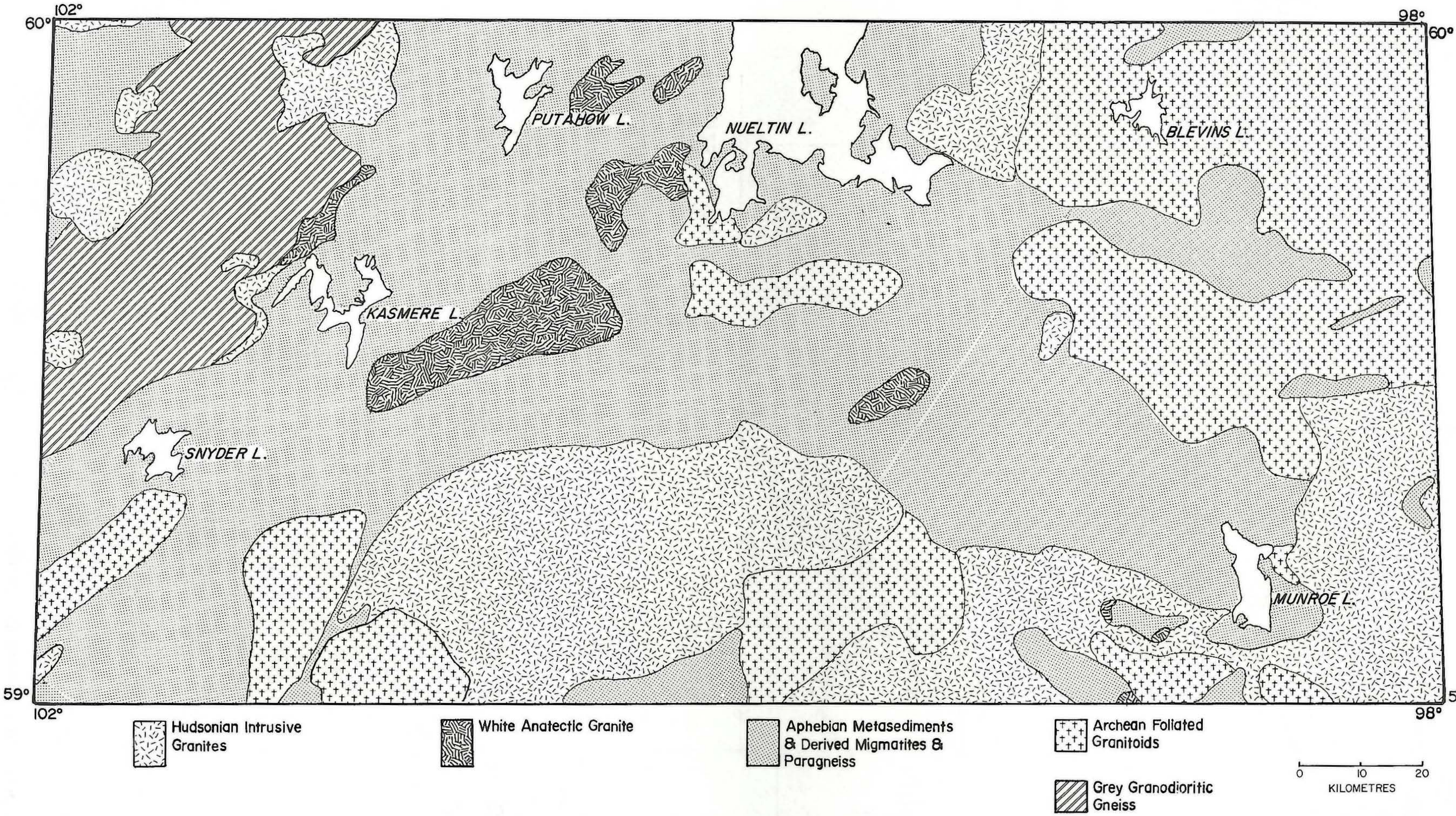


FIGURE 3: Simplified regional geology, Kasmere-Munroe area

The airborne high sensitivity gamma-ray spectrometer used in the survey has been described by Darnley (1972). Fifty litres of thallium-activated sodium iodide are used for gamma detection. The digitized pulses are summed to produce counts in the following four windows: total count, 0.41 — 2.81 MeV; potassium 40, 1.37 — 1.57 MeV; bismuth 214, 1.67 — 1.87 MeV; and thallium 208, 2.41 — 2.81 MeV. The counts from these windows are recorded on digital tape along with the altimeter and navigational data for subsequent computer processing. The survey was flown on a line spacing of 5 km at a speed of about 190 km/hour with a nominal terrain clearance of 120 m and line orientation north-south. Data processing, included corrections for background, deviation from planned altitude and spectral scattering. The gamma flux in every channel, except total count, was converted to equivalent concentrations of the corresponding radioelement. The data, in the form of contour maps and stacked profiles, was presented at a scale of 1:250 000. The following seven parameters were presented in both formats; total count, equivalent uranium, equivalent thorium, potassium, eU/eTh, eU/K and eTh/K. The profiles represent gamma flux gathered over 2.5 seconds for each digitized point for the differentiating channels, and 0.5 second for the total count. The contour maps were based on data points averaged from 17 such counting intervals.

The URP geochemical surveys used organic-rich centre-lake bottom sediments from the deepest parts of suitable lakes. Surface lake waters were also analyzed, but only for uranium. The average density was one sample per 13 km^2. The uranium in waters was determined by fluorimetry. The sediment, after being dried and sieved at minus 80 mesh, was analyzed for U, Zn, Cu, Pb, Ni, Co, Ag, Mn, Fe, Mo, As, Hg and loss on ignition. The uranium content was determined by the delayed neutron activation method. Data were plotted on 1:250 000 scale maps using symbols to represent selected concentration ranges, determined by computer-assisted statistical analysis. The exact element concentrations for every sampling point are available on computer printouts.

RESULTS:

Figure 4 indicates the general pattern of gamma radiation over the Kasmere-Munroe area in the uranium channel, obtained from the URP data. The map shows areas with more than 3 ppm, between 3 ppm and 2 ppm, between 2 ppm and 1.6 ppm and less than 1.6 ppm equivalent uranium. A notable feature on this map is the sharp drop off in radiation to the east of a southwest trending line through Blevins Lake. The zone of high radiation west of this boundary is a general continuation of a similar high in Saskatchewan, in the region between Wollaston and Reindeer Lakes (Richardson and Carson, 1976).

A comparison of Figure 4 with Figure 3 reveals a distinct correlation between the uranium channel gamma radiation intensity and the regional geology. Four main zones, labelled A to D, each corresponding to areas of anomalous radiation, have been outlined on Figure 4. Zone A corresponds to the northeast-southwest trending belt of metasediments which also contains fairly large zones of the anatectic leucogranites. This belt is a part of the Wollaston fold belt which has also been mapped in Saskatchewan (cited by Weber, et al. 1975b). Zone A has some fairly high amplitude anomalies, e.g. in excess of 4 ppm equivalent uranium, and some highly favourable uranium to thorium ratios are also recorded, e.g., the anomaly midway between Snyder and Kasmere Lakes has a ratio in excess of 0.55.

Zones B1 to B5 are widely separated, but all coincide with the Hudsonian intrusive granites. Zone B1 is the largest of these, covering an area of some 1 600 km^2. The other four are smaller.

Zone C on Map 4 coincides with two different types of geological formations. The easternmost anomaly in the zone coincides with anatectic leucogranite, whereas the rest coincide with intrusive granites, similar to those in Zone B.

Zone D coincides with the Archean granites. It may be noted that in this map-area there is a fairly extensive occurrence of the Archean granites; however, the coincidence with anomalous radioactivity is confined only to this relatively small area. A possible explanation for this situation may be that this is the only Archean granite west of the southwest trending line through Blevins Lake, which is here postulated to be a boundary between two major areas of differing regional radioactivity levels.

Zones A to D include the majority of the gamma-ray anomalies in the Kasmere-Munroe area. Two anomalies in the 1.6 to 2 ppm range which are outside these zones are located between zones A and B3. It is interesting to note that one coincides with a showing near Veal Lake where uranium in leucogranites grading up to 10 lbs/ton has been reported (Weber et al., 1975b).

Figure 5 indicates the results of the URP lake sediment survey for uranium in the Kasmere-Munroe area. The population has been partitioned semiarbitrarily at the 20 ppm and 50 ppm levels since the former is the approximate geometric mean for sheet 64N.

The regional correspondence with the spectrometer results (Figure 4) is quite pronounced. A prominent anomalous zone on the geochemical map coincides almost perfectly with anomaly A on the radiometric map. Zones B1, B2, B3, and B5 of the latter are also reflected in Figure 5. It is interesting to note that the geochemical anomaly corresponding to Zone B is more pronounced on the edges of the associated pluton than at its centre, whereas the gamma flux appears to be uniform over the entire pluton. A possible explanation is that the uranium is more mobile at the edge of the pluton than at its centre. Such an effect is not noticeable for the other Hudsonian intrusives in this map area, but that could possibly be due to inadequate and unrepresentative sampling of these areally small bodies. An anomalous area corresponding to Zone C is evident on the geochemistry map. A corresponding anomaly also exists over Zone D, but it is not sufficiently resolved from B1.

The drop-off in uranium concentration to the east of a southwest trending line through Blevins Lake, apparent in the spectrometer map, is also evident in the lake sediment map, though perhaps not to the same extent. This break is confirmed by statistical analysis which indicated that the geometric mean for uranium in lake sediments for the west half (Kasmere Lake sheet) is twice that in the east half (Munroe Lake sheet).

METHODS AND PROCEDURES

Helicopter-borne scintillometer and lake-sediment sampling were the two field techniques employed for the surveys described in this report. A rapid and crude analysis of the data was done in the field, often within hours of the completion of a segment of the survey. A more complete analysis has also been done subsequently, the results of which are presented in the following section of this report.

FIELD METHODS

AIRBORNE SCINTILLOMETER:

A 1.8 litre thallium-activated sodium iodide sensor was employed for the helicopter-borne scintillometer survey. Even though this detector and the associated equipment can be used in the discriminating mode, it was operated solely in the total count

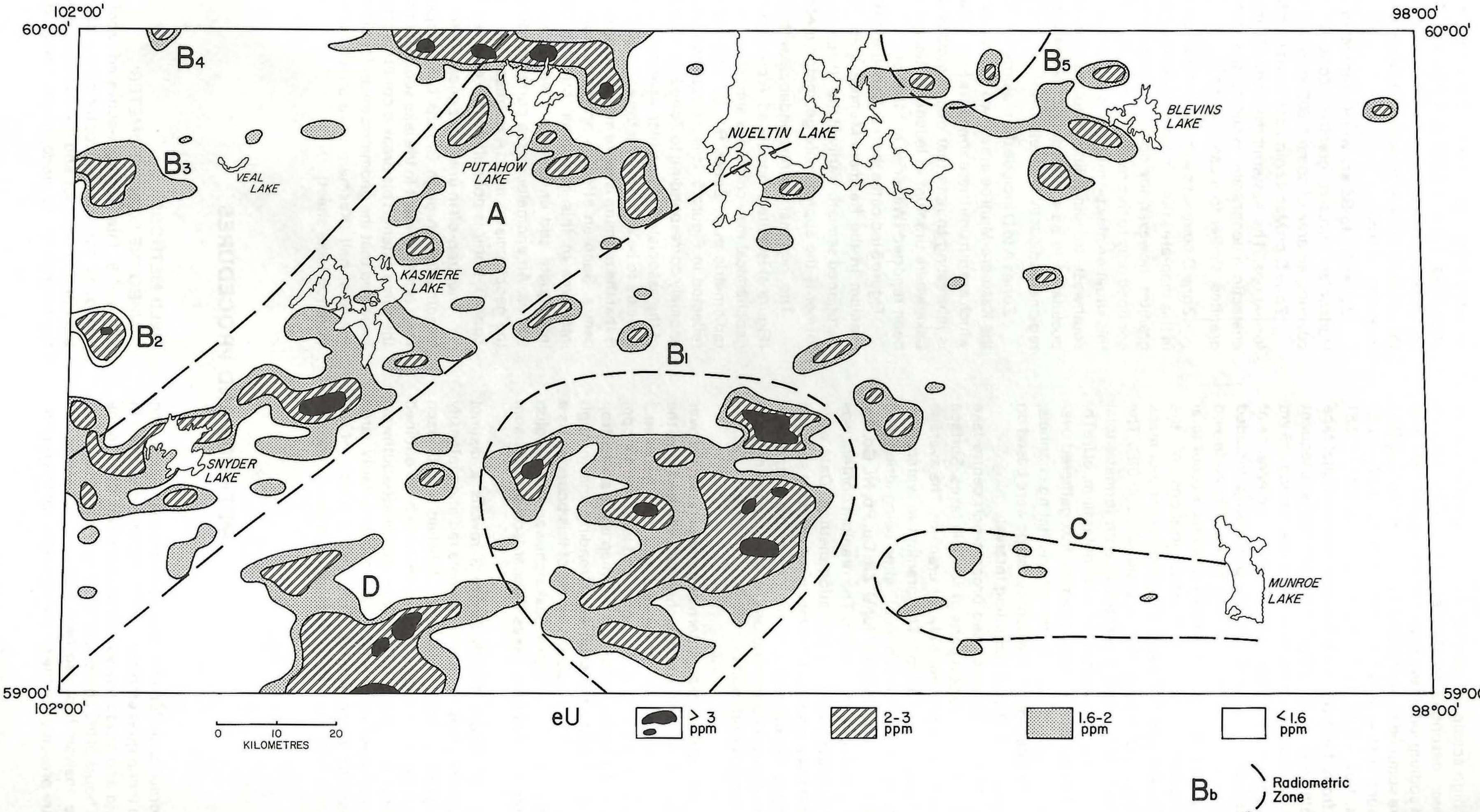


FIGURE 4: Uranium channel airborne gamma-ray spectrometer anomalies — Kasmere-Munroe area

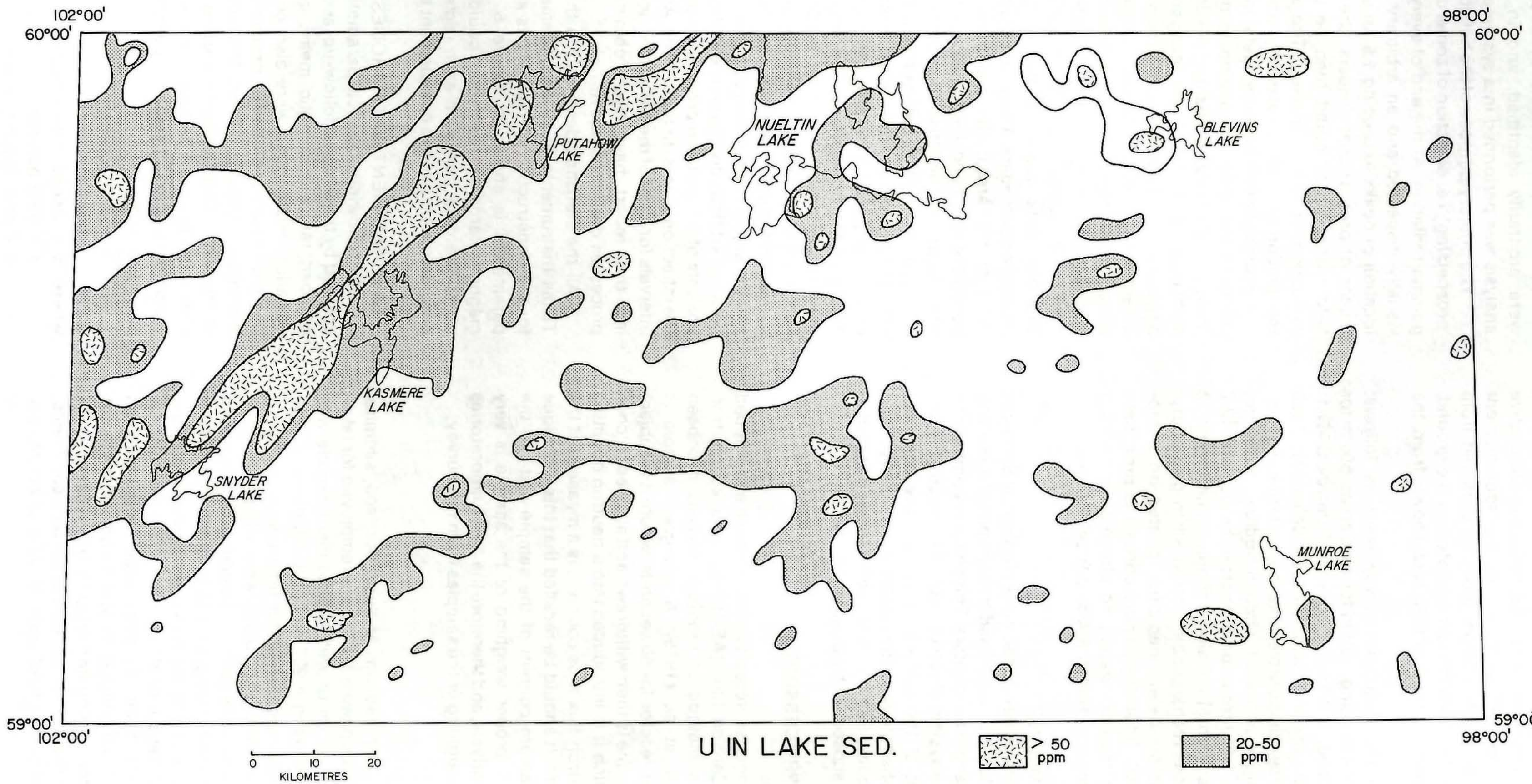


FIGURE 5: URP lake-sediment uranium anomalies, Kasmere-Munroe area

mode, because acceptable counting statistics cannot be obtained in any of the discriminating channels with a sensor of this relatively small size. This limitation was of little concern since the objective of this 'prospecting survey' was the accurate delineation of radioactive zones first outlined by the URP surveys, and not radioelement analysis. However, the latter information could be obtained from selected stations by a digital spectrometer operated on the ground, once the precise location of the anomaly was known from the helicopter-survey results.

The parameters of the helicopter-survey were as follows: nominal altitude, 40 m; line spacing, 250 m for nine areas, 500 m for two areas; helicopter speed, 110 km/hr; console, Scintrex GAD-1; threshold, 0.15 MeV; time constant, 1 sec; full-scale deflection, 3 000 counts/sec; power source, disposable alkaline batteries; sensor, Scintrex GSA-61, thallium activated sodium iodide, 15.24 cm diameter, 10.16 cm thick, 1.85 litre volume, photo-tube diameter 12.7 cm; recorder, Hewlett-Packard 7155B single channel, chart width 12 cm, chart speed 10 sec/cm, rechargeable internal silica-gel battery; navigation, visual along pre-determined lines plotted on photomosaics of scale 1:50 000, fiducial numbers correlated prominent landmarks to marks on recorder paper, no altimeter or tracking camera employed; helicopters, Bell 206 A and B Jet Ranger.

LAKE-SEDIMENT SAMPLING:

Lake samplers of a design developed at the Geological Survey of Canada (Davenport et al., 1975) were used from a special mounting on the floats of Bell Jet Ranger helicopters. This sampler comprises a weighted steel pipe with a system of valves to allow a smooth descent to the lake bottom, but at the same time prevent the collected sediment from being washed away on the upward trip. A fin at the end of the pipe provides stability. Samples were collected and stored in Kraft sample bags, and subsequently dried at the camp.

ANALYSIS AND DATA PROCESSING

URANIUM ANALYSIS:

The lake-sediment samples were sieved to -80 mesh and shipped to Atomic Energy of Canada Ltd. (AECL) for delayed neutron activation analysis. This method of uranium analysis has been described by Boulanger et al. (1975). A one-gram sample is introduced into a nuclear reactor for 60 seconds, where it is subject to a neutron flux. The sample is then withdrawn and allowed to 'cool' for 10 seconds, after which it is introduced into a neutron counting device. The delayed neutron flux thus counted, is a measure of the sample's uranium content. It should be recalled that this technique determines the total uranium content of the sample and not the leachable component. A proper weighing of the sample is very critical for an accurate analysis, and therefore the AECL laboratories were entrusted with the weighing of the samples from this survey.

RADIUM ANALYSIS:

The technique of field radium analysis for soil samples described by Sutton and Soonawala (1975), was employed for lake-sediment samples. About 40 ml of wet lakesediment sample was immersed for about four days in a 227 ml bottle full of water. The glass bottles had metal caps, and during this time were stored in an inverted position. Subsequently, the bottles were stirred and their contents transferred to a radon de-gassing apparatus. By means of a vacuum generated by a bicycle pump, air was bubbled through the sample for four minutes, and this air was then introduced into a zincsulphide coated chamber coupled to a photomultiplier tube 5.1 cm in diameter, and a digital scaler. At the cessation of bubbling, an alpha count was taken for four minutes, to which a correction factor was applied to account for varying immersion times. These results were a direct measure of the radium content of the lake sediments, and were directly plotted on the field maps in units of counts per minute.

AIRBORNE SCINTILLOMETER DATA PROCESSING:

The helicopter-scintillometer data were processed by two distinct techniques. In one process only the outstanding anomalies were arbitrarily identified, and in the other detailed statistical analysis was performed in a systematic manner.

The primary purpose of the helicopter-scintillometer survey was 'prospecting', i.e. detection of zones distinctly anomalous as regards gamma radiation. At the end of every flight, the flight records were visually inspected and an arbitrary background determined. The location of peaks exceeding 1.5 times this value was noted, and by means of proportional dividers, the locations were transferred to field maps, which could then be used immediately for ground evaluation of the anomalies. The process of airborne anomaly recognition and transfer was very rapid, taking less than a few hours.

In order to extract more useful information from the helicopter-scintillometer data, in addition to that obtained by the 'hot spot' identification described earlier, the data were manually digitized and statistically analysed. Every recognizable peak and trough on the analogue record was digitized. It was decided not to digitize at a pre-determined uniform interval, because that would have involved either the digitization of an excessively high number of points, or non-recognition of some important features. The average density of digitization turned out to be about two points per line kilometre. Digitized data were transferred to 1:50 000 scale maps by proportional dividers. The following parameters were computed for most of the areas; the maximum, minimum, arithmetic mean, geometric mean and the population. Histograms were also drawn, in order to provide an illustration of the nature of the distribution, i.e., unimodal or multimodal and also to provide means for visually estimating anomaly thresholds. Plots on normal and/or lognormal probability paper were also used in some cases to determine the nature of the populations. If it was found that a population was multimodal, an attempt was made to separate the constituent populations. This could be done either by the construction and subsequent superimposition of a number of artificial histograms, and the adjustment of their parameters until a close fit was obtained between artificial distribution and the observed distribution; or by an analysis of the plots on probability-paper, based on the locations of the inflection points on these plots. Anomaly thresholds and contour intervals for most of the helicopter-scintillometer maps accompanying this report have been obtained from the interpretational processes described above.

All the statistics described in this report were computed on a Texas Instruments TI-59 programmable calculator. The algorithm for the construction of histograms and determination of statistical parameters is shown in Figure 6. Data could be recorded on magnetic cards, and each card could store sixty data-registers with up to five data points on each register. Smaller input and output programs were used to complement the program shown in Figure 6.

LAKE-SEDIMENT DATA PROCESSING:

The following statistical parameters were calculated for all areas covered by the regional follow-up lake-sediment surveys; population number; range, arithmetic mean, geometric mean and standard deviation. Histograms were also constructed and the cumulative percent frequency plotted on probability paper, in order to determine the nature of the distribution. The calculations were done on a Texas Instruments TI-59 calculator using an algorithm similar to that shown in Figure 6. The following unweighted formula was used for the determination of standard deviation:

$$S^2 = \frac{\sum x^2}{n} - \left(\frac{\sum x}{n}\right)^2$$

where, S = standard deviation,
x = data number,
n = population number

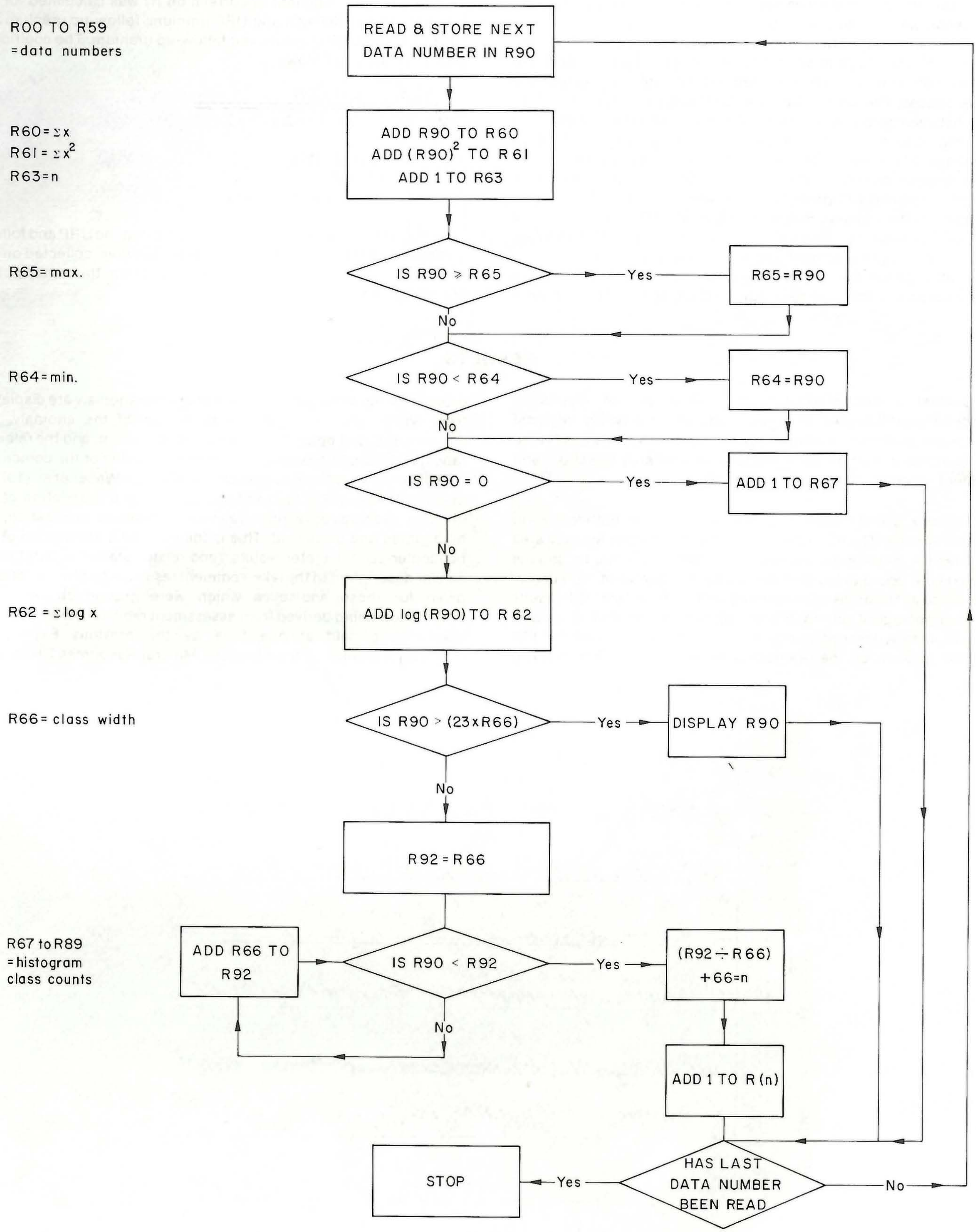


FIGURE 6: Algorithm for statistical analysis and histogram construction, adapted for the TI-59 programmable calculator

The unweighted formula was appropriate, since in every case, the population was well above thirty.

The results of the statistical analysis were used in presenting the data on the final maps at scale 1:50 000. At each lake sampled, the element concentration was indicated by a symbol representing one of five classes. The lowest class was for the element concentrations lying between zero and the arithmetic mean, and the highest class included concentrations exceeding mean-plus-three-standard deviations. The other three classes equally divided the range from mean to mean-plus-three-standard deviations. Except for one area, loss-on-ignition (LOI) determinations were not done on samples collected in the regional follow-up. However, LOI results from the 1975 URP surveys provided an estimate of the degree of correlation between the organic content and the uranium content of the lake sediments. About 13% of the lakes sampled under this regional follow-up survey had also been sampled under the URP. For these data points the coefficient of correlation (r) was calculated for the following pairs; URP LOI and URP uranium; follow-up uranium and URP LOI; and URP uranium and follow-up uranium. The coefficient was calculated as follows:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2]\,[n\sum y^2 - (\sum y)^2]}}$$

where x = first variable
y = second variable
n = number of data pairs

In evaluating this data, it should be recalled that the URP and follow-up determinations were made on different samples, collected one or two years apart, and probably not collected from the same spot on any given lake.

RESULTS

Qualitative and analytical descriptions of the results of helicopter-scintillometer and lake-sediment follow-up regional surveys are given in this chapter for each of the twelve areas (Table 1). Reference is also made to the rationale for area selection, and pertinent recommendations for future work.

Tables 2, 3 and 4 summarize the statistics from both follow-up regional surveys. The title-line heading the description for each area indicates the maps (in pocket) which should be referred to, and the approximate coordinates of a point near the centre of the survey-area. Since all the areas were selected on the basis of the URP results and their geological setting, the first part of the narrative deals with these aspects. A description if given of the general nature of the URP anomaly as seen on the uranium channel contours. The stacked profiles for the principal URP line through the anomaly are displayed from which one can note the resolution of the anomaly, the concentrations of potassium, uranium and thorium, and the relevant ratios. A description is also given where possible of the coincident URP lake-sediment uranium anomaly. Maps by Weber et al. (1975b) or Schledewitz (1976) are used exclusively for a description of the geology. Geological features relevant to uranium exploration, are highlighted and discussed. This is followed by a description of the helicopter-scintillometer results, (and related statistical data) and a similar description of the lake-sediment results. A brief description is given for those anomalies which were ground checked, the information being derived from assessment reports of work done on claim-blocks held at one time by the previous Exploration Operations Branch of the Manitoba Mineral Resources Division.

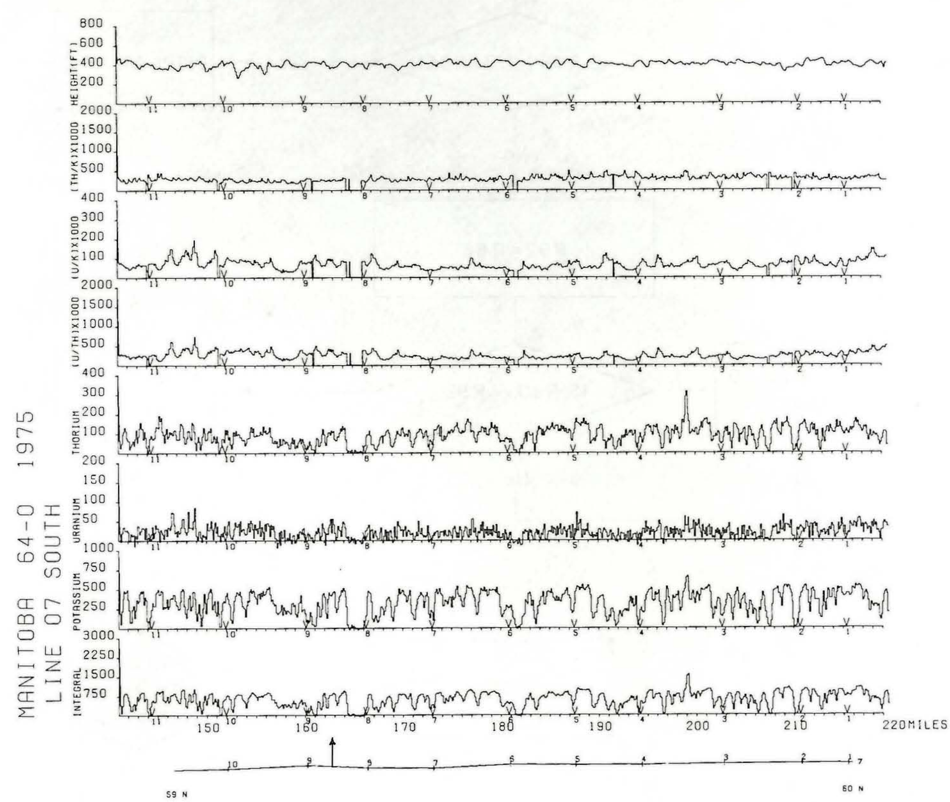


FIGURE 7: URP stacked profiles, Munroe Lake East

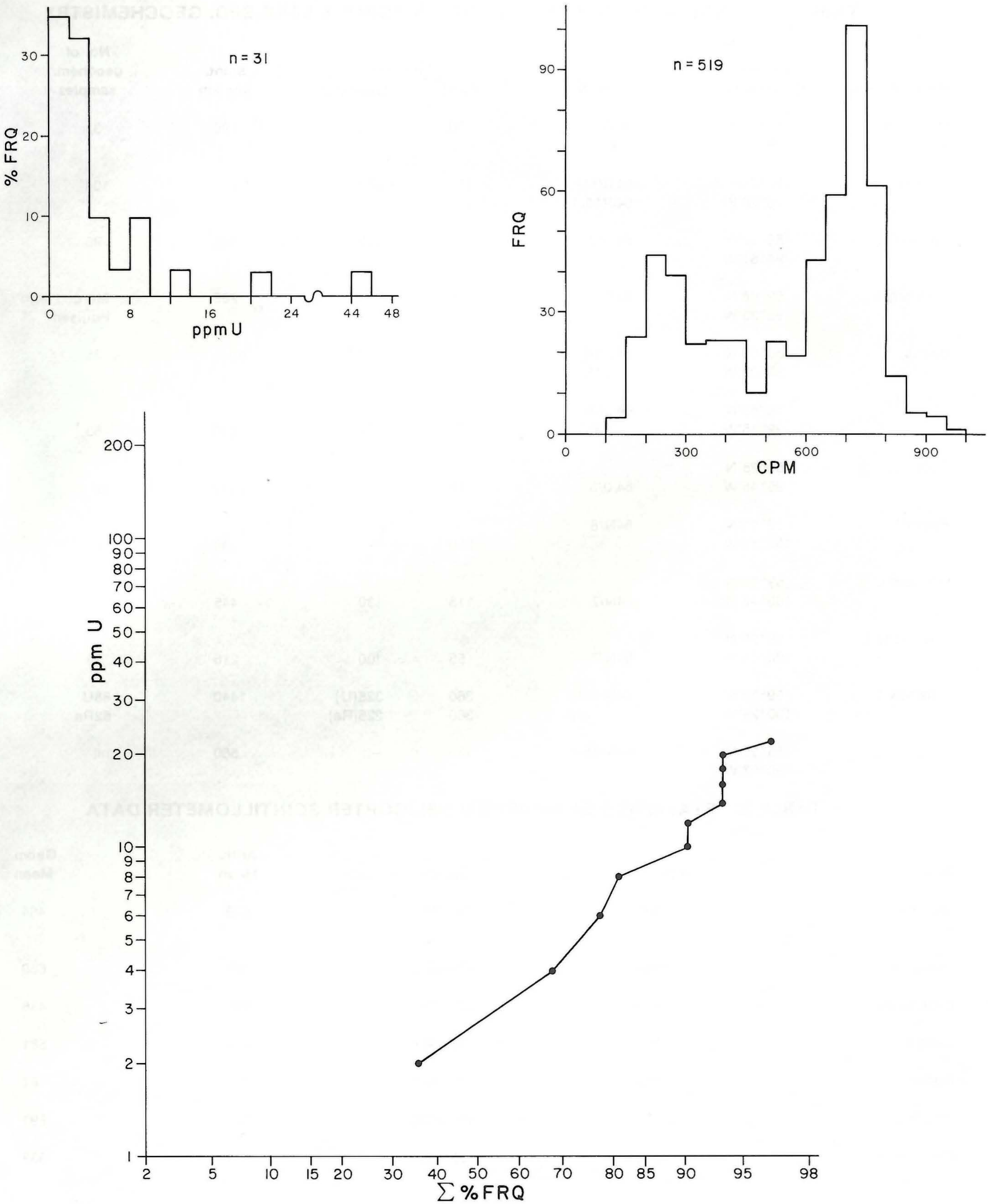


FIGURE 8: Statistical plots, Munroe Lake East

TABLE 1: AREAS SURVEYED BY HELICOPTER SCINT. & LAKE-SED. GEOCHEMISTRY

Name of Area	Approx. Coordinates	NTS	Size (km^2) Scint.	Size (km^2) Geochem.	Scint. line km	No. of geochem. samples
Munroe L. East	59°15'N 98°24'W	64 0/ 1/8	50	85	195	31
Overby L.	59°00N 98°20'W	64 0/1/2 64J/15/16	215	280	855	104
Poulsen L.	59°10'N 98°51'W	64 0/2	90	260	350	95
Greening L.	59°08'N 98°35'W	64 0/2	135	—	265	Merged with Poulsen
Bain L.	58°53'N 99°02'W	64J/14 /15	—	100	nil	35
Legg L.	59°53'N 99°15'W	64 0/3/4 /5/6	80	160	310	63
Booth L.	59°25'N 99°45'W	64 0/5	140	—	550	nil
Finner L.	59°23'N 100°18'W	64N/8	250	—	500	nil
Rodgers L.	59°23'N 100°42'W	64N/7	115	130	445	46
Choquette L.	59°20'N 100°56'W	64N/7	55	100	215	29
Putahow L.	59°50'N 100°25'W	64N/9/15 /16	360 360	325(U) 225(Ra)	1440	88U 62Ra
Bagg L.	59°55'N 100°07'W	64N/16	150	—	560	nil

TABLE 2: STATISTICS OF DIGITIZED HELICOPTER SCINTILLOMETER DATA

Area	Population	Range	Arith. Mean	Geom. Mean
Munroe L. East	519	125-975	539	484
Overby L.	1552	125-1800	689	669
Greening L.	429	100-1125	496	436
Legg L.	739	50-1925	719	581
Booth L.	1122	125-1825	877	761
Rodgers L.	717	125-2300	973	891
Choquette L.	570	125-1850	771	632

NOTE: Scintillometer readings in units of counts per second with the following instrumental configuration; Scintrex GAD-1 spectrometer with GSA-61 sensor (1.8 litres) in the total count mode.

TABLE 3: STATISTICS OF LAKE-SEDIMENT GEOCHEMICAL DATA

Area	Population (n)	Range	Arith. Mean ($\bar{x}$)	Geom. Mean (G)	Std. Dev. (s)	$\bar{x}$+s	$\bar{x}$+2s	$\bar{x}$+3s	s/$\bar{x}$
Munroe L. East	31	1-44.9	5.48	3.31	8.28	13.8	22.0	30.3	1.51
Overby L.	104	0.4-109	9.23	5.17	13.86	23.1	36.9	50.8	1.50
Poulsen L.	95	0.4-73.1	10.72	6.13	13.30	24.0	37.3	50.6	1.24
Bain L.	35	3.2-110	19.83	12.34	22.65	42.5	65.1	87.8	1.14
Legg L.	63	0.6-38.4	10.11	7.18	9.2	19.3	28.5	37.7	0.91
Rodgers & Choquette L.	75	2.7-102	18.80	14.28	16.02	34.8	50.8	66.9	0.85
Putahow (U)	88	1.6-210	32.58	21.20	36.9	69.5	106	143	1.13
Putahow (Ra)	62	0-16.25	4.54	3.50	3.39	7.94	11.3	14.7	0.75

NOTE: All concentrations in parts per million uranium; except last row where radium concentration is expressed in arbitrary units of counts/minute.

TABLE 4: COEFFICIENTS OF CORRELATION, LAKE-SEDIMENT SURVEYS

Area	Number of Data Pairs	URP LOI & URP Uranium	URP LOI & Follow-up Uranium	URP Uranium & Follow-up Uranium
Overby L.	11	-0.387	0.118	0.46
Poulsen L.	8	0.48	0.41	0.98
Bain L.	8	-0.046	-0.167	0.635
Legg L.	12	-0.42	-0.13	0.58
Rodgers & Choquette L.	16	0.251	0.067	0.97
Putahow L.	8	0.102	0.070	0.980
All Areas	63	0.044	0.038	0.807

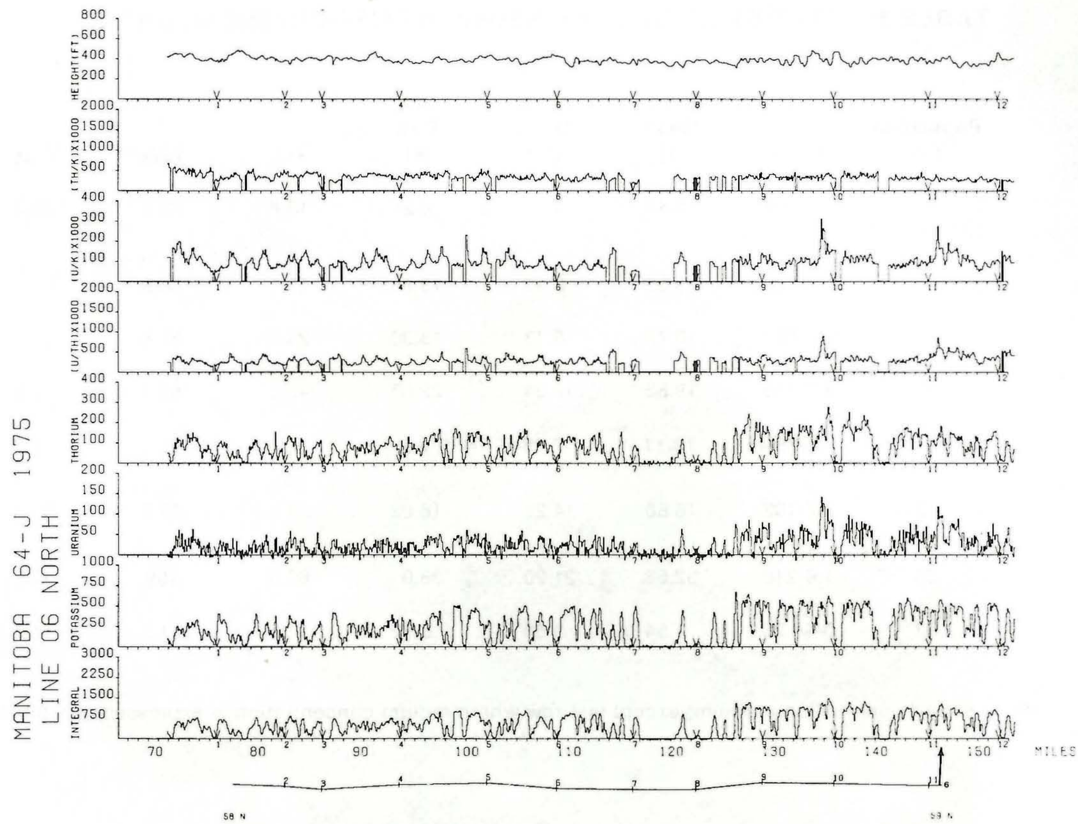


FIGURE 9: URP stacked profiles Overby Lake

MUNROE LAKE EAST (MAPS 1a & 1b; 59° 15'N, 98° 24'W):

The URP radiometric map shows an anomaly of good resolution but low amplitude in the Munroe Lake East area. The peak corresponds to only 0.6 ppm eU on the contour map, but the anomaly is well-resolved mainly because of the low uranium concentrations in the neighbouring areas. This is well illustrated by the principal profile through the area (Figure 7). An increase in the eU/eTh and eU/K ratios is also noted. There is a coincident increase in the concentration of all radioelements over this area. There is no corresponding geochemical anomaly in the URP data.

A histogram of the 519 digitized points from the helicopter-scintillometer survey exhibits the multimodal character of the distribution. The arithmetic mean is 539 counts/second. The scintillometer plot (Map 1a), on which all anomalies of amplitude 800 counts/second or higher are plotted, shows the scattered nature of the anomalies. Lines 32 to 39 have the largest number of anomalies, including the highest reading of 975 counts/second which is located on line 32.

The histogram and the cumulative frequency plot for the lake-sediment survey are shown on Figure 8 and the statistics are given in Table 3. The distribution appears to be lognormal. The threshold, if taken at mean plus two standard deviations, is 22 ppm uranium. Only one reading at 44.9 ppm exceeds this value and it is located in the north central part of the area. There is no coincident scintillometer anomaly. From the geological map (Schledewitz, 1976), it appears that this anomaly is located in Hudsonian granites.

The Munroe Lake East area appears to be featureless, and no further work is recommended.

OVERBY LAKE (MAPS 2a & 2b; 59°N, 98° 20'W):

A 1.6 ppm eU uranium channel anomaly from the URP radiometric survey lies directly over this area. This anomaly straddles the 59th parallel, and therefore is located in NTS areas 64J and 64 O. The pear shape of the anomaly suggests that it consists of two components which have been insufficiently resolved. Figure 9 shows the stacked profiles relating to the principal URP line through this anomaly, from which it can be noted that there is no corresponding increase in the thorium or potassium channels, and consequently there is a marked increase in the eU/eTh and eU/K ratios.

The URP geochemical data does not indicate a prominent uranium anomaly in this area. However there seems to be the continuation of a northwest trending anomaly, which is quite prominent to the north-west of the Overby Lake area, i.e., near the southwest corner of Munroe Lake.

The geological map (Schledewitz, 1976) indicates a predominance of Archean grey gneiss with minor amphibolite, surrounded on all sides by a Hudsonian granite. Within the area there are also several relatively minor occurrences of Aphebian pelitic to semi-pelitic biotite gneiss, particularly in the south (just north of Overby Lake) and west of Greening Lake. Thus from the point of view of uranium exploration the area is attractive because of the presence of the Archean-Aphebian unconformity and the presence of the pelites and associated anatectic white granite.

The helicopter-scintillometer survey (Map 2a) confirms two parts to the radiometric anomaly, one lying north of flight line 39, and the other south of line 44. Both zones appear to coincide reasonably well with the Archean gneiss. The helicopter scintillometer readings

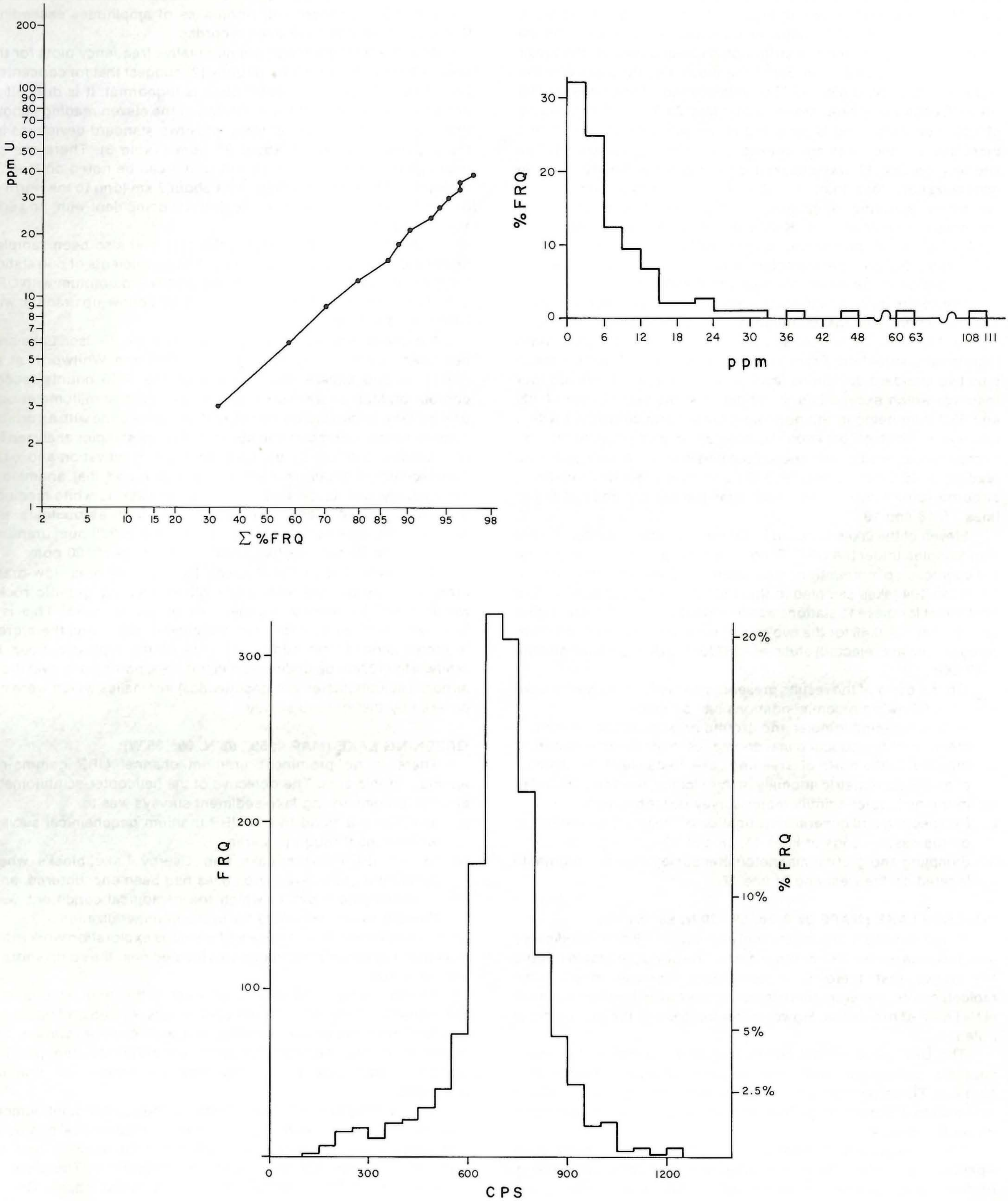


FIGURE 10: Statistical plots, Overby Lake

were digitized at 1552 points, the statistics of which are given in Table 2 and the histogram shown in Figure 10. The histogram has good definition. It appears to be negatively skewed, which is perhaps the effect of a low-population distribution superimposed on the lower end of the main distribution. Since the mode, i.e., the class with the highest frequency, is 650 — 700 counts/second all anomalies of 800 counts/second or greater are shown on Map 2a. The highest reading of 1800 counts/second is recorded at the west end of line 17, and there are six other readings in excess of 1100 counts/second. The anomaly on line 17 was checked on the ground. Spotty uranium mineralization, less than a metre in width, was found in pink pegmatite intruding a granodioritic gneiss. The pegmatite is composed principally of K-feldspar and accompanied by a concentration of magnetite. It was estimated by means of a calibrated digital spectrometer that the maximum uranium concentration in the pegmatite was about 400 ppm.

The centre lake-sediment uranium values are shown on Map 2b. The histogram and the cumulative frequency plot are shown in Figure 10, both of which suggest that it is a straightforward lognormal distribution. From Table 3 it can be noted that the mean plus two standard deviations level is about 37 ppm. There are four readings which exceed this threshold, with the two highest of 109 and 65.3 ppm being in the northwest corner and coincident with a geological contact between Hudsonian quartz monzonite and feldspathic quartzite with sporadic calc-silicates. A lake-sediment reading of 46.3 ppm coincides with a relatively isolated cluster of airborne scintillometer anomalies near the eastern ends of flight-lines 17, 18 and 19.

Eleven of the lakes sampled in the survey under discussion were also sampled under the URP. Therefore it was possible to determine the coefficient of correlation (r) between uranium and LOI for at least 11 of the 104 lakes sampled in this follow-up regional survey. The coefficient for these 11 stations was found to be 0.118. It is interesting to note that r = 0.46 for the two sets of uranium samples (0.68 if two sample pairs are rejected) and r = -.387 for the URP uranium and the URP LOI.

On the basis of the results presented above for the Overby Lake area, the following recommendations can be made:

1. Helicopter scintillometer and ground prospecting to be done in the area of the geochemical anomalies in the northwest part of the area, to the north of Greening Lake. Because of the absence of a URP radiometric anomaly in this vicinity, it was not included in the helicopter-scintillometer survey described here.
2. Prospecting and general investigation of the group of anomalies on the eastern ends of lines 17, 18 and 19.
3. Sampling and ground magnetometer survey over the pegmatite located on the west end of line 17.

POULSEN LAKE (MAPS 3a & 3b; 59° 10'N, 98° 51'W):

A well-defined uranium channel anomaly of 1.6 ppm is indicated over this area on the URP contour maps. The principal profile (Figure 11) shows that there is a coincident increase in all three radioelements, therefore there is no increase over the anomaly in the eU/eTh or eTh/K ratios. However, an increase in the eU/K ratio is noted.

The URP geochemical survey indicates a prominent uranium anomaly coincident with the above-mentioned spectrometer anomaly. Three neighbouring samples have uranium concentrations in the 50 to 100 ppm range. This anomaly is a part of a larger trend through this area.

The geological map (Schledewitz, 1976) indicates an Archean-Aphebian unconformity in the area, with the rock units being; Archean grey gneiss, Aphebian pelites and Hudsonian quartz monzonites.

On Map 3a, the helicopter-scintillometer map, there are two major and six relatively minor closures of the 800 counts/second contour. The radiation background for this scintillometer in this area is about 500 counts/second. Anomalies of amplitudes exceeding 1600 counts/second have been recorded.

Both the histogram and the cumulative frequency plots for the lake-sediment uranium data (Figure 12) suggest that for concentrations below 21 ppm, the distribution is lognormal. It is difficult to evaluate the nature of the distribution of the eleven readings above that level. The threshold, at mean plus two standard deviations for the geochemical data is about 37 ppm (Table 3). There are six readings exceeding this threshold, and it can be noted on Map 3b that five of them lie on a linear belt about 7 km long to the north of Schacht Lake. This is adjacent to, but not coincident with, an aerial scintillometer high.

Eight lakes in the Poulsen Lake area had also been sampled under the URP geochemical survey. The coefficients of correlation for the eight data pairs are as follows: Follow-up uranium with URP LOI, 0.41; URP uranium with URP LOI, 0.48; Follow-up uranium with URP uranium, 0.98.

A detailed ground follow-up program in the Poulsen Lake area has been described by Whitworth (1978a) and Whitworth et al. (1977). A one square mile block near the 1600 counts/second contour on Map 3a was surveyed with a ground scintillometer on a grid pattern. In-situ radioelement analyses were done with a portable gamma-ray spectrometer and about thirty rock samples analyzed for uranium and thorium by the delayed neutron activation and x-ray fluorescence methods respectively. It was found that anomalous radioactivity was associated with a garnet-bearing white medium- to coarse grained granite, which occurred both as boulders and outcrop. Five rock samples assayed in excess of 200 ppm uranium, and 10 of the 30 samples had uranium in excess of 100 ppm.

It appears that in the Poulsen Lake survey area, low-grade uranium is associated with white garnet-bearing granitic rocks, which could be anatectic derivatives of pelitic rocks. This is a favourable environment for uranium mineralization, and therefore it is recommended that additional work of the type described by Whitworth (1978a) be undertaken in this area, particularly over those airborne scintillometer and geochemical anomalies which were not covered by that ground survey.

GREENING LAKE (MAP 4; 59° 08'N, 98° 35'W):

There is no prominent uranium channel URP gamma-ray anomaly in this area. The objective of the helicopter-scintillometer and the accompanying lake-sediment surveys was to:

a) investigate a trend in the URP uranium geochemical surveys which runs through this area,
b) to link the Poulsen Lake and Overby Lake blocks where prominent gamma-ray anomalies had been encountered, and
c) to investigate a belt in which the geological conditions were thought to be favourable for uranium mineralization.

Also, it was known from a review of previous exploration work in this area that a uranium occurrence was located near the south shore of Munroe Lake.

The following three rock types exist in this area according to Schledewitz (1976); an Archean grey gneiss, Aphebian feldspathic quartzite with minor calc-silicates and a Hudsonian granite. The presence of the Archean-Aphebian unconformity and possibly anatectic granitoids make this area favourable for uranium exploration.

The histogram of 429 digitized helicopter-scintillometer readings (Figure 13a) exhibits a pronounced multi-modal character. The cumulative frequency plots (Figure 13b) suggest that the population is made up of two distinct distributions. The plots are fairly linear on both normal as well lognormal paper. On the scintillometer plot (Map 4) all readings equal to or exceeding 700 counts/second have been plotted. As can be verified from the histogram, this threshold lies in the upper part of the distribution and

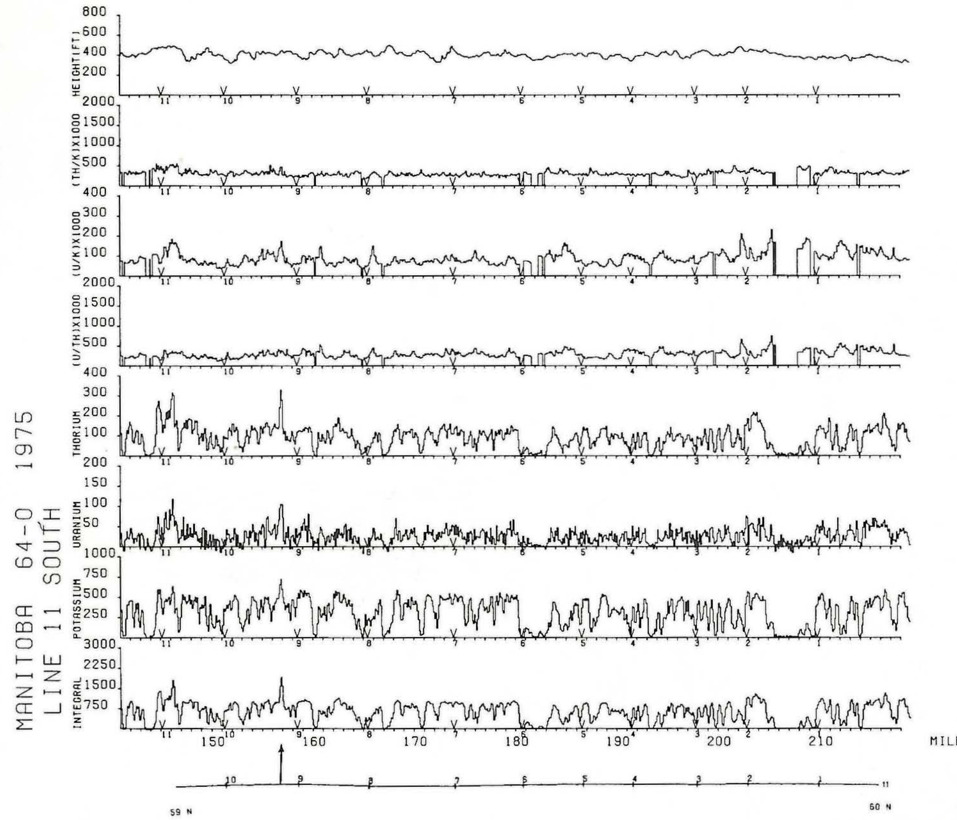
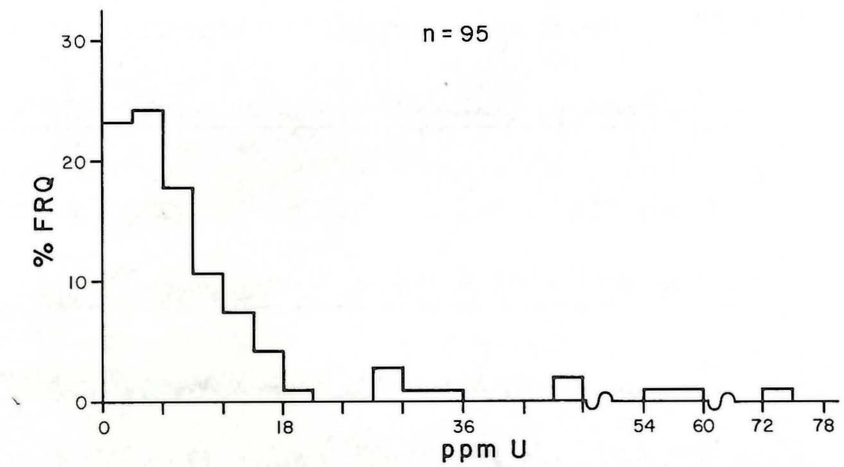


FIGURE 11: *URP stacked profile, Poulsen Lake*



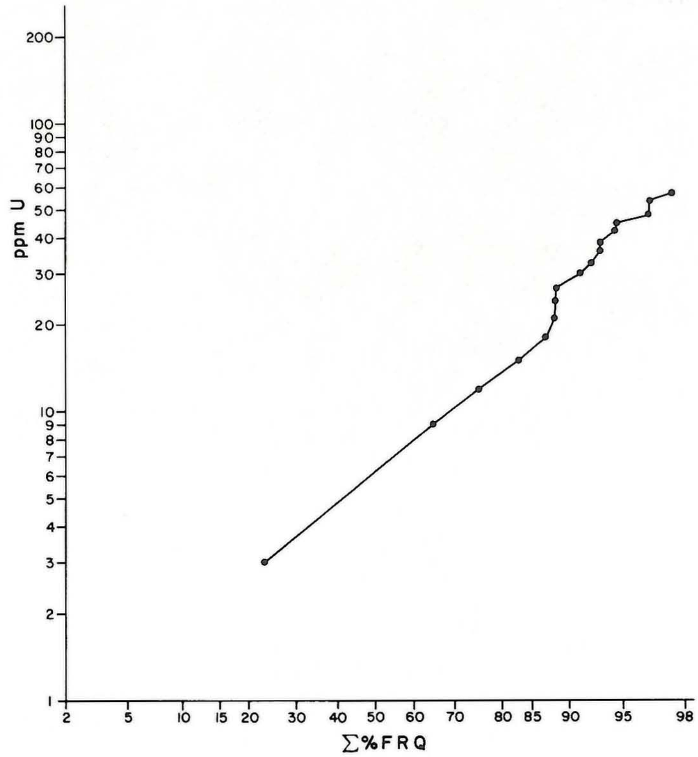
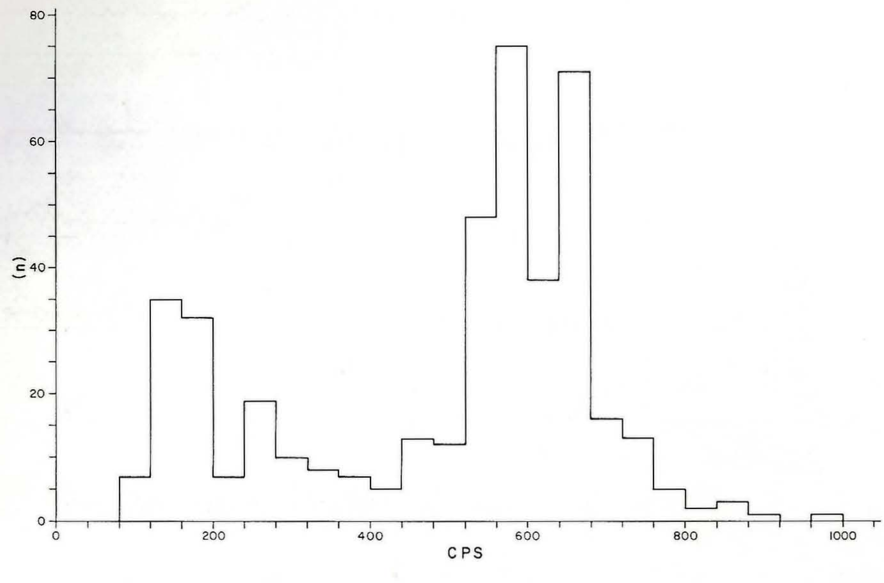
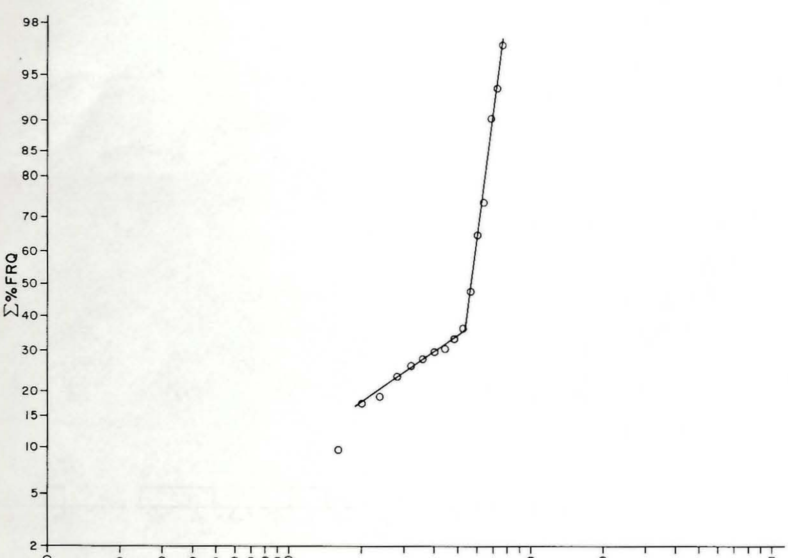


FIGURE 12: Geochemical statistical plots, Poulsen Lake





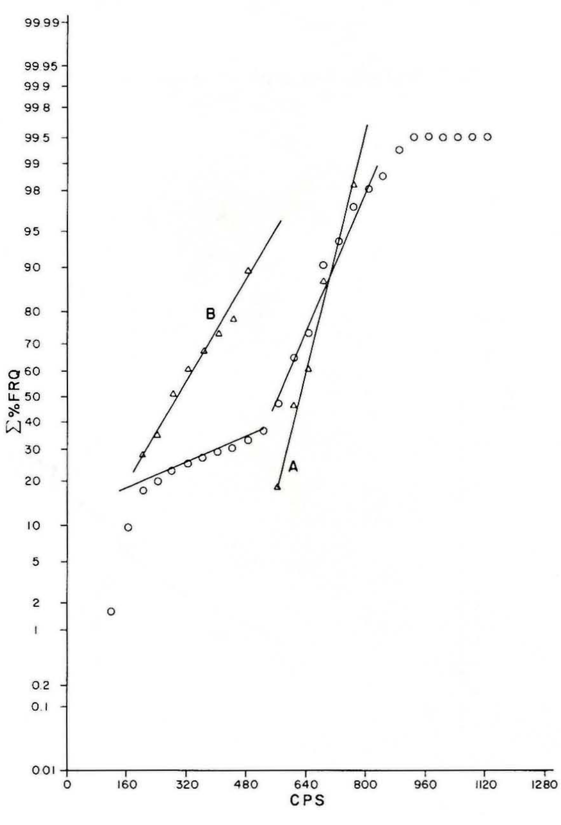


FIGURE 13: Helicopter-Scintillometer statistical plots, Greening Lake

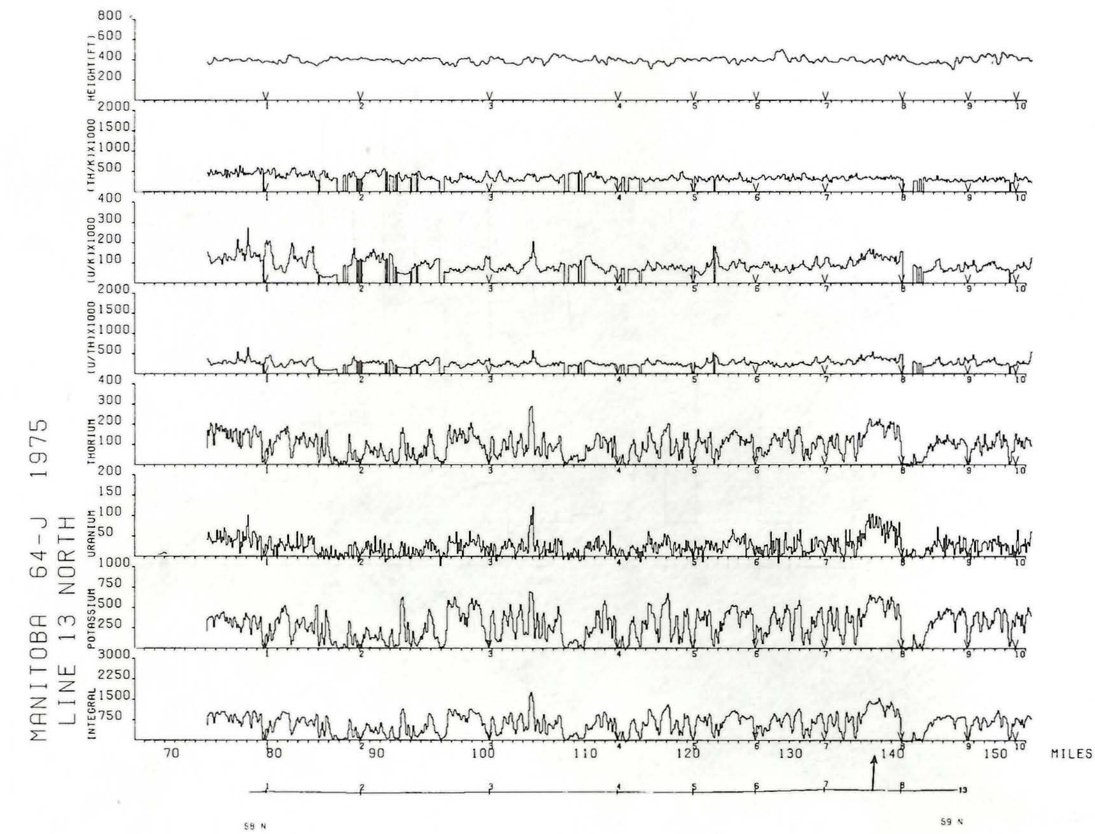
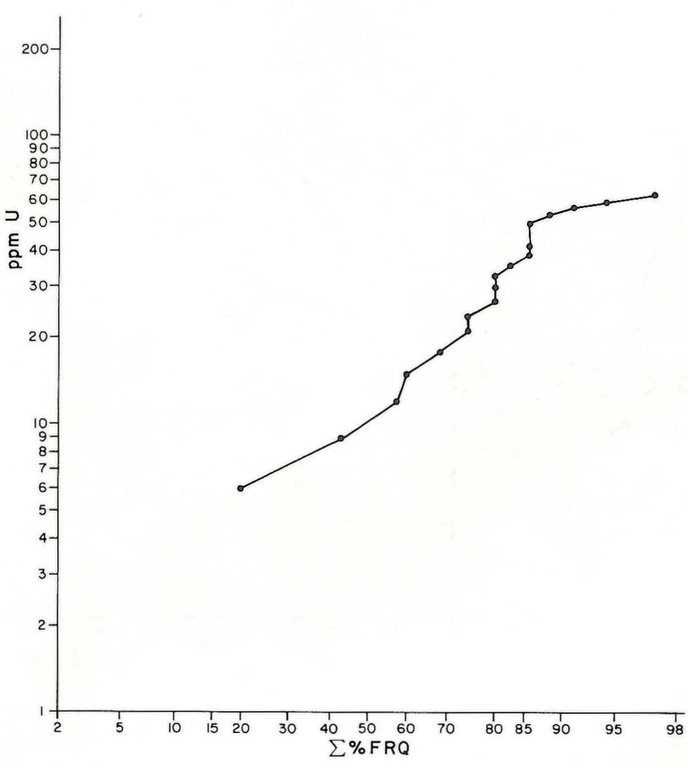


FIGURE 14: URP stacked profiles, Bain Lake



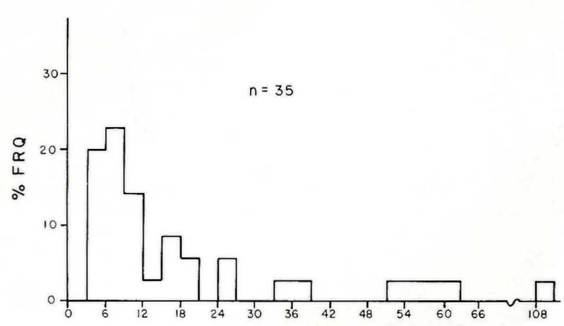


FIGURE 15: Geochemical statistical plots, Bain Lake

is about 50% higher than the arithmetic mean (Table 2). The highest reading of 1125 counts/second was recorded on line 2 just west of Schacht Lake. This is the eastward continuation of a 800 counts/second closure on the map for Poulsen Lake (Map 3a). The rest of the Greening Lake block is featureless, except for a small group of anomalies on lines 26 to 31 north of Greening Lake.

Whitworth (1978b) describes a uranium occurrence in magnetite bearing pink pegmatite which is in the vicinity of the north ends of lines 25 and 26. This showing was not detected by the helicopter survey, probably because it was located between two flight lines. The country rock at this occurrence is fine- to medium-grained quartzite which contains accessory biotite and microcline. The pegmatite occurs as small lenses which have intruded the quartzite. Pink K-felspar is the predominant mineral in pegmatite, with accessory biotite, quartz and magnetite. Thirteen samples were analyzed for uranium and thorium by the delayed neutron activation and x-ray fluorescence methods respectively. The nature of the mineralization is best illustrated by six samples taken at regular half-metre spacing across the most radioactive section of the pegmatite. The samples (in sequence) assayed: 621, 363, 14 250, 105, 26 and 125 ppm uranium. X-ray diffraction analysis showed that the uranium minerals present were uranophane and kasolite.

BAIN LAKE (MAP 5; 58° 53'N, 99° 02'W):

The URP uranium contour map shows a well-defined anomaly of amplitude 2.2 ppm. The principal profile through this anomaly (Figure 14) indicates that the resolution of the anomaly is only fair. There is a coincident increase in all three radioelements, with only a very slight increase in the eU/eTh ratio and a moderate increase in the eU/K ratio. The URP lake-sediment uranium plot shows a very prominent isolated anomaly in the 50 ppm to 100 ppm range. The geology of this area (Schledewitz, 1976) consists of the following rock types; pelitic biotite gneiss, biotite psammitic gneiss with calc-silicate, anatectic white granite and porphyritic granite, all Aphebian in age. The combination of pelitic gneiss and its anatectic derivatives appears to be favourable for uranium mineralization.

Because of time limitations it was not possible to do a helicopter-scintillometer survey over this area. The results of the follow-up lake-sediment survey are shown in Map 5 and Figure 15. Both the histogram and the cumulative frequency plot indicate the lognormal nature of the distribution with a suggestion that it is bimodal. From Table 3, the threshold at mean plus two standard deviations is 65.1 ppm uranium. One isolated anomaly of 110 ppm on Map 5 exceeds this value.

It is recommended that a helicopter-scintillometer survey be implemented in this area, and further, that the geology and the radiation pattern in the vicinity of the isolated geochemical anomaly be examined in detail.

LEGG LAKE (MAPS 6a & 6b; 59° 14'N, 99° 15'W):

The areas designated as Legg lake are actually distinct as regards the helicopter-scintillometer and lake-sediment coverage, there being only a slight overlap at the west end of the scintillometer coverage and the east end of the lake-sediment survey.

The most pronounced feature in the URP radiometric maps is the thorium anomaly in this area, which reaches above 15 ppm eTh. There is also a distinct coincident uranium anomaly, which can be divided into two parts, one north of the other. On the contour map, the amplitude of the anomaly is shown to be 1.8 ppm eU. The principal profile through the area (Figure 16) illustrates the character of the radiometric anomaly. It may be noted that the high thorium concentration coincides only with the south part of the uranium anomaly. There is also a pronounced potassium rise, but again only over the south part.

The URP lake-sediment map indicates two anomalies in the 20 to 50 ppm range which are closely associated with the URP radiometric anomaly. The rest of the area is featureless, except for one more reading in the same class near the western extremity of the follow-up lake-sediment survey area.

According to the geological map (Schledewitz, 1976) the rock units in the area are as follows; Aphebian pelitic to semi-pelitic biotite gneiss, quartzite, meta-arkose and Hudsonian granite. The Aphebian units, especially the pelites, make this area attractive for uranium exploration.

The histogram of 739 helicopter-scintillometer digitized readings indicates that the distribution is complex (Figure 17a). The cumulative frequency plot on normal probability paper (Figure 17b) shows that there is no component of the distribution which approaches the normal distribution. The plot on lognormal paper shows that there may be several lognormal distributions which go to make up the main distribution. The arithmetic mean of the digitized scintillometer readings is 719 counts/second. The scintillometer plot (Map 6a) confirms the division of the anomaly into two halves. The southern half is more pronounced with amplitudes in excess of 1600 counts/second. The north part of the anomaly has a closure of the 1400 counts/second contour.

Sixty-three samples were taken in the lake-sediment geochemical survey (Map 6b). The threshold at mean plus two standard deviations is 28.5 ppm uranium. Six readings exceed this value and they are all caused by adjacent lakes in the western part of the survey area. The histogram and the cumulative probability plot, (Figure 18) both suggest a lognormal distribution for the geochemical data.

Coefficients of correlation were calculated for twelve lakes which had been sampled under both the URP and the follow-up Regional Survey. They are as follows; URP uranium and URP LOI, -0.42; follow-up uranium and URP LOI, -0.13; URP uranium and follow-up uranium, 0.58.

No ground follow-up has been done in this area. It is recommended that the helicopter-scintillometer anomalies be examined on the ground. Furthermore, the helicopter survey should be extended to the west, in order to sample the region of high geochemical anomalies near the western edge of Map 6b. Depending on the results of this survey, ground follow-up may also be required.

BOOTH LAKE (MAP 7: 59° 25'N, 99° 45'W):

The Booth Lake area is characterized by high amplitude anomalies on the URP radiometric maps. An east trending high is almost 30 km long, within which there are two anomalies which peak significantly higher than the surroundings. The principal profiles through these peaks are shown in Figures 19 and 20. On the contour map the western anomaly has a peak of 3.4 ppm eU. Figure 20 indicates the good resolution of the anomaly, particularly in the uranium channel. Though there is a coincident increase in the other two radioelements the uranium increase is the most pronounced, causing an increase in the eU/eTh and the eU/K ratios. The eastern anomaly (Figure 19) is not as sharply defined as the other. Here the increase in the uranium channel is the most pronounced (2.88 ppm eU) which causes higher ratios as well.

The URP lake-sediment results indicate a fairly good correlation between the radiometric highs and a geochemical trend, with several anomalies in the 50 to 100 ppm range.

Schledewitz (1976) has mapped a contact between Aphebian pelitic gneisses and porphyritic granites directly through this area. The strike of the contact is almost east-west.

The helicopter-scintillometer survey confirms the high levels of gamma radiation over this area. Table 2 shows that the arithmetic mean of 1122 digitized readings is 877 counts/second, which is the second highest for the seven areas for which this parameter has been

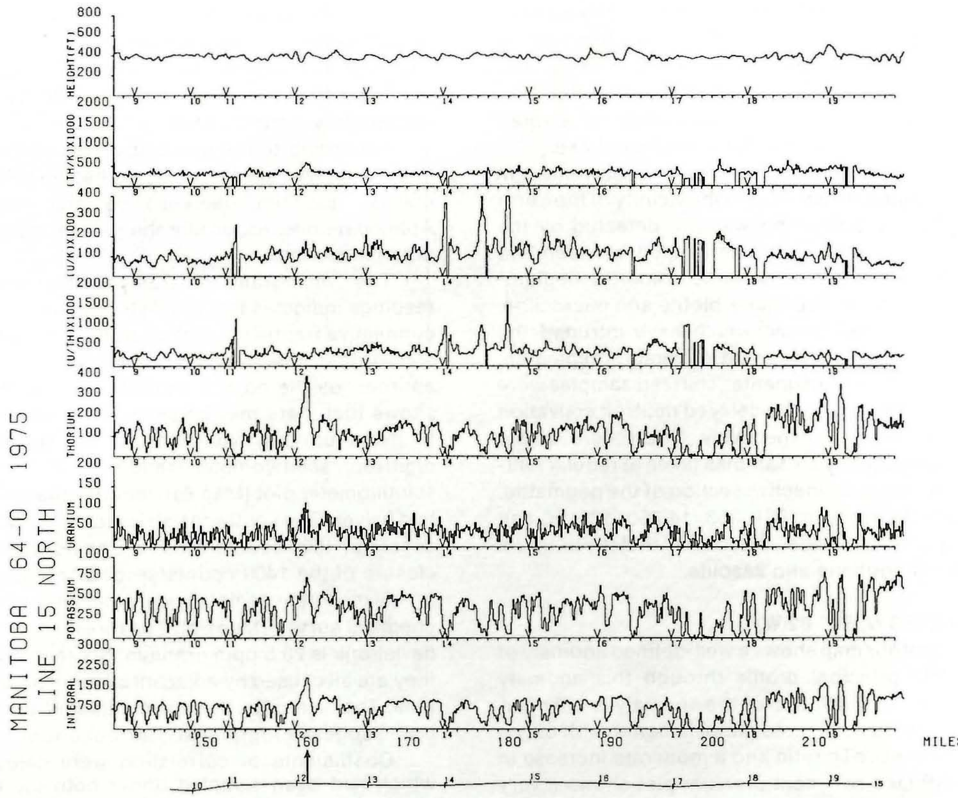


FIGURE 16: URP stacked profiles, Legg Lake

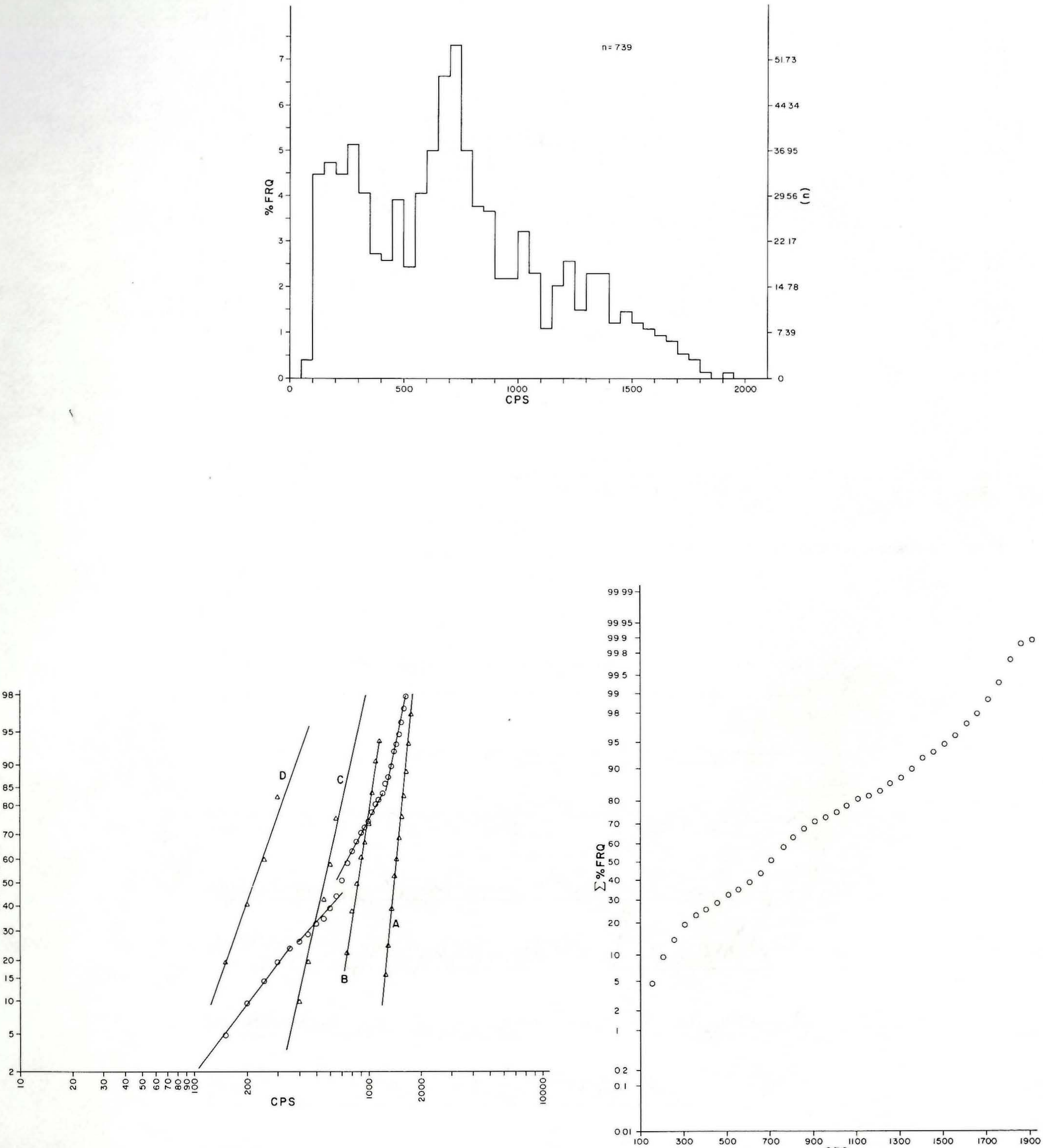


FIGURE 17: Helicopter-scintillometer statistical plots, Legg Lake

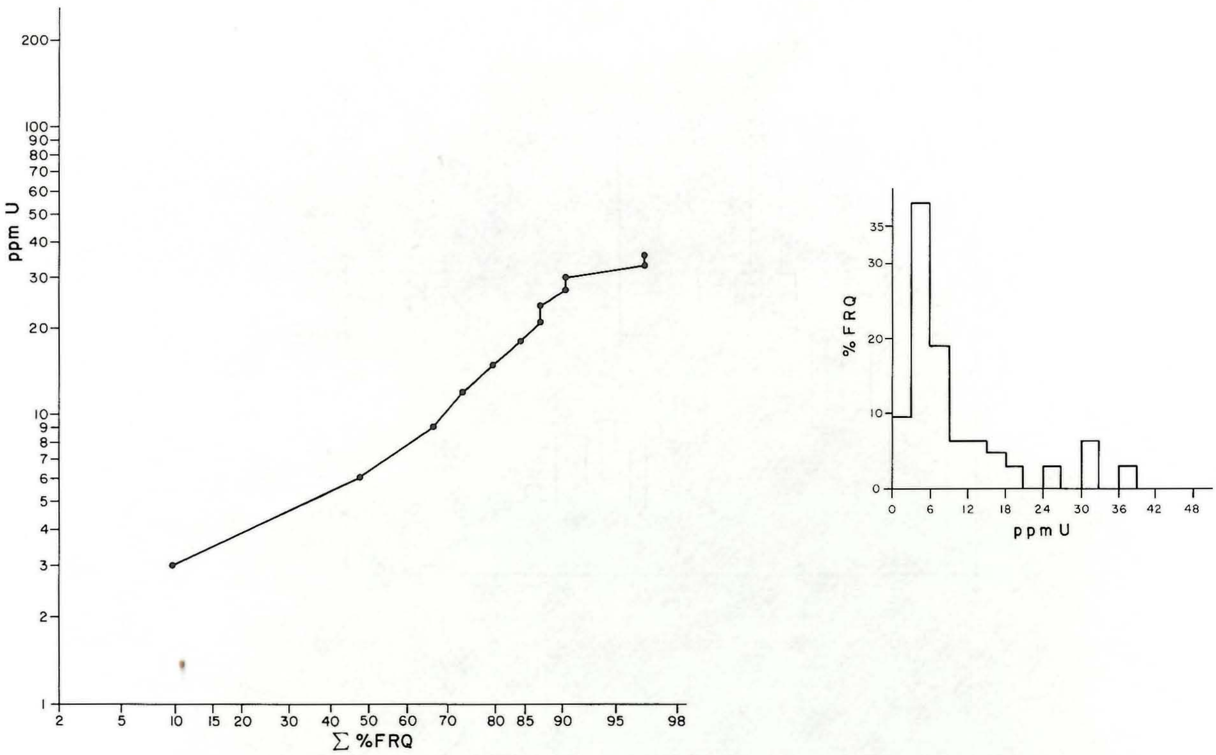


FIGURE 18: Lake-sediment statistical plots, Legg Lake

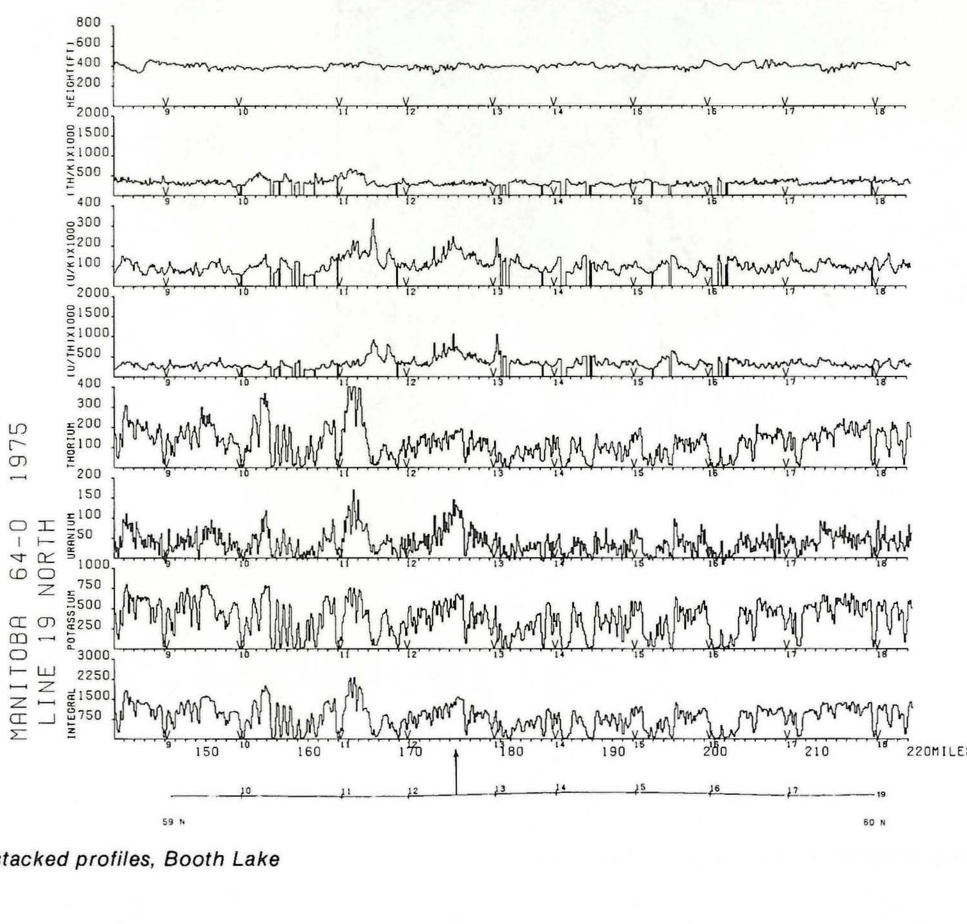


FIGURE 19: URP stacked profiles, Booth Lake

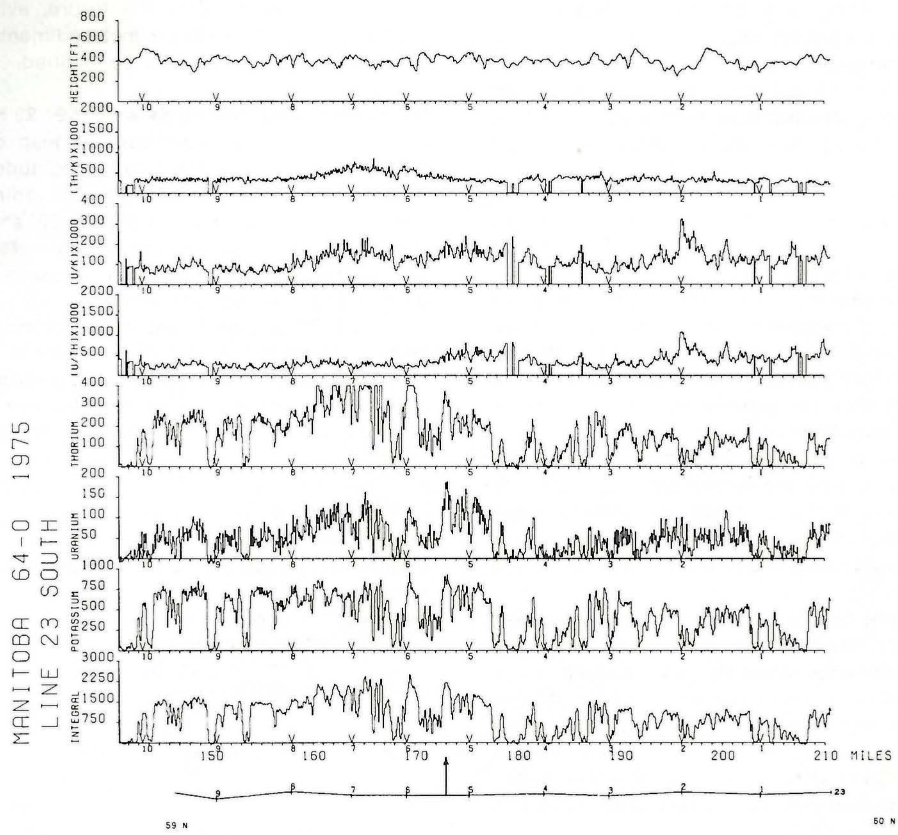


FIGURE 20: URP stacked profiles, Booth Lake

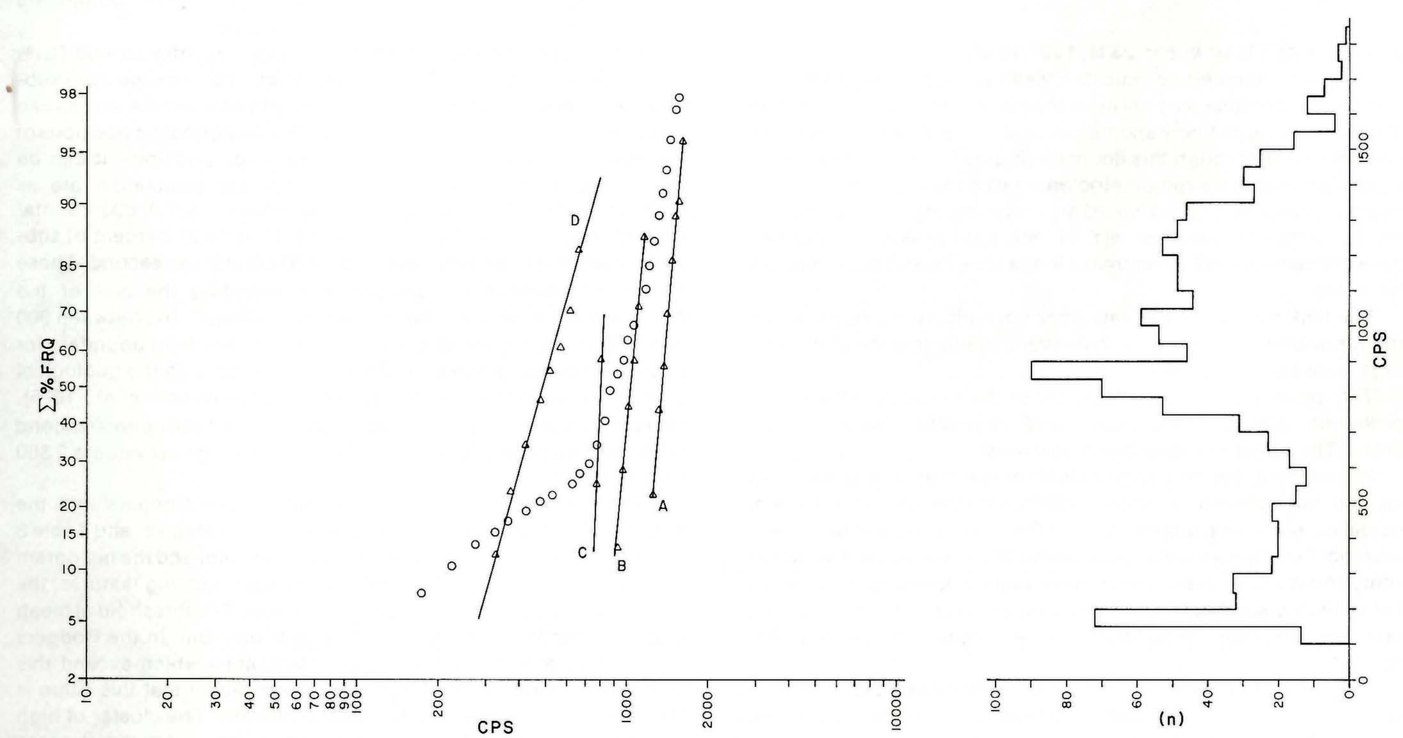


FIGURE 21: Helicopter-scintillometer statistical plots, Booth Lake

computed. The highest reading is 1 825 counts/second. The histogram (Figure 21) has a bimodal character. The cumulative frequency plot on lognormal paper also indicates the presence of two distinct distributions, both of which can be considered to be lognormal. The cumulative frequency data were also plotted on normal probability paper, but the data points did not fall on a straight line.

Map 7 is a plot of the helicopter-scintillometer readings. The dotted contour (950 — 1150 counts/second) indicates areas which would fall in the lower half of the upper distribution shown in the histogram. The higher contour 1 200 to 1 500 counts/second, covers the upper half of the same segment of the histogram. The point anomalies indicate those data points which are outside and above the histogram altogether. Areas not included in either one of the two contours would correspond to the lower of the two distributions. The geological significance of this radiometric distribution should eventually be investigated. Map 7 shows that in the Booth Lake area there are essentially three anomalous areas; the first and the strongest to the west of flight line 50, the second between flight lines 21 and 36, and the third being in the northeastern corner between lines 1 and 14. The strike length of the western anomaly is more than 14 km and it includes all except one of the peaks which exceed 1 500 counts/second.

The western anomaly was briefly examined on the ground near the northern part of line 93 (Whitworth et al., 1977). It was concluded that the helicopter-scintillometer anomaly was caused by a uniformly high background radiation from a boulder field of large granitic boulders. Uniform radiation levels of about 250 counts/second were recorded on a broad-band scintillometer of detector volume 43 cm^3. (Scintrex BGS 1). Other rock units, ranging between 1 to 5% in abundance included dolomite, calc-silicate rock and greywacke.

It appears that most of the gamma radiation is caused by a high uniform background in the granite, therefore this area cannot be recommended for further work. However it might be fruitful to spend some more time in the examination of the pelites and the associated rock units.

FINNER LAKE (MAP 8: 59° 23'N, 100° 18'W):

The URP radiometrics indicate a well-resolved uranium channel anomaly of amplitude 3.2 ppm eU in the Finner Lake survey area. The area as a whole is distincly anomalous in all three radioelements. The principal profile through this anomaly (Figure 22) shows the nature of the high-amplitude radiometric anomalies prevalent in this area. The potassium and thorium values are uniformly high throughout the area, but in the uranium channel the Finner Lake peak stands out well above the background. An increase in the eU/eTh and eU/K ratios is also noted.

The URP lake-sediment data does not indicate any outstanding uranium anomalies in this area, but several readings in the 20-50 ppm range have been recorded.

The geology of the area consists of the following rock types; porphyritic granite, meta-arkose and migmatite (Weber et al., 1975b). The major contacts trend east-west.

From Map 8, the helicopter-scintillometer map, it may be noted that the background is about 500 counts/second and several anomalies, some with amplitudes of 1 000 counts/second have been recorded. Twenty-five readings exceed 700 counts/second, of which twenty-three are in areas which have been mapped as porphyritic granite. In the southeast and southwest corners of the survey area there are anomaly groupings whose amplitudes exceed 900 counts/second.

No ground follow-up has been done in this area, but it appears that the radiometric anomalies are associated with the porphyritic granite. This is not an encouraging environment for uranium mineralization and therefore no further work can be recommended in this area. However, if in the future, evidence is gathered that indicates radioactivity in the metasediments, i.e., in the north half of the area, further work would be justified.

RODGERS LAKE (MAPS 9a & 9b: 59° 23'N, 100° 42'W):

The URP radiometric contour map of the uranium channel shows an oval shaped anomaly of amplitude 3.2 ppm eU. It occurs in an area which is uniformly high in its radiation level. The principal profile through this anomaly (Figure 23) shows that it is an anomaly of fair resolution with a coincident increase in the concentrations of all three radioelements, with no increase in the eU/eTh ratio, but the eU/K ratio shows a slight increase.

The URP lake-sediment shows an isolated uranium high in the 50 to 100 ppm range, and several more in the 20 to 50 ppm range.

An approximately east trending geological contact is indicated, going approximately through the middle of the area with porphyritic granite to the south, and meta-arkose in the north half. (Weber et al., 1975).

The histogram of 717 digitized points from the helicopter-scintillometer survey (Figure 24) shows the complex nature of the distribution. The plot on normal probability paper indicates that the distribution consists of about three normally distributed populations, the highest of which is labelled A. An attempt was made to separate this population using the following formula to plot a new cumulative frequence plot for this population;

$$\text{Cum. Frq. (new)} = \frac{\text{Cum. Frq. (Old)} - \text{Infl. Prev.}}{\text{Infl. Prst.} - \text{Infl. Prev.}} \times 100$$

where; Cum.Frq. (new) = the cumulative frequency at a given point for the separated component of the population,

Cum.Frq. (old) = the cumulative frequency at the same point for the observed undifferentiated distribution,

Infl.Prst and Infl.Prev — are the two inflection points (present and previous) on the probability plot which bound the sub-population

In the case given here, for sub-population A, Infl.Prst = 99.721% and Infl.Prev. = 42.678%. The probability plot for the separated sub-population A is also shown on Figure 24 by the dotted line, and as can be observed it is normally distributed. Also, on noting the positions of the 50%, 16% and 84% cumulative frequency positions, it can be determined that the parameters for this sub-population are as follows; mean = 1 250 counts/second, mean + s = 1 600 counts/second, mean - s = 900 counts/second. Thus 68.27 percent of sub-population A lies between 900 and 1 600 counts per second. These computed statistics are utilized in interpreting the plot of the scintillometer readings (Map 9a), where readings lying between 900 and 1 600 counts/second are delineated. The northern boundary for this group has a remarkably close coincidence with the geological contact between the granite and meta-arkose (Weber et al., 1975). Helicopter-scintillometer values of greater than 1 600 counts/second are shown as point anomalies on Map 9a. The highest value is 2 300 counts/second.

The lake-sediment uranium values for the Rodgers and the adjacent Choquette Lakes areas are plotted on Map 9b, and Table 3 lists the statistics. The cumulative probability plot and the histogram (Figure 25) indicate that in spite of some complicating features, the distribution is quite close to being lognormal. The threshold at mean plus two standard deviations is 50.8 ppm uranium. In the Rodgers Lake survey area there are two concentrations which exceed this level, the highest being 102 ppm. It is significant that this value is from a lake which is within the meta-sediments. The cluster of high helicopter-scintillometer anomalies in the southwest part of the area do not have a marked coincidence with the geochemical data. Data

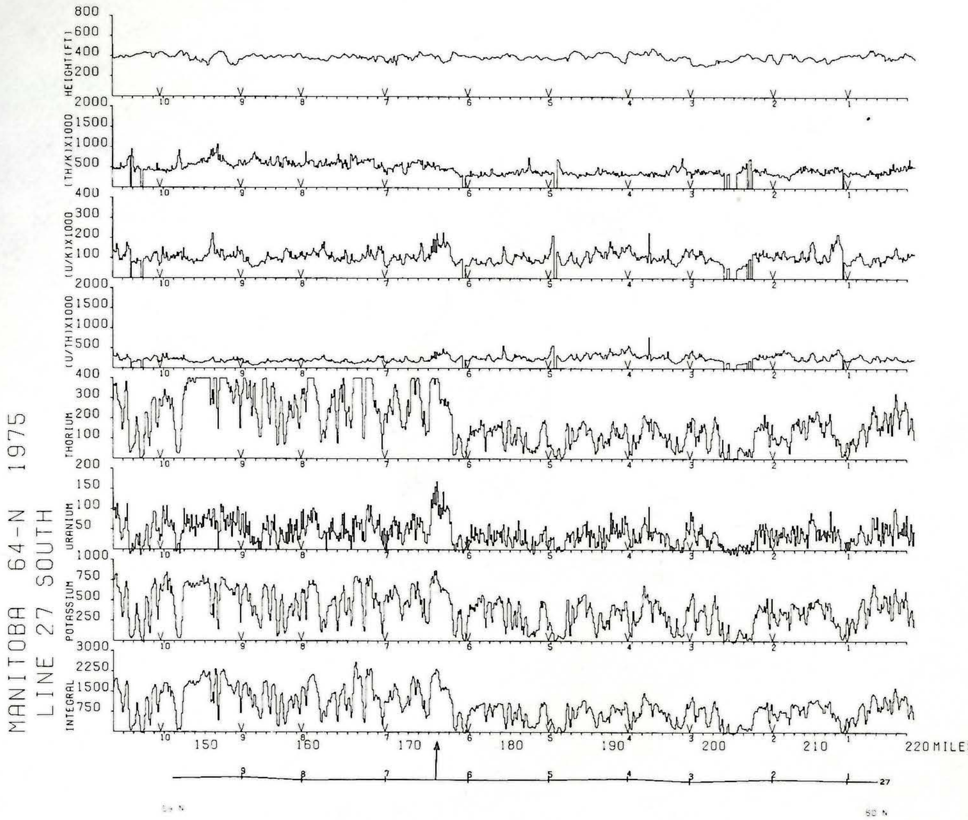


FIGURE 22: URP stacked profiles, Finner Lake

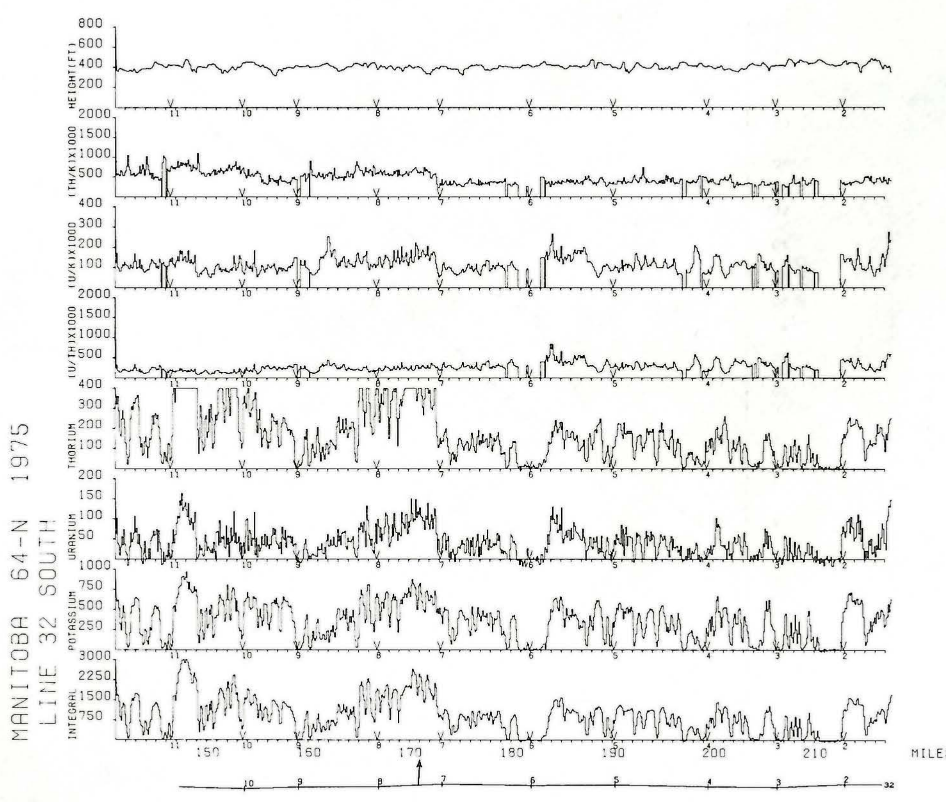


FIGURE: 23: URP stacked profiles, Rodgers Lake

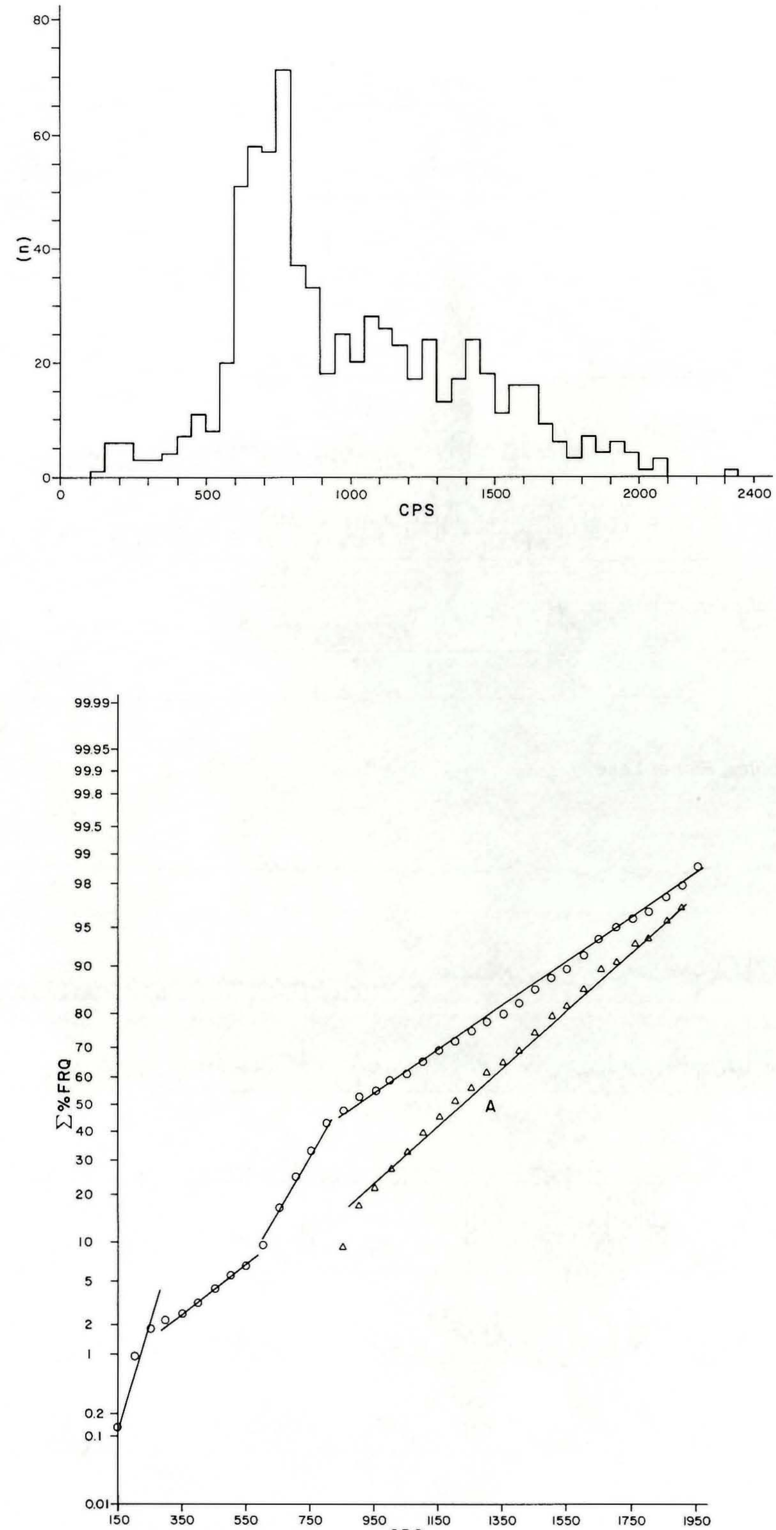


FIGURE: 24: Helicopter-scintillometer statistical plots, Rodgers Lake from the sixteen lakes samples under both the URP and the follow-up regional survey in the Rodgers-Choquette area show a remarkably close correlation between the two sets of uranium values at r = 0.967. The coefficient of correlation between the follow-up uranium and the URP loss-on-ignition is 0.067, and the coefficient between URP uranium and URP LOI is 0.251.

Whitworth (1978c) and Whitworth et al. (1977) have described the results of a detailed ground follow-up in area between lines 11 and 14 on the cluster of point anomalies on Map 9a. Ten grab samples taken in the course of this survey were analyzed by the neutron activation method for uranium. The highest value was 402 ppm. The mean for the rest of the nine samples was 9.4 ppm U. Five of the same samples were also analyzed for thorium by the x-ray fluorescence method, and values ranged from no-detection to 234 ppm Th. The radioactivity was exclusively confined to the pink porphyritic granite which is associated with a late-stage pluton. Most of the radiation can be attributed to boulders between 0.2 to 3 metres in their dimensions and quite angular. The same rock type appears as outcrop as well. The granite consists of potassium feldspar, plagioclase, quartz, biotite and magnetite. The weathered surface is pink and quite often streaked brown because of the weathering of the magnetite. The porphyritic texture is due to phenocrysts of potassium feldspar, 3 to 5 cm in size, in a medium grained groundmass.

Since it is apparent that the radiometric anomalies are caused by the porphyritic granite, with an average uranium content of about 10 ppm uranium, no further work can be recommended. However, the geochemical lake-sediment anomaly within the meta-arkose could be significant.

CHOQUETTE LAKE (MAPS 9b & 10: 59° 20'N, 100° 56'W):

The URP radiometric contour map for the uranium channel exhibits a well-defined anomaly of peak 2.6 ppm eU. The principal profile through this anomaly (Figure 26), indicates the coincident increase in the concentrations of all three radioelements, with the largest increase being in eTh. The eU/eTh ratio does not show an increase, but a marked increase is noted in the eU/K ratio.

The URP lake-sediment uranium data shows an isolated high in the 50 to 100 ppm range, and about two more readings in the 20 to 50 ppm range.

The histogram derived from 570 digitized helicopter-scintillometer readings is shown in Figure 27, from which it is apparent that it is a complex distribution. An attempt was made to resolve this into a number of normal or lognormal sub-populations. Artificial histograms were generated on the TI-59 programmable calculator, and their results superimposed on each other to simulate a distribution consisting of several sub-populations. The factor x^2 defined below,

$$x^2 = \sum_j \frac{(O_j - e_j)^2}{e_j}$$

where Oj = observed value in histogram class j
ej = expected value in histogram class j

was calculated to assess the degree of fit between the empirical and the artificial distributions. The lower the value of x^2, the better was the fit. Figure 27 shows the degree of fit obtained with $x^2 = 49.771$, after six attempts with four sub-populations considered, the lowermost being lognormal, and the rest normal. Their parameters are as follows:

The range mean ± one standard deviation encompasses 68.27% of a normal distribution. For population A this range is 1120 to 1540 counts/second, and for population B it is 650 to 1 030 counts/second. Therefore on the plot of the scintillometer readings (Map 10), areas encompassing readings between 1100 and 1550 counts/second and between 650 to 1050 counts/second have been indicated by appropriate boundaries. Readings of greater than 1600 counts/second have been indicated as point anomalies.

The geology in the area is the same as in the case of Rodgers Lake, but because of outcrop the geological map does not indicate the location of the contact. The lake-sediment plot indicates only one value greater than mean plus two standard deviations.

No further work is recommended in this area.

PUTAHOW LAKE (MAPS 11a, b & c; 59° 50'N, 100° 25'W):

This survey area lies within the Snyder-Putahow Belt, an area with one of the highest regional concentrations of uranium. The general nature of the distribution of this radioelement as recorded in the URP survey can be noted from Figure 4. The survey area includes the three anomalies of between 2.4 and 2.6 ppm eU which are located to the southeast of Putahow Lake. The principal profile through the anomaly in the middle of this group is shown in Figure 28. The noteworthy feature in this diagram is the very high level of uranium enrichment, and the relatively low thorium enrichment. Consequently, the eU/eTh and eU/K ratios are quite high.

The lake-sediment uranium map from the URP also indicates considerable amount of uranium enrichment. There are three readings in the 50 to 100 ppm range, and several more in the 20 to 50 ppm range.

The regional geology map (Weber et al., 1975b) is not complete because of the lack of outcrop. However, from the limited amount of data shown, it is evident that the principal rock types are the pelitic biotite gneiss, and the associated anatectic white granite.

The results of the helicopter-scintillometer survey are shown in Map 11a. The background at about 800 counts/second is relatively high. Peaks exceeding 2 600 counts/second have been noted, which are the highest amongst all the twelve areas covered by surveys of this nature. On Map 11a three main trends can be noted, all trending approximately north. The westernmost of these includes the anomalies labelled A and B, the middle one includes the anomalies C and D, and the third trend is close to the eastern margin of the survey area.

The lake-sediment uranium and radium results are shown on Maps 11b and 11c respectively. Table 3 lists the statistics of these geochemical surveys. The arithmetic mean at 32.58 ppm U is the highest amongst all the areas surveyed. The threshold, if taken at mean plus two standard deviations, turns out to be 106 ppm U. There is a marked coincidence betwen the uranium and radium anomalies. From the histograms and the cumulative frequency plots (Figure 29 & 30) it can be concluded that the distribution in the case of both the elements is approximately lognormal.

For the eight lakes which were sampled both under the URP and the follow-up survey, the coefficients of correlation were as follows: URP uranium with follow-up uranium, 0.980; URP uranium with URP LOI, 0.102; follow-up uranium with URP LOI, 0.070.

Eleven anomalies, which have been labelled A to K on Map 11a, can be identified as a result of the helicopter-scintillometer, lake-sediment uranium and lake-sediment radium surveys.

Anomaly A has a high amplitude and good resolution in the scintillometer trace. It reaches a peak in excess of 1800 counts/second. There is a coincident lake-sediment uranium anomaly of 155 ppm and a lake-sediment radium anomaly of 16.25 counts/minute, both of which are clearly anomalous.

Anomalies B and C have a moderate expression of about twice background on the helicopter-scintillometer trace. Anomaly B could not be sampled by the lake-sediment method, because the adjacent lake is too shallow. Anomaly C has a coincident lake-sediment uranium anomaly of 151 ppm. Zone D has considerable strike-length and scintillometer amplitudes in excess of 2 400 counts/second, which are the highest radiometric amplitudes encountered in all the

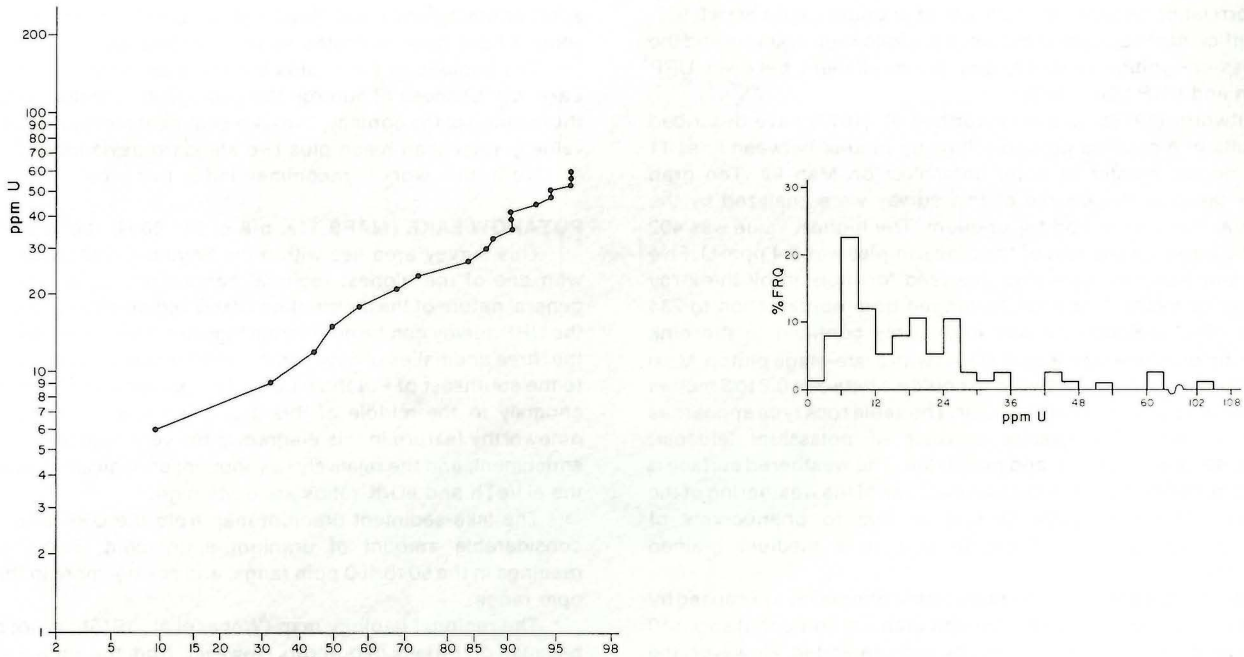


FIGURE: 25: Lake-sediment statistical plots, Rodgers and Choquette Lakes

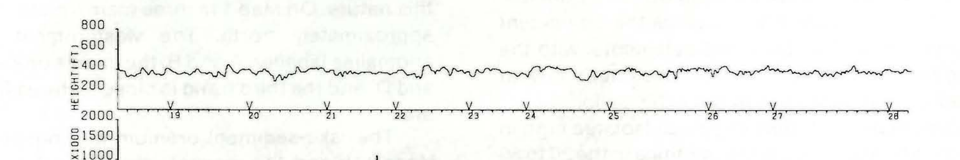


FIGURE: 26: URP stacked profiles, Choquette Lake

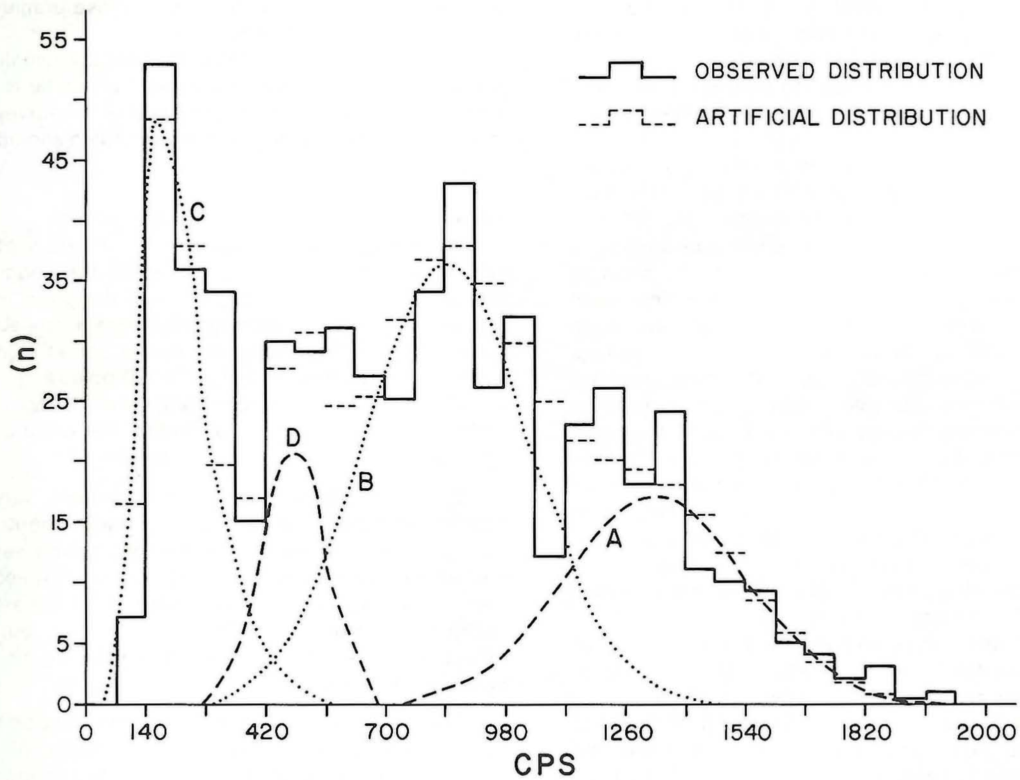


FIGURE: 27: Helicopter-scintillometer histogram, Choquette Lake

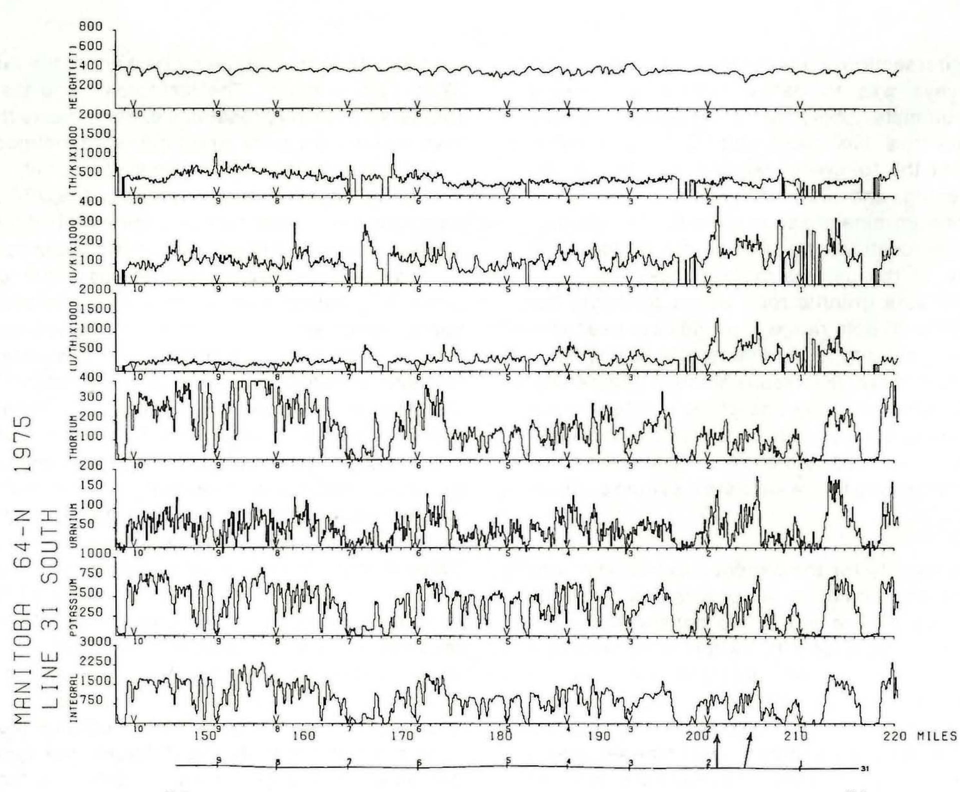


FIGURE: 28: URP stacked profiles, Putahow Lake survey areas. There is a coincident trend of lake-sediment anomalies, the highest of which is 158 ppm. Anomaly E is a weak elongated anomaly on the helicopter-scintillometer plot with no coincident geochemical anomalies. Zones F to K have relatively high amplitudes, both in the airborne-scintillometer and lake-sediment data.

Extensive ground follow-up has been done in the Putahow Lake area including about 1 700 m of diamond drilling (Soonawala et al., 1979; Garber and Soonawala, 1978; and Whitworth et al., 1977).

Anomaly A (Map 11a) which has been referred to as the Koona Lake showing has been investigated in detail. On the basis of scintillometer and radon survey results, several boulders were sampled and analyzed for uranium by the delayed neutron activation method. This was followed by about 1 700 m of diamond drilling. Uranium mineralization was found in a leucogranite which is massive and forms stocks of variable size and shape. Quartz, potassium feldspar and plagioclase are the essential minerals of this rock, which has a predominantly hypidiomorphic granular texture. Variable but minor amounts of biotite, garnet, tourmaline, pinitized cordierite and graphite are also present. This leucogranite is invariably associated with pelitic gneiss. Layers of pale green calc-silicate rock and pale grey impure quartzite also occur in the sequence. Drilling proved the presence of uranium mineralization over a strike-length of about one kilometre in the 100 ppm to 1 000 ppm range. The main uranium-bearing mineral was uraninite, which appeared to be associated with the more mafic portions of the rock. The mineral allanite was also detected in accessory amounts.

A situation similar to that at Anomaly A was encountered at Anomaly B, except that the grade of mineralization was lower, the highest assay being about 300 ppm uranium. Anomalies G, H, I and J were also checked on the ground, and it was found that the radiation was associated with granitic rocks, whose uranium contents was estimated to be less than 50 ppm.

Further drilling can be recommended at anomalies A and B, if the grade of mineralization encountered there so far is thought to be of interest. Anomalies in the eastern part of the survey area should be checked in greater detail, and the boulders should be assayed for uranium.

BAGG LAKE (MAP 12: 59° 55'N, 100° 07'W):

A low-amplitude but well-defined anomaly of 1.6 ppm eU is indicated in the URP contour map for the Bagg Lake area. The stacked profiles (Figure 31) confirm the good resolution of the anomaly. There is an attendant increase in the eU/eTh and eU/K ratios. The URP lake-sediment survey shows significant uranium anomalies in the area, in the 50 to 100 ppm range.

The geology according to Weber et al. (1975b) consists of pelitic biotite gneiss, its anatectic derivative, the white quartz monzonite and meta-greywacke and meta-siltstone.

The results of the helicopter-scintillometer survey are shown in Map 19. This map is quite featureless with about 50% of the area having radiation levels of less than 300 counts/second. There are only about four isolated spots with readings exceeding 500 counts/second. On the whole the northern half of the area has radiation backgrounds higher than the southern half, but this may be a reflection of the nature of the overburden, as the southern part is quite wet and swampy.

Though this area seemed quite promising on the basis of URP results and regional geology, the results of the helicopter-scintillometer survey turned out to be quite disappointing. No further work is recommended.

CONCLUSIONS

As mentioned in the first section of this report, the purpose of the follow-up regional surveys was to define targets for ground exploration with the ultimate objective of locating uranium mineralization. This objective has been met. Ground surveys, undertaken as a result of the follow-up regional surveys, in the Overby, Poulsen, Greening and Putahow survey areas were successful in locating uranium mineralization in the 100 to 1 000 ppm range. At some of the other locations, e.g., Choquette, Rodgers and Finner areas the source of the gamma radiation has also been unambiguously identified as a granitic rock with a relatively low uranium content in the 10 to 30 ppm range. It would have been very expensive and laborious, if not altogether impossible, to plan such ground surveys on the basis of the URP results alone. A comparison of the data in Figures 4 and 5 with any one of the nineteen maps produced as a result of these surveys, demonstrates the degree of precision which has been introduced by the follow-up surveys. Most of the targets so defined for ground follow-up were less than a square kilometre in extent.

The average sample density for the geochemical surveys was one sample per three square kilometres. It appears that no useful information would have been obtained if this density had been increased. Accordingly it is necessary to switch to geophysical methods, whether airborne or ground, at some stage in the exploration sequence in order to obtain data of the quality necessary for a ground follow-up program. The lake-sediment uranium anomalies do not correlate with the organic content of the sediments (r is 0.038) and therefore it may be concluded that these are 'genuine' anomalies. The arithmetic mean for the seven areas is between 5 and 33 ppm uranium with the 10 to 20 ppm range being the most common. The lowest concentrations are in the Munroe Lake East area at 5.48 ppm, and the highest are in the Putahow Lake block at 32.58 ppm uranium. The histograms and the cumulative percent frequency plots on probability paper indicate that the lake-sediment distributions are quite straightforward, unimodal with the distribution being very close to lognormal. It is rather comforting to note that the coefficient of correlation between the URP uranium data and the data from the current survey is fairly high at 0.807, even though the surveys were done either one or two years apart.

The helicopter-scintillometer was meant to be prospecting tool, and in this respect it has been quite successful in outlining the 'hot-spots', which led to the location of the sources of radiation on the ground. The statistical analysis of this data proved that it also contains a wealth of additional information. The distributions are almost invariably multimodal and quite complex. Two methods were tried to separate these sub-populations, one being the established method of analyzing data plotted on probability paper, and the other the novel method of generating an artificial histogram and then varying its parameters to obtain the best fit between it and the observed distribution. The latter is evidently more appropriate in cases where the data is being machine processed. Logically, this separation process should lead to the identification of rock types of differing radiometric signatures, some of which would be more favourable hosts for uranium mineralization than others. However, this process initially leads to the identification of areas with a gross difference in their radiometric characteristics, e.g., boulder fields and swamps, but the potential to continue the process further and radiometrically identify the different rock types, is still there. The demarcation of a geological boundary in the Rodgers Lake area (Map 9a) by this method is remarkable, and in all probability the boundary as indicated by radiometrics is more precise than that shown on the geological map.

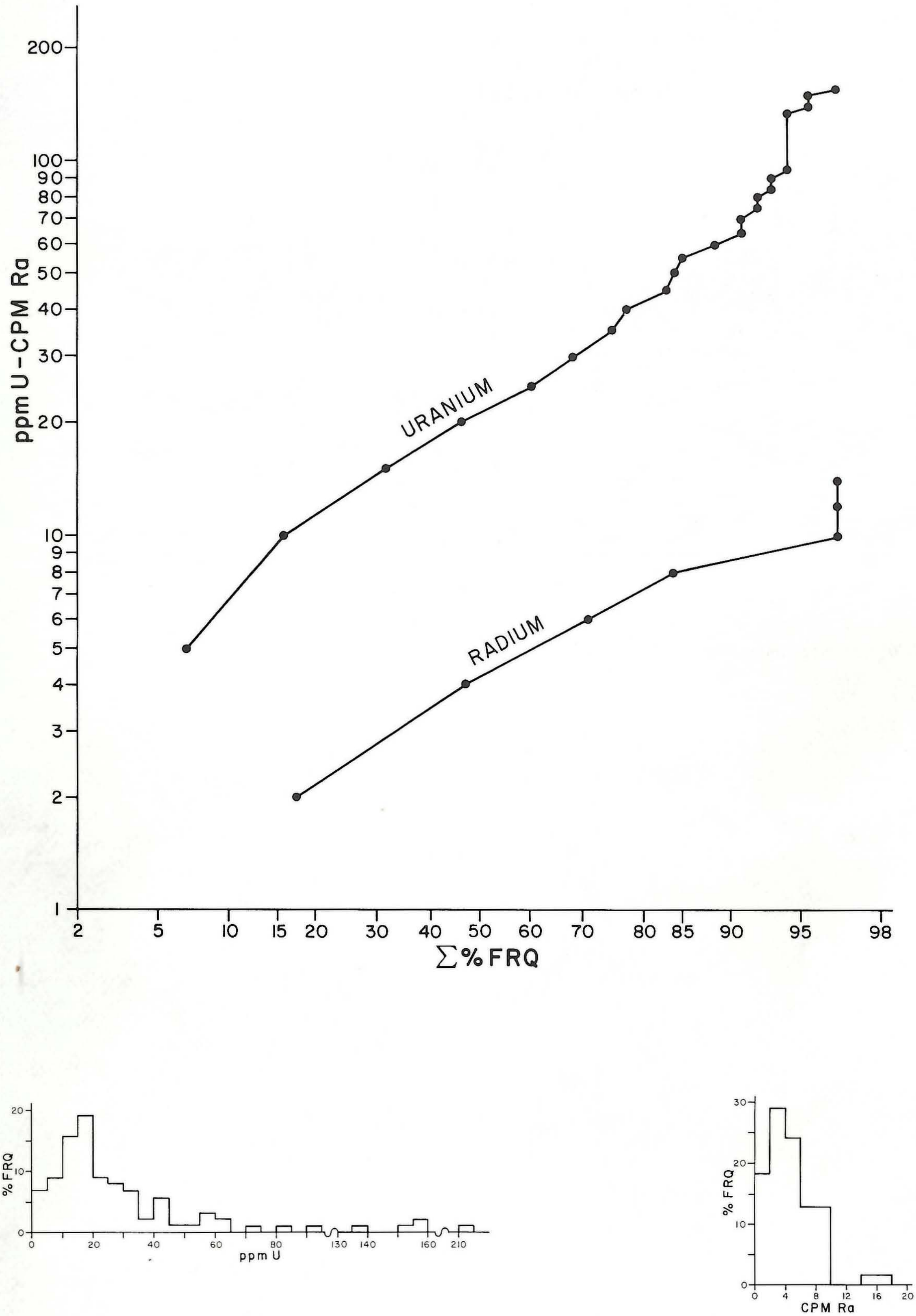


FIGURE: 29: Lake-sediment statistical plots, Putahow Lake

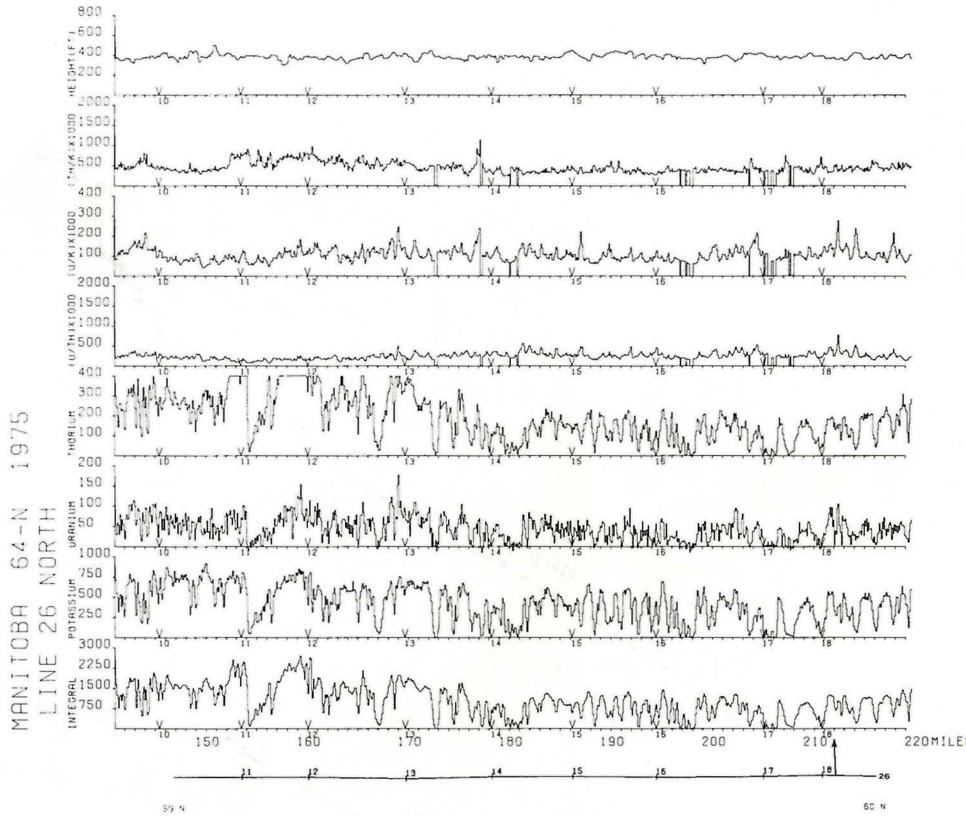


FIGURE: 30: URP stacked profiles, Bagg Lake

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