OFFICE MILITAIRE NATIONAL POUR LES INDUSTRIES STRATEGIQUES

REPOBLIKA DEMOKRATIKA MALAGASY

AIRBORNE GEOPHYSICAL SURVEY

FORT DAUPHIN AREA

Hunting Geology and Geophysics Ltd.,
Elstree Way,
Boreham Wood,
Hertfordshire, WD6 1SB,
England

Telephone: 01-953 6161
Cables: ASTEREO BOREHAMWOOD
Telex: 23517 HUNBOR G

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ABSTRACT

An airborne magnetic and spectrometric survey was undertaken over an area of calc-silicate Precambrian basement rocks in southeast Madagascar for the purpose of assessing the uranium potential of the area, and determining the extent of previous mining operations.

The main source of uranium is the mineral urano-thorianite which occurs within a layered sequence of para-pyroxenites, although the major radioactive element present within the survey area is thorium.

The survey has been successful in identifying and classifying many linear radioactive zones containing uranium and determining their strike length.

Several first priority uranium anomalies have been located in areas where no previous mining has taken place. In old mining areas many good quality anomalies exist, though some of these are produced by contamination associated with mine dumps, old crushing plants and worked out quarries. Every effort has been made to determine the true origin of all spectrometric anomalies by reference to existing maps and the tracking film.

Generally the major zones of radioactivity are associated with broad magnetic 'lows', although it has not usually been possible, from the air, to resolve magnetic anomalies associated directly with radioactive pyroxenites.

CONTENTS

PART 1 - INTERPRETATION REPORT

PART 2 - OPERATIONS REPORT

PART 1

INTERPRETATION REPORT

1. INTRODUCTION

This report describes the results of a combined airborne magnetic and spectrometric survey undertaken for the Office Militaire National pour les Industries Stratégiques by Hunting Geology and Geophysics Limited over an area immediately to the west of Fort Dauphin, S.E. Madagascar.

The purpose of the survey was to assess the uranium potential of the area and to determine the extent of previous mining operations.

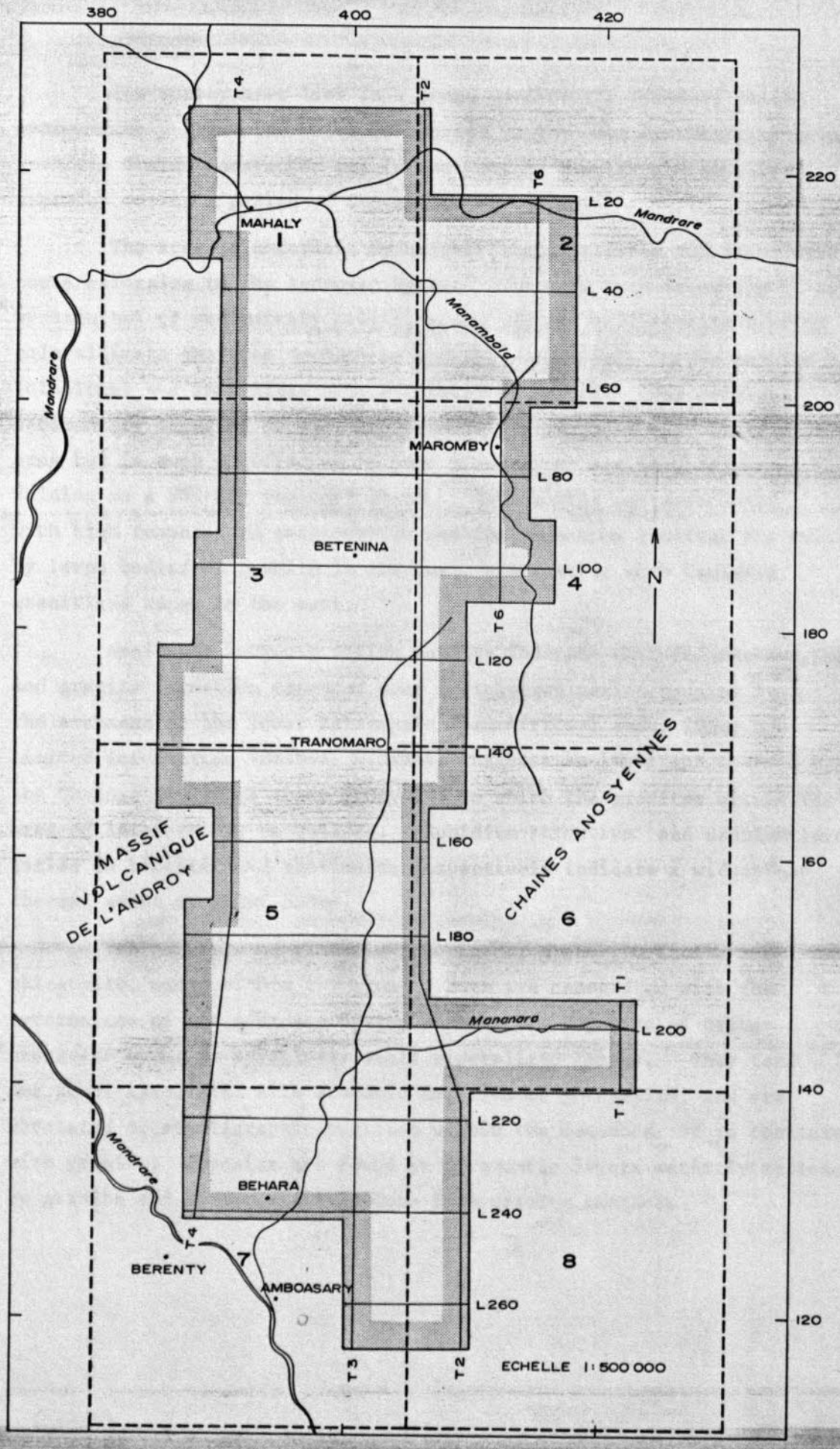
Whilst the main emphasis of the survey was placed on the spectrometric results, the magnetics were flown primarily to determine the magnetic response of the pyroxenites which were known to contain urano-thorianite, the most important uranium bearing mineral, as well as to assist in the geological mapping of the area.

The flying was undertaken by our associate company Aerial Surveys Botswana (Pty.) Ltd. using a Douglas DC-3 aircraft registration A2-ZFD between 22nd March and 10th April 1977. The total distance flown was 7310 line kilometres, which includes 40km of flying in the Tsanerna area.

Flying operations throughout the survey period were restricted by low cloud and rain, particularly on the mountains at the eastern and western ends of the flight lines.

Hunting Geology and Geophysics Limited would like to express their appreciation for the help and assistance given by OMNIS personnel.

TABLEAU D'ASSEMBLAGE DES FEUILLES A 1·50000 ET POSITION DES LIGNES DE VOL



2. GEOLOGY

The survey area lies in a broad north-south trending valley approximately 30km wide which is bounded in the east by the Precambrian granitic Chaines Anosyennes and in the west by basalts and rhyolites extruded during a period of Cretaceous vulcanism.

The area is underlain by calc-silicate gneisses and associated rocks belonging to the Androyen System. The main rock types are pyroxenites of sedimentary origin, scapolite and wollastonite bearing calc-silicate gneisses (wenerites and wollastonites), impure marbles (cipolins) and leptynites with cordierite or garnet. The original sedimentary layering of this sequence is preserved in most parts of the area but is much modified by intense deformation and large-scale folding on a NNE-SSW regional trend. Deformation was associated with high temperature metamorphism and the formation granites are represented by large bodies of granite in the west, and smaller more isolated granitised zones in the east.

Available isotopic dating results indicate that deformation, metamorphism and granite formation extended over a prolonged period ranging from the Archaean to the lower Paleaozoic (pan-African) about 500my ago. Limited information (Delbos, L. 1964) suggests an important thermal event in the Chaines Anosynnes about 900my ago to which the granites within the area of interest may be related. Rubidium-strontium and uranium-lead ratios in biotites and thorianite respectively indicate a widespread thermal event at about 500my.

Two minerals of economic importance, urano-thorianite and phlogopite, occur within the area. Both are associated with the pyroxenites of the Androyen System. Economic deposits of urano-thoranite occur in relatively small mineralised lenses. They tend not to be associated with economic deposits of phlogopite, and are unrelated to stratigraphic position within the sequence or to contacts with granite; deposits are found in pyroxenite layers entirely enclosed by granite and at localities remote from granite contacts.

3. SPECTROMETRIC SURVEY AND DATA PROCESSING

3.1 Theory

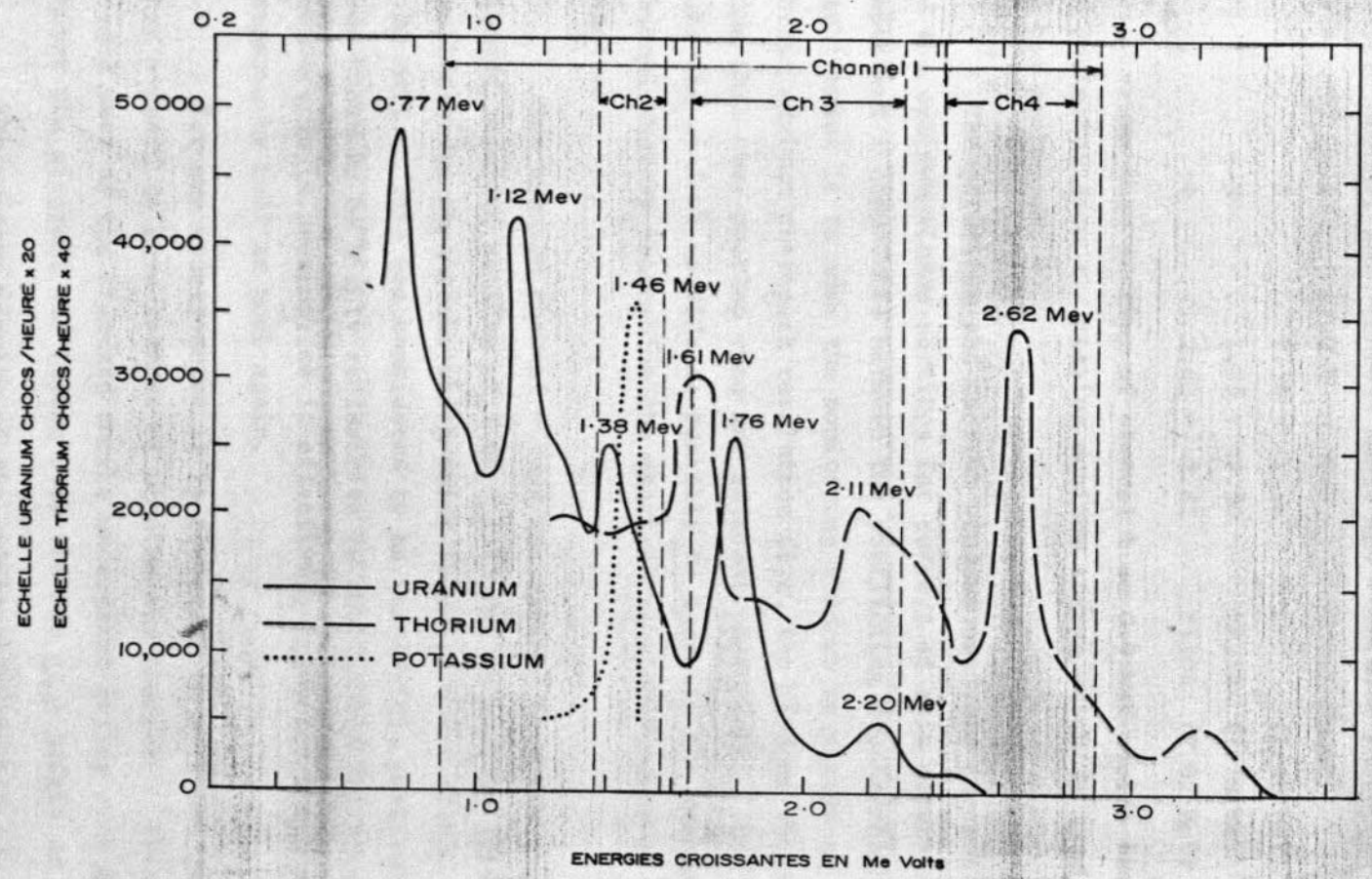
Natural gamma radiation is created from the radioactive decay of isotopes belonging to the U-238 and Th-232 decay series, from the radioactive isotope K-40, which forms 0.012% of all potassium, and also from cosmic radiation. The decay series associated with U-235 is not usually considered in radiometric prospecting as its concentration relative to the U-238 series is only about 0.7%.

In the U-238 and Th-232 series the original 'parent' nuclide disintegrates spontaneously, via a series of 'daughter' products, to form respectively stable isotopes Pb-206 and Pb-208. The most important types of radiation emitted during this decay process are alpha radiation (positive helium nuclei), beta radiation (negative electrons) and gamma radiation (electromagnetic energy). Alpha and beta particles are only weakly penetrating in air whilst gamma radiation has much greater range and penetrating power as it has neither mass nor charge.

U-238, Th-232 and K-40 are recognisable by their gamma ray spectra, as each spectrum is characterised by particular photo peak energy levels (see Figure 2) which represent specific disintegration stages. The U-238 series is usually identified by a major photopeak at 1.76 million electron volts (MeV), from the decay of bismuth 214, and the Th-232 series by the 2.62 MeV peak of thallium 208; potassium 40 has a single photo peak at 1.46 MeV. These particular peaks are the ones generally used for source discrimination as they can be isolated more readily from peaks belonging to other disintegrations.

It will be seen from Figure 2 that the spectra are superimposed on a continuous background which increases towards the lower energy end of the spectrum. This background count rate is called the Compton Continuum and results from the partial loss of gamma ray energy by their collision with the orbital electrons of the atoms contained in either the original source material, the intervening atmosphere or in the detecting crystals.

In a differential, four-channel, gamma ray spectrometer equipment it is conventional to adjust three of the energy windows to monitor the three main photo peaks at 1.46, 1.76 and 2.62 MeV whilst the remaining



SPECTROGRAMMES PARTIELS D'ENERGIE POUR LES SERIES DE DESINTEGRATION DE L'URANIUM ET DU THORIUM ET PIC DU POTASSIUM A 1.46 MeV

D'APRES LE RAPPORT A.E.R.E. EL/R2696 DE U.K. ATOMIC ENERGY AUTHORITY

channel records a large portion of the total spectrum. For this survey the window settings were as follows:-

Channel No.	Energy Range MeV	Primary Photopeak	Series
1	0.9 - 2.9	Total Count	
2	1.36 - 1.56	K40 (1.46 MeV)	K
3	1.65 - 2.30	Bi214 (1.76 MeV)	U
4	2.42 - 2.82	Tl208 (2.62 MeV)	Th

The base setting of channel 1 at 0.9 MeV avoids the inclusion of radiation from a caesium monitor source which is used in the stabilisation of the equipment.

The potassium and thorium windows used are currently regarded as the optimum window settings for surveys of this nature and represent a compromise between two conflicting requirements. The first requirement is to make the monitoring windows as narrow as possible to obtain maximum photopeak resolution (i.e. the windows should not be so wide that they overlap onto any adjacent photopeak). The second is to make the windows as wide as possible to increase the response in each channel thereby increasing the statistical significance of any anomaly detected.

The uranium channel window was widened from the originally planned standard setting of 1.66 - 1.86 MeV to include three additional smaller Bi214 photopeaks which exist above 1.76 MeV (1.85, 2.12 and 2.20 MeV). This was considered to be beneficial, particularly in an area known to be highly radioactive in thorium and relatively weakly radioactive in uranium, as it effectively increases the uranium channel response by half as much again.

For any spectrometer it is essential to know how it responds when exposed to pure sources of uranium and thorium. This experiment formed part of the standard checks undertaken during each day's flying whilst the aircraft was flying over the sea at a height of 150 metres.

The average results of the calibration checks gave the following percentage responses in each channel.

	Th Channel	U Channel	K Channel
Thorium Source	35%	41%	24%
Uranium Source	3%	59%	38%
Potassium Source	0	0	100%

As no potassium 40 source was available during the survey, the figures given above for potassium represent the theoretical response of an ideal system. In practice it is often found that 1% or 2% of the counts from a potassium source appear in the uranium channel.

It is evident from these figures that for pure thorium and uranium sources unwanted counts are recorded in adjacent channels. This leakage of energy between channels is produced partly from Compton Scattering of gamma radiation and partly by window settings overlapping other photopeak energies.

This interference may be removed by a process known as 'stripping' which is achieved electronically by the spectrometer for the analogue recorded data and by a computer program during the processing of the digitally recorded data. (See section 3.4.3 and Operations Report Section 3.2).

3.2 Airborne Methods

Surface gamma radiation can be detected at ground clearances of up to and occasionally greater than 300 metres although useful information is usually obtained between 50 and 200 metres where the original ground intensity is reduced by 25% and 75% respectively. The detecting crystals receive the bulk of signal from a circular area on the ground beneath the aircraft with a radius approximately equal to the flying height. This implies that for 'complete' coverage, traverses should be separated by about twice the flying height. In order that the results on adjacent flight lines may be correlated with each other it is necessary to maintain a constant ground clearance. Since this is impossible in practice, reference to an accurate radar altimeter is essential to enable spectrometric data to be corrected to a common datum. The method of compensation normally assumes that the ground is flat and of uniform radioactivity. The result is that an erroneous correction is applied to radiation emitted from effectively point or line sources, in which the intensity fall off is inversely proportional to the distance squared and distance respectively; also no account is taken of variations in solid angle due to changes in topography. Errors, therefore, tend to be greatest in areas of high relief where compensation is most needed.

3.3 Factors Affecting the Radiometric Response of Rocks

The amplitude of radiation emitted from the ground is influenced by a number of factors which are independent of the intensity of the

radioactive source; the following list summarieses the most significant factors.

(a) Overburden

Gamma radiation in the range 1.46 - 2.62 MeV is readily attenuated by rock and overburden. Approximately 90% of the total gamma radiation from a rock of 2.7 g/cm^3 comes from the upper 15-23cm; from dry overburden of density 1.5g/cm^3, 90% of the radiation comes from the upper 30-45cm. Gamma radiation measurements therefore, only detect radioactive elements in a relatively thin surface layer. The surface material must be representative of the bedrock composition, and in an area which is covered by detritus, the surface material must be residual or locally derived if the measurements are to be meaningful. Also, the outcropping rocks and overburden must not have suffered removal of significant constituents through weathering; uranium is particularly susceptible to this kind of alteration.

Consequently if a radioactive source is buried beneath one metre of non-radioactive soil or drift (e.g. alluvium sand or water) or 20cm of bedrock, no anomaly will be detected as all gamma radiation will have been entirely absorbed by the overburden.

(b) Vegetation

Dense vegetation with a high moisture content will also attenuate anomalies.

(c) Climatic Changes

Rainstorms can reduce the count rates by over half for several hours due to sources being blanketed by a layer of moisture. However anomalies can be created temporarily by radioactive dust deposited by rain and/or wind. Temperature inversion effects can also restrict the mobility of radon gas, thus producing anomalous background counts near ground level.

(d) Topography

Topographic relief affect the surface area which the spectrometer monitors, and produces the so-called solid angle effect for which no perfect correction can be applied.

(e) Aircraft Speed

This affects the count rates as the higher the aircraft speed the shorter the time the aircraft spends within the radioactive flux, and consequently reduces the anomaly amplitude as well as distorting its shape.

(f) Flying Height

Variations in ground clearance affect the amplitude due to varying attenuation of gamma radiation in air. An approximate empirical correction has been determined for the effect and applied to all the data. (See sections 3.2 and 3.4)

3.4 Correction of Data

3.4.1 The non-geological background radiation usually known as the cosmic background is of complex composition and includes contributions from cosmic radiation, atmospheric radon, the aircraft structure and its equipment. In addition apparent changes in background levels throughout a day's flying may be caused by slight changes in the operating temperature of the spectrometer and detecting crystals.

Background levels were monitored at the beginning and end of each sortie by flying a test line over the sea at the flying altitude of 150 metres. Water never emits gamma radiation from its surface.

The mean values of the cosmic background recorded were:-

	Total Count	K	U	Th
Cosmic Background (Unstripped) counts/sec.	500	40	16	6

In the digital processing of the data these values were subtracted from the appropriate channel.

3.4.2 The remaining ground-originating radiation was corrected for variations produced by changes in the flying height of the aircraft. Gamma radiation is attenuated approximately exponentially in air within several hundreds of metres above the ground. The approximate empirical correction for this affect is:-

$$C_{150} = C_h \exp(-k(150-h))$$

where C_{150} = count rate corrected to 150 metres

C_h = count rate at h metres

k = attenuation constant per metre

Values for k based on the work published by Darnley (1973) give the following values for k:

	CHANNEL			
	T.C.	K	U	Th
k per metre	0.0066	0.0075	0.0056	0.0056

Tests undertaken on the Fort Dauphin survey data indicated that these attenuation constants were too great and over-corrected each channel for height. This tended to produce false anomalies when the aircraft was flying well above the flying height of 150 metres.

It was found that an attenuation constant (k) of 0.003 per metre gave much improved results without over-correcting the data, and this correction factor was used on all channels for the height correction.

The limitations of this method of height correction are discussed in section 3.2.

3.4.3 As the digital data were recorded in a raw unstripped form, the potassium, uranium and thorium channels were stripped using stripping ratios which were derived from the response of the spectrometer to pure sources of uranium and thorium. (See section 3.1 and Operations Report Section 4.)

α = counts in U channel per count in Th channel = 1.17
β = counts in K channel per count in Th channel = 0.68
γ = count in K channel per count in U channel = 0.64
δ = count in Th channel per count in U channel = 0.05

The three simultaneous equations which require solving in order that stripping may be undertaken digitally are:-

$$Th_{corr} = N_{Th} - \delta U_{corr}$$

$$U_{corr} = N_u - \alpha Th_{corr}$$

$$K_{corr} = N_k - \beta Th_{corr} - \gamma U_{corr}$$

Where N_{Th}, N_u and N_k represent the observed count rates in the relevant windows less their respective cosmic backgrounds.

The solutions of these equations give:-

$$Th_{corr} = 1.063\ N_{Th} - 0.054\ N_u$$

$$U_{corr} = 1.063\ N_u - 1.246\ N_{Th}$$

$$K_{corr} = 1.000\ N_k - 0.648\ N_u + 0.073\ N_{Th}$$

3.5 Preparation of CALCOMP profiles

The CALCOMP profiles refer to computer drawn profiles which include three spectrometer channels (K, U and Th), U/Th ratio, altimeter and magnetic traces, all stacked above one another for each flight line.

Prior to plotting, the potassium, uranium and thorium channels were corrected (see section 3.4) and processed by an equal weight five point smoothing filter which reduced much of the statistical noise inherent in the original stepped data recorded each second. This filter has the slight adverse effect of broadening very narrow anomalies but overall greatly improves the appearance and usefulness of the profiles.

The U/Th channel ratio profile was calculated using the corrected and stripped uranium and thorium channel values and plotted after 5 point smoothing.

Magnetic and altimeter profiles were plotted directly from the raw data recorded on magnetic tape.

The plotting scales used for each profile are given below:-

	Scale	Base Value
Altimeter (bottom of chart)	1 inch = 100 metres	50 metres
Potassium Corrected	1 inch = 100 cps	Zero
Uranium Corrected	1 inch = 100 cps	Zero
Thorium Corrected	1 inch = 100 cps	Zero
U/Th ratio	1 inch = 1 unit	Zero
Magnetometer (top of chart)	1 inch = 1000 nT	31500 or 32500 nT

The horizontal scale was 1 inch = 20 seconds which would represent a true scale of 1:50,000 if the aircraft flew at a constant ground speed of 228.7km/hr.

In using the CALCOMP profiles for interpretation purposes the following points may be of assistance.

(a) The altimeter trace is plotted in the opposite sense to the altimeter profile on the MARS analogue records.

(b) The U/Th ratio profile is more sensitive in displaying a reduction in thorium radiation rather than an increase in uranium. This is because of the inherently lower number of counts being recorded in the thorium channel in comparison with

those in the uranium channel. Reduced thorium counts which result in U/Th anomalies are usually produced either by geological factors or excessive terrain clearance. The height correction is relatively unsuccessful in correcting thorium counts as this value approaches zero. (See section 4.2.5) For interpretation purposes no value has been found in the U/Th ratio parameter.

(c) Discontinuities in the uranium and potassium channel profiles are evident occasionally where negative values were produced after stripping. These are caused by the existence of unfavourable statistical relationships between the K, U and Th channels and frequently arise in areas of steep radiation gradients where individual channel responses are not always exactly in phase.

(d) The value of the various data correction processes, particularly stripping, is well illustrated by the CALCOMP profiles in their ability to distinguish between good quality thorium anomalies which contain some uranium from those which do not. (See Anomalies on FL.67 and FL.184)

3.6 ANOMSEC Anomaly Selection Program

The initial correction of the data was identical to that used for the CALCOMP profiles except that three point smoothing was used instead of five. The total count channel was processed after the subtraction of a cosmic background of 500 counts per second and height corrected using an attenuation constant of 0.003.

Anomaly seeking was undertaken on the uncorrected and unstripped channel 3 (uranium) data which represents approximately a summation of uranium and thorium radiation.

Using this technique it is theoretically possible that a potassium anomaly may be overlooked, though for the present survey this was considered to be unlikely. The criteria for anomaly selection was that an anomaly should have a peak channel 3 amplitude greater than 50 cps and a width of at least 3 seconds. (Note: It is not possible to identify an anomaly in less than three recording points.)

3.6.1 The ANOMSEC output listing of anomalies gives:

(i) The Line Number. The last digit refers to the part of the line (e.g. Flight Line No.135 is referred to as Line 1351;

the last digit, one, being the part number of the line).

(ii) The anomaly number along the line is used as an anomaly reference number on the interpretation maps.

(iii) The 'peak time' gives the time of the anomaly peak in channel 3 (in seconds). This number corresponds with the fiducial times plotted along each line and permits each anomaly to be plotted accurately onto the flight path map.

(iv) The two 'half width times' of the anomaly. These times correspond to the locations of where an anomaly is reduced to half its amplitude above background after three point smoothing.

(v) The 'peak altitude' gives the flying height of the aircraft in metres at the anomaly peak.

(vi) The 'peak raw counts' give the amplitude of the total count channel, less cosmic background, at the total count peak which must lie within ± 3 seconds of the channel 3 peak.

(vii) The 'channel 1 peak time' gives the time of the total count anomaly peak. This is generally the same as the channel 3 peak time but may occasionally differ by a second or two.

(viii) The central 'corrected counts' box gives the 'peak' values for each channel at the peak anomaly time after each channel has been corrected for the removal of cosmic background and height corrected.

Background values for each channel are located by finding two minima, one on either side of the maximum value, constructing an imaginary straight line between the two minima and recording as background the value where this line intersects the peak time.

The 'anomaly' represents the difference between peak and background values for channel 1. For the remaining channels it is the difference between peak and background values after stripping. Occasionally if the source contains no potassium (say) the 'anomaly' in channel 2 may have either a small positive or negative number of counts, which effectively represents the residual noise of that channel.

The '%' gives the relative percentage of potassium, uranium and thorium radiation of the anomaly source. Negative anomaly counts are ignored for this calculation. The calculation is described below in Section 3.6.1 item (x).

(ix) In the right hand box the ratios of U/Th, U^2/Th and U/K are presented using the corrected and stripped values for the anomaly above background.

(x) The 'anomaly type' refers to the classification of the anomaly based on its position on a ternary diagram. (See Figure 3)

Most natural radioactive sources are rarely pure but contain variable amounts of all three radio elements. In order to isolate the dominant source the height corrected percentage response in each of channels 2, 3 and 4 is plotted on a ternary diagram. This percentage represents the K, U, Th system and is divided into nine fields, each field representing a range of ratios of the percentage response in the three channels as in the accompanying diagram. The percentage response in channels 2, 3 and 4 are calculated as follows:-

$$\% K = \frac{Ch2}{Ch2 + Ch3 + Ch4} \times 100$$

$$\% U = \frac{Ch3}{Ch2 + Ch3 + Ch4} \times 100$$

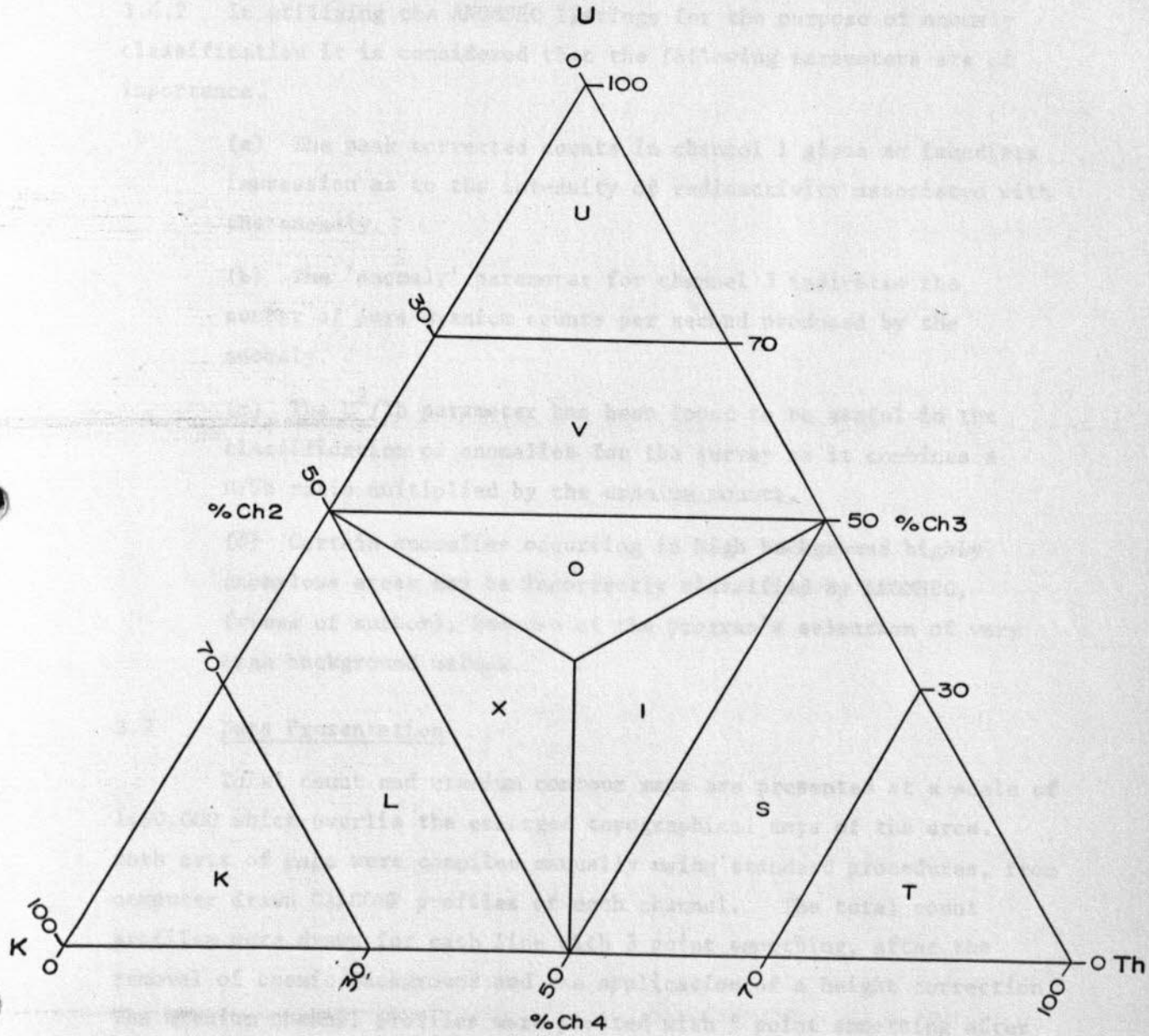
$$\% Th = \frac{Ch4}{Ch2 + Ch3 + Ch4} \times 100$$

where Ch2, Ch3 and Ch4 are the corrected and stripped counts, above local background, of channels 2, 3 and 4.

It should be noted that this method of diagnosis assumes radioactive equilibrium of the decay series. Disequilibrium can result from the escape or migration of radioactive daughter products in the series. This consideration is of particular importance in the uranium series, where one daughter product, radon, is gaseous.

(xi) The 'source' is an identification of the predominant radioactive material producing the anomaly. (See ternary diagram Figure 3.)

K-U-Th DIAGRAME TERNAIRE
MONTRAINT LES CHAMPS SPECTROMETRIQUES



Champ	Identification	
U	U	Sources dominantes d'uranium, potassium ou thorium respectivement.
K	K	
T	Th	
V	U + Mélangé	Sources predominantes d'uranium, potassium ou thorium avec potassium et thorium, uranium et thorium, et potassium et uranium inférieur respectivement.
L	K + Mélangé	
S	Th + Mélangé	
O	Mélangé (U)	Sources mélangées avec faible prédominance d'uranium, potassium ou thorium respectivement.
X	Mélangé (K)	
I	Mélangé (Th)	

3.6.2 In utilizing the ANOMSEC listings for the purpose of anomaly classification it is considered that the following parameters are of importance.

(a) The peak corrected counts in channel 1 gives an immediate impression as to the intensity of radioactivity associated with the anomaly.

(b) The 'anomaly' parameter for channel 3 indicates the number of pure uranium counts per second produced by the anomaly.

(c) The U^2/Th parameter has been found to be useful in the classification of anomalies for the survey as it combines a U/Th ratio multiplied by the uranium counts.

(d) Certain anomalies occurring in high background highly anomalous areas may be incorrectly classified by ANOMSEC, (views of author), because of the program's selection of very high background values.

3.7 Data Presentation

Total count and uranium contour maps are presented at a scale of 1:50,000 which overlie the enlarged topographical maps of the area. Both sets of maps were compiled manually using standard procedures, from computer drawn CALCOMP profiles of each channel. The total count profiles were drawn for each line with 3 point smoothing, after the removal of cosmic background and the application of a height correction. The uranium channel profiles were plotted with 5 point smoothing after cosmic background, height and stripping corrections had been applied.

The total count map was contoured whenever possible at an interval of 100 cps and the uranium map at an interval of 25 cps with the minimum contour value being 50 cps.

The interpretation maps show selected computer anomalies identified by their ANOMSEC numbers (e.g. 123/3 represents flight line 123 ANOMSEC anomaly number 3), their relationship to anomalies on adjacent lines and their classification. (See section 4.2)

4. SPECTROMETRIC INTERPRETATION

4.1 Geology and Radioactive Minerals

It is understood that the survey area possesses three main sources of radioactivity:

(i) As urano-thorianite which is known to occur in economic concentrations in lenses within the para-pyroxenites. Previous mapping and mining operations suggest that the lenses are generally ellipsoidal in shape and have a major axis strike length of between 200 metress and 1 kilometre. It is also expected that they can occur with a variable orientation virtually in any position along a fold.

Although the main source of uranium is urano-thorianite the dominant radioactive element within this mineral is thorium. Sampling of known quarries and trenches throughout the area have indicated that the ratios of U/Th concentrations are very variable throughout the area as a whole.

(ii) As pegmatites which are expected to be predominantly thorium anomalies.

(iii) As alluvium, colluvium or eluvium deposits of monazite possibly with some residual zircon and urano-thorianite. Monazite is mainly a thorium source but usually contains some uranium; zircon also contains uranium. These resistant minerals are known to occur as beach sand deposits on the coast and also within the survey area as alluvial and eluvial deposits. At present their extent and economic importance within the survey area, if any, is not known.

4.2 Anomaly Classification

Consideration was given to the following factors in classifying anomalies:

(i) The corrected and stripped uranium channel anomaly

(ii) The total count channel amplitude

(iii) Anomaly shape

(iv) The relationship of an anomaly to anomalies on adjacent lines.

(v) U^2/Th ratio

4.2.1 First Priority Anomalies

First priority anomalies are characterised by having corrected and stripped uranium channel amplitudes above background, greater than 100 cps and peak total count values greater than 1500 cps, and frequently greater than 3000 cps. Qualitatively they may be described as indicating a predominantly mixed radioactive source of either a high or very high thorium content occurring in association with relatively high uranium.

These anomalies are interpreted as having the best potential of being associated with economic uranium mineralisation. However it must be emphasised that the probable origin of anomalies has not influenced their classification. Many first priority anomalies are known to be associated with previous mining operations and include anomalies produced by worked out quarries, mine dumps and crushing or separation plants. The probable origin of anomalies are presented in tabular form in Appendix 1 and discussed in detail in section 4.3. In general there is excellent agreement between the plotted positions of quarries and first or second order priorities.

It is recommended that the true origin of all first priority anomalies be established by field checking.

4.2.2 Second Priority Anomalies

Second priority anomalies are characterised by having corrected and stripped uranium channel amplitudes above background of between 60 and 100 cps and peak total count values greater than 1500 cps.

These anomalies are interpreted as being predominantly thorium anomalies but contain definite indications that uranium is present. However from the spectrometric results alone it is impossible to say whether the mineralisation occurs in economic quantities.

It is recommended that all second priority anomalies warrant ground follow-up and that their true origin be established.

4.2.3 Third Priority Anomalies

Third priority anomalies are weak to moderate thorium anomalies having corrected and stripped uranium counts above background of between 30 and 60 cps and total count anomaly peaks greater than 1000 cps.

Generally the uranium potential of these anomalies must be regarded as poor. However, included in this classification may be anomalies associated with thorium/uranium radiation whose amplitude is reduced by surficial cover. At a later stage and after a thorough investigation of first and second order priority anomalies it may be possible to identify such anomalies from their geological and magnetic setting and by careful study of the CALCOMP profiles.

Several of the major first and second order priority linear anomalies are continued along strike or linked by third priority anomalies. The significance of this type of anomaly is not known. It may represent the continuation of a pyroxenite bed with reduced concentrations of uranothorianite or it may represent an anomaly whose amplitude is reduced by either adverse geometry (e.g. on a hill slope which faced away from the aircraft) or surficial cover.

Not all third priority anomalies are shown on the Interpretation Map particularly if they occur as single line anomalies.

4.2.4 Fourth Priority Anomalies

Fourth priority anomalies have been selected by ANOMSEC as weak thorium anomalies displaying relatively small total count amplitudes (less than 1000 cps) with little or no indications of any uranium content. As with third priority anomalies consideration must be given to the possibility that the amplitude of fourth priority anomalies is reduced by overburden.

Not all fourth priority anomalies have been plotted.

4.2.5 Discussion

The main criticism of the above classification is that it is based almost entirely on total count and uranium amplitudes. As mentioned previously (see sections 3.3 and 4.2.3) this can be a dangerous method of approach and is generally overcome at the interpretation stage by considering various channel ratios which usually remain constant whilst amplitudes may vary. However conditions in this area are unusual as the dominant radioactive element is thorium, whilst uranium occurs in association with thorium as the mineral urano-thorianite. The known ratios of U/Th concentrations in potentially ore grade pyroxenites throughout the survey area vary from 0.833 to less than 0.05. Hence

it may be expected that U/Th channel ratios may either fall or rise over radioactive pyroxenites which clearly reduce the effectiveness of this parameter for anomaly classification. This view is substantiated by inspection of the U/Th ratio CALCOMP profiles of first, second and third order priority profiles.

The CALCOMP profiles also illustrate the very low and constant potassium response obtained throughout the area with the result that Th/K and U/K ratios provide little or no assistance in anomaly diagnosis. It is difficult to explain the reason for a low potassium response in an area containing granitic rocks.

4.3 Uranium and Total Count Contour Maps

The main value to be gained from these maps is in assessing the distribution of uranium throughout the area in comparison with the distribution of all other radioactive elements. It is evident that in general the main areas of high radioactivity also correspond with areas of high uranium. A closer quantitative comparison between individual anomalies indicates that no simple relationship exists between corresponding uranium and total count amplitudes.

The difference in the regional radioactive response is well illustrated by comparing the very low backgrounds recorded in the north on sheets 1 and 2 with the high backgrounds found in the south on sheets 7 and 8. A possible explanation for this difference, which is supported by the magnetic results, is that the northern area is composed mainly of non-radioactive granitised rocks, whilst the high radioactivity in the south is produced by the widespread occurrence of radioactive pyroxenites which has produced an extensive surficial cover of resistant radioactive minerals. Contamination produced by river alluvium, road construction and general cultural interference produced by human hibitation is also more common in the southern part of the area.

The two main areas of previous mining activity (zones S2 and S5) on the eastern side of the area are clearly identified by high uranium and total count anomalies within well defined high background areas, which may largely be produced by contamination. This may be contrasted with the more isolated mines of Ilapalita, Andranokaola and Amboanemba on sheet 5 where backgrounds are much lower in the areas immediately surrounding the mines.

Little attempt has been made to interpret the spectrometric contour maps geologically because of the unknown effect of contamination in the area. Some faults are however visible on both the total count and magnetic contour maps.

4.4 Tabulation of Anomalies

Wherever possible, anomalies which occur close together on adjacent lines, have been joined and interpreted as a single linear spectrometric anomaly. All linear spectrometric anomalies possessing some uranium potential have been tabulated in Appendix 1 which presents the following properties for each anomaly:

Column 1 'Anomaly or Linear Anomaly No.'

Each selected linear anomaly is identified by the ANOMSEC numbers of its beginning and end anomalies. For a single line anomaly the ANOMSEC number is given.

Column 2 'Average Priority'

This is an estimate of the average priority of the whole linear anomaly. (See section 4.2)

Column 3 'Total Strike Length'

This is a measurement of the length of a linear anomaly. For a single line anomaly the total strike length is taken as being probably 200 metres. (i.e. 100 metres on each side of the flight line) Conversely it may be either a point source anomaly with effectively no strike length, or have a strike length much greater than 200 metres at an acute angle to the flight lines.

Column 4 'Strike Length of First and Second Priority Anomalies'

This is a measurement of those portions of a linear anomaly which have a first or second priority rating. Again when the anomalies occur in isolation á 200 metre strike length has generally been assumed.

Column 5 'The Best Quality Anomaly' occurring within each linear anomaly is identified by its ANOMSEC number.

Column 6 'The Priority Rating'

The priority rating is given of the anomaly selected in column 5.

Column 7 'The Magnetic Zone Classification'

The magnetic zone within which each linear anomaly occurs is identified.

Column 8 'Mine Association'

This is by way of a question as to whether there is any association between the linear anomaly and previous mining operations. Where anomalies are associated with previous mining operations the name or number of the mine is given whenever possible.

Column 9 'Conformable with Bedrock'

This again is by way of a question which asks whether there is any similarity of strike between the linear anomaly and the magnetics.

(a) A positive answer to this question suggests that the anomaly occurs within layered meta-sediments and has a urano-thorianite/pyroxenite origin.

(b) An answer 'yes?' indicates that although the anomaly generally has a similar strike to the magnetics the agreement is not perfect. This may be caused by an apparent change of strike of the linear anomaly produced by contamination or by some uncertainty as to the true strike of the country rocks as they are relatively non-magnetic.

(c) A negative answer suggests that the anomaly does not originate from within the layered meta-sediments and that its probable origin is from residual radioactive materials, pegmatites, or from contamination.

(d) An answer 'no?' indicates that although the major part of the evidence suggests a non meta-sedimentary source it is possible that the sub-outcropping rocks are non magnetic and that the magnetic pattern is produced by deeper magnetic rocks with a different strike direction.

Column 10 'Inferred Origin/Geology'

For each linear anomaly every effort has been made to discover whether its origin could be other than from a bedrock source. It is to be expected that linear anomalies may be produced by river alluvium or from the waste products of mining being spread along roads. In an attempt to identify anomalies of this type reference has been made to the existing aerial photographs, the topographical maps and the aircraft tracking film.

Where an anomaly has been classified as arising from a bedrock source an attempt has been made to specify the probable geology.

4.5 Discussion of Spectrometric Anomalies

A detailed listing of all significant anomalies is given in Appendix 1. The discussion of spectrometric anomalies given below relates to either anomalies and linear anomalies of good uranium potential or to broad zones possessing a high radioactive background.

4.5.1 Anomaly 4/6-14/4 and Zone S1 occurs in the north western corner of the survey area on Sheet 1. This is a high background area with good uranium potential. No evidence can be found of previous mining operations taking place in this region. Zone S1 occurs over Mt. Amenda which rises to a height of 601 metres or approximately 300 metres above the level of the surrounding plain. The individual anomalies within S1 are affected, mainly quantitatively, by the elevation problems encountered in flying this region. The size of the S1 zone is almost certainly produced by the presence of talus materials on either side of the mountain.

Anomaly 4/6-14/4 lies very close to the Sahanony River. It is possible that river alluvium is partly responsible for this linear anomaly although the best individual anomalies (11/1, 12/3) lie definitely to the west of the river. These first priority anomalies are very broad (500 metres wide) in comparison with first priority anomalies which occur further south. The whole area lies in a broad magnetic 'low'.

Anomaly 1/2-3/3 which lies on the ridge of Mt. Vohibanda to the north of zone S1 also warrants consideration.

4.5.2 Anomaly 19/5-25/5 and 26/2-33/6. These anomalies occur in the north eastern portion of the survey area on Sheet 2. The major anomaly 19/5-25/5 is a narrow high amplitude anomaly with similar characteristics to those produced by known quarry anomalies which occur further south. There is no evidence that this anomaly is associated with any form of contamination or previous mine workings. The best individual anomalies are 24/2 and 23/5. It is possible that it may continue northwards of flight line 19 towards the Mandrare River.

The whole region lies in a broad magnetic low.

Anomaly 26/2-33/6 warrants special investigation because of its close proximity to anomaly 19/5-25/5.

4.5.3 Zone S2

Zone S2, occurring in the south east corner of sheets 1 and 2 and in the north east corner of sheets 3 and 4, is an area of previous mining activity and contains many known quarries. The region is highly contaminated particularly along the Manambolo and Intranatra Rivers. It is to be expected that associated mine dumps, crushing plants and roads are all sources of contamination although it is difficult to relate individual anomalies with particular types of contamination.

It is recommended that special attention begiven to anomalies 59/3, 79/2 and 73/2-76/6 for which no definite origin may be assigned with certainty.

4.5.4 Anomaly 73/1-84/6

This linear anomaly lies to the east of zone S2 but within the generally high background area associated with this zone. Its origin and relationship to the nearby first priority anomaly, 78/4, which is coincident with an old quarry, is unknown. Evidence from the tracking film indicates that tothe north of 77/1 the anomaly follows the Manambolo River with the probability that this branch of the anomaly is caused by contamination. To the south of 79/1, although several of the individual anomalies coincide with a small north flowing stream, the whole of the anomaly may not be attributed to contamination as there is no known origin for the contamination. Consequently it must be concluded that a genuine anomaly does occur somewhere along the anomaly 79/1-84/6 and this warrants detailed investigation.

4.5.5 Zone S3

Zone S3 forms a broad zone of high radioactivity with a third priority rating on the western side of sheet 3. Several anomalies show good uranium potential but were down graded because of their large width. The zone coincides almost exactly with a magnetic zone M1A which indicates an area of high positive magnetic values which are interpreted as granite.

4.5.6 Zone S4

Zone S4 forms a broad moderately high radioactive zone in the south western corner of sheet 3 with apparently low uranium potential.

The main interest of this area is that the magnetic response suggests that the area is geologically similar (M2B/M2C) to the known mining areas in the east. The spectrometric response of this area may have been reduced by superficial cover deposits, but generally this zone should be given a low priority rating.

4.5.7 Zone S5

Zone S5 is a known mining district situated in the south eastern corner of sheets 3 and 4 and the north eastern corner of sheets 5 and 6. Although several major anomalies coincide with known mining operations the area is characterised by the occurrence of high quality linear anomalies (1st and 2nd order priorities) which have no obvious connection with known mining activities. These include anomalies 133/1-136/5, 135/1-141/2, 143/2-146/3 and 140/4-142/3. There is evidence from the tracking film to suggest that portions of these anomalies may be related to road contamination.

4.5.8 Anomaly 222/9-228/2. This anomaly occurs in the western side of sheet 7 in an area where there is no evidence of previous mining. Its magnetic setting is unique in that it occurs in magnetic zone M2D. This provides evidence to suggest that low magnetic D areas may be similar geologically to magnetic C areas. Two first priority anomalies, 224/2 and 225/9 occur in the centre of this linear anomaly. Also of interest is the neighbouring anomaly 227/2-233/1.

4.5.9 Zone S6

Zone S6 forms an area of very high radioactivity at the northern end of the very short flight lines on sheet 7. This area was previously considered to be highly radioactive on account of the presence of residual monazite sands. The relatively random nature of the anomalies occurring within this area are certainly in agreement with this interpretation. However the occurrence of a first order priority anomaly, 248/3 and several second orderpriority anomalies demand that their true origin be investigated.

4.5.10 Other Anomalies

The anomalies selected below also warrant detailed investigation at an early stage.

Anomaly 164/7-175/4 is situated on the eastern edge of the survey area (sheet 6) and is associated with the quarry Milatsaha (MR FD 071). It is specially selected because of its considerable strike length and the possibility that it may actually join up to anomaly 190/6-204/4 (see Total Count Contour Map). On several lines this anomaly was detected at ground clearances greater than 300 metres.

Other linear anomalies containing second order priority anomalies not apparently associated with previous mining operations, include 163/7-166/1, 166/3-167/4, 175/4-178/2, 187/3-194/7, 197/2-199/2, 199/5-212/7, 226/4-242/10, 259/1-263/1, 265/1-266/3.

5. MAGNETIC METHOD

5.1 Theory

The magnetic method of geophysical prospecting depends on measuring accurately variations in the total intensity of the Earth's magnetic field produced by the presence of varying amounts of magnetic minerals (mainly disseminated magnetite) which occur in different rocks. The Earth's magnetic field and rock magnetisations are vector quantities in that they possess both a direction and magnitude. In southern Madagascar the approximate parameters of the Earth's magnetic field are:-

Total intensity:	32000 nT
Inclination:	59° South
Declination:	18° West

Note: 10^5 gamma = 10^5 nT (nanotesla) = 1 gauss

The magnetisation of rocks is caused partly by induction in the Earth's field and partly by residual (remanent) magnetism. Induced magnetisation depends primarily upon the magnetic susceptibility of rocks and has the same direction as the inducing magnetic field of the Earth. Remanent magnetisation is independent of the strength and direction of the present day Earth's field and represents a permanent magnetisation of rocks acquired during an earlier geological period. Consequently the induced and remanent magnetisations are not necessarily similar in either magnitude or direction. They both combine vectorially with the Earth's field to produce a resultant total magnetic field intensity, and it is this parameter which is measured during magnetic surveys by total field magnetometers.

The shape and magnitude of a magnetic anomaly caused by a magnetic body depends upon:-

(a) The inclination and intensity of the Earth's magnetic field.

(b) Shape and size, and orientation of the body in the Earth's field.

(c) The magnetic susceptibility contrast with the country rocks.

(d) The magnitude and direction of any remanent magnetisation.

(e) The distance between the body and the magnetometer.

(i.e. for airborne surveys the depth of burial plus the flying height of the aircraft)

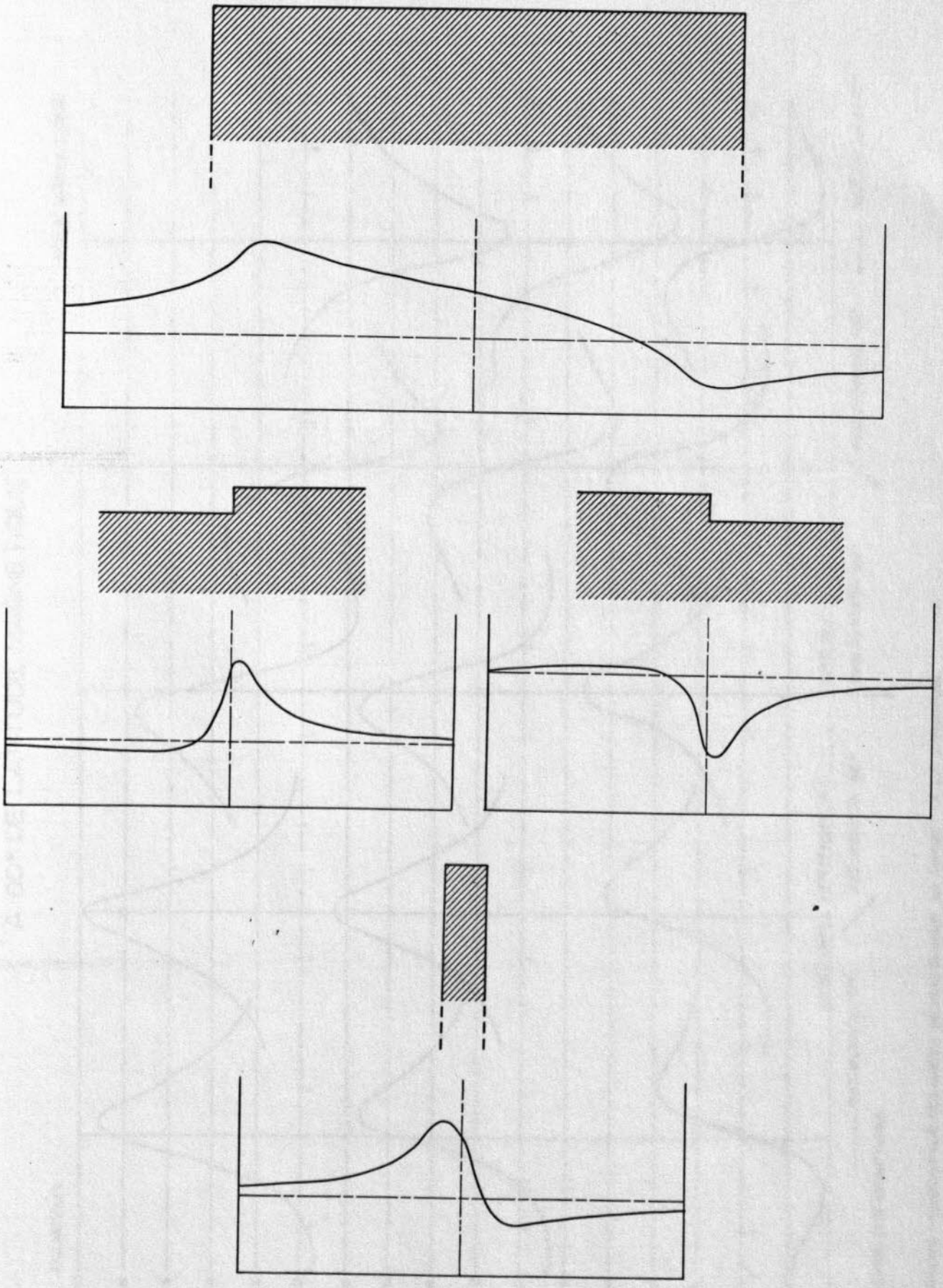
A theoretical magnetic anomaly can be computed when the shape and depth of the body is known as well as the magnetisation vector, susceptibility contrast and the inclination of the Earth's field. In this case the solution is unique. However for the inverse problem, for a given magnetic anomaly there corresponds, theoretically, an infinite number of solutions as to the size, shape and depth of burial of the body. Thus, the interpretation of magnetic anomalies depends largely on comparisons with theoretical anomalies which can be calculated for relatively simple geometrical bodies together with some prior knowledge of the geology. The latter is needed in order that the simple bodies chosen may approximate to known or possible geological structures. (See Figures 4 and 4A.)

Generally ultrabasic and basic igneous rocks are more magnetic than acidic igneous rocks which in turn are more magnetic than metamorphic and sedimentary rocks. The magnetic properties of metamorphic rocks are clearly influenced by the original igneous or sedimentary rocks from which they were derived whilst some iron bearing sediments may also be strongly magnetic.

5.2 Qualitative Interpretation

The success of any qualitative magnetic interpretation is dependent upon being able to identify both geological structures and different rock types from features which are contained on a magnetic contour map. In many cases rock types can be distinguished from each other by their magnetic signature. The term signature encompasses a multitude of different magnetic properties which include, level of intensity, strike direction, anomaly amplitude, wavelength, magnetic gradient, and characteristic patterns or shapes of magnetic contours.

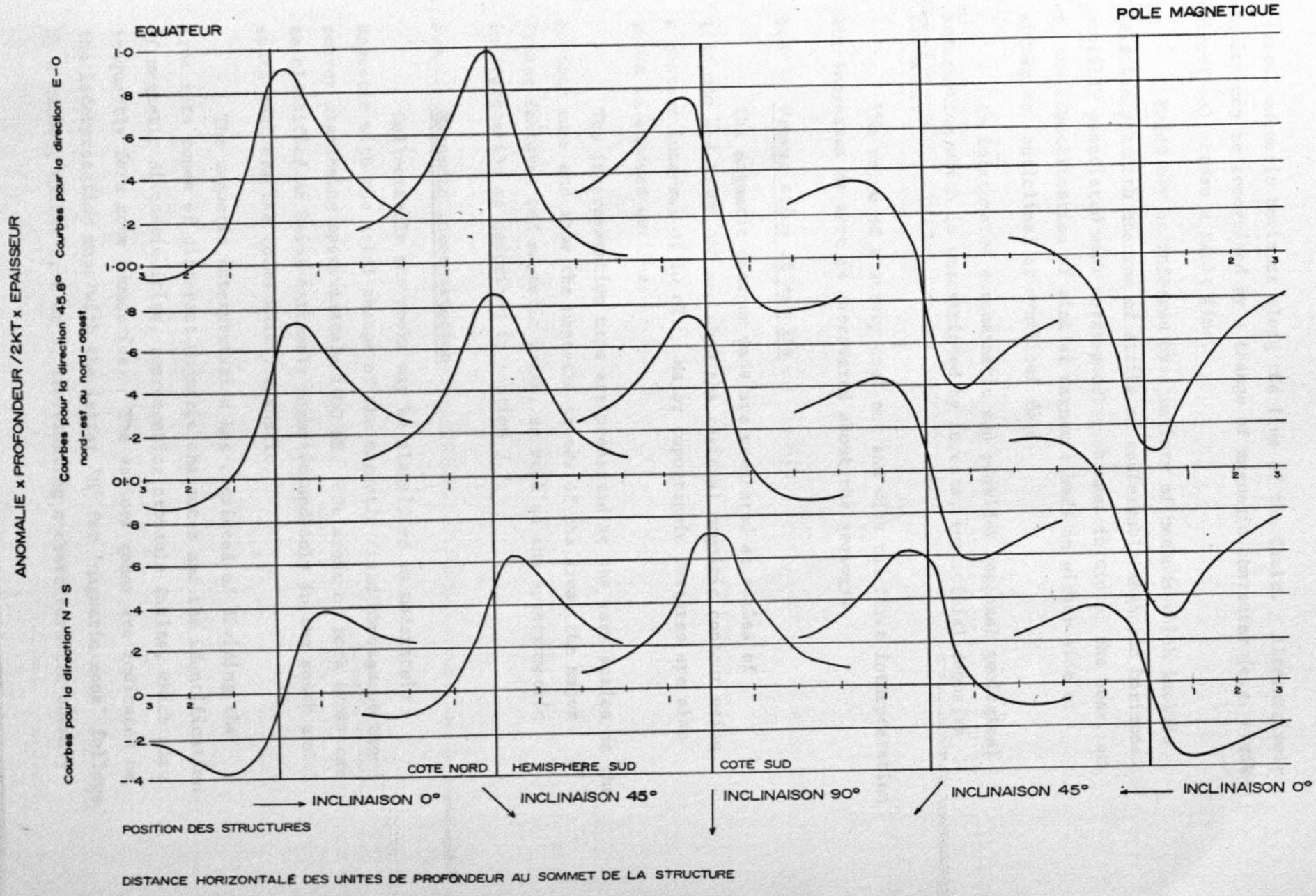
The principal structural elements identified qualitatively are faults and folds. Faults may be recognised on magnetic maps either by the displacement of a magnetic marker horizon, which can be recognised on both sides of the fault or by the termination of perhaps



ANOMALIES DU CHAMP MAGNETIQUE TOTAL POUR DES STRUCTURES SIMPLES A 60° DE LATITUDE MAGNETIQUE

ANOMALIES DU CHAMP MAGNETIQUE TOTAL POUR DES STRUCTURES SIMPLES

A 60° DE LATITUDE MAGNETIQUE



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several magnetic horizons along the line of the fault. Alternatively faults may be recognised by a change of magnetic character (e.g. strike direction) across a fault line.

Folds may be inferred by a variety of methods which include relatively smooth changes of strike of conformable magnetic horizons possibly associated with corresponding changes in dip of the beds, or by the identification of similar magnetic beds on either side of either an anticlinal or synclinal fold.

An interpreted aeromagnetic map provides regional geological information which is unrestricted by forests, superficial deposits or water.

The value of a survey does not end with the first interpretation but increases as more is discovered about the geology.

5.3 Presentation of Results

The magnetic contour maps are presented at scales of 1:50,000 and 1:100,000 and show the residual magnetic contour using a contour interval of 10 nT. Major topographic features are also shown in subdued outline.

The interpretation maps are presented at the same scales as the contour maps and show the magnetic trends of the area, the major linear features and magnetic zones, as well as the spectrometric interpretation as described in section 3.7.

5.4 Magnetic Interpretation

Collectively the rocks may be classified as moderately magnetic with the total change of the magnetic field throughout the survey area being approximately 1400 nT. No areas or rock types can be classified as being extremely magnetic and only in the south and south east are the rocks weakly magnetic.

The magnetic interpretation has consisted of dividing the area into zones of different magnetic character and the identification of magnetic discontinuities, representing probable faults, which also frequently form zone boundaries. The various zones are indicated on the interpretation maps with the letter 'M' for 'magnetic zone' followed by a number, either 1, 2 or 3, representing a characteristic anomaly

shape, and a letter A, B, C or D representing a level of magnetic intensity. An explanation of these symbols is given below:-

Type A zones represent predominantly positive magnetic anomalies produced mainly by induced magnetisation with a magnetic level generally greater than 3700 nT. Most 'A' zones occur on sheets 1 and 3 and strike approximately NNE-SSW across the north western corner of the area. They are interpreted as representing areas of either granite/gneiss or possibly magnetic quartzite where much of the layered nature of the original sediments has been mainly destroyed. In general these broad areas are associated with weak or very weak thorium anomalies with little or no uranium potential. 'A' zones also occur further east as isolated irregularly shaped masses which often occur within known areas of high uranium potential.

Type B zones where the magnetic level is between approximately 3500 and 3700 nT, are interpreted as indicating areas which have experienced minor effects of granitisation but where the layered nature of the original sediments has not been completely destroyed.

Type C zones are characterised by broad magnetic 'lows' with a magnetic level of between 3100 and 3500 nT. They are interpreted as probably representing weakly magnetic meta-sedimentary rocks within which it is expected that the pyroxenites are magnetic and display some remanent magnetisation. It is significant that virtually all the major linear spectrometric anomalies, many of which are associated with previous mining operations, occur within 'C' type areas.

Type D zones are associated with large negative magnetic areas with a magnetic level less than 3100 nT. These areas may be either more magnetic versions of type 'C' zones or associated with much younger rocks of unknown lithology which are called Neogene Continental on the Ampanihy geological sheet. Type 'D' areas occur only in the south and south west on sheets 5 and 7. Spectrometrically it is not possible to distinguish type 'C' from type 'D' areas which suggests that they are essentially C type areas.

Type 1 zones represent anomalies of generally a rounded character possessing a slightly longer wavelength than average in which the strike direction is indefinite or variable. These areas are

encountered mainly in northern granitic areas and in the south where the rocks are less magnetic.

Type 2 zones represent anomalies which possess a definite strike direction which is usually the same as that of the country rocks. This is interpreted as being possibly indicative of moderate folding mainly along fold axes parallel with the strike.

Type 3 zones represent anomalies, usually of narrow wavelength, possessing a variable strike direction, which are interpreted as being indicative of intense folding.

For example; a zone labelled M3C may be interpreted as a magnetic interpretation zone of low magnetic field strength, where negative anomalies predominate, which is intensely folded.

It has not always been possible to assign a single label to each zone. For example, zones exist which, besides having a dominant strike direction, are also intensely folded. In these cases the zone has been allocated a double symbol. (e.g. M3C/M2C)

Inferred faults, which have been identified from both discontinuities and linear features occurring within the magnetic pattern, are widely distributed throughout the survey area. It is most probable that many more faults exist than it has been possible to show. The two predominant directions of faulting are approximately northwest-southeast and northeast-southwest. Many of the major faults stop at or within 'A' type zones which suggest that the faults are generally older than the period of granitisation.

On the ERTS satellite photography of southern Madagascar a prominant lineation bisects the survey area in an approximate northeast-southwest direction. The probable position of this feature has been interpreted from the magnetic results.

Also it is significant to note that many of the linear spectrometric anomalies are terminated by faulting.

One possible explanation of the overall magnetic picture, as it is today, is to assume that the areas of predominantly negative magnetic anomalies (i.e. D and C zones) are caused by a combination of remanent and induced magnetisation. It may be postulated that the remanent magnetisation was acquired when Madagascar was in a latitude of low

magnetic inclination. This may have been in pre-Ordovician times when Madagascar formed part of Gondwanaland and was situated close to the magnetic equator. During subsequent periods of granitisation, which have been dated isotopically at approximately 500 million years, the original remanent magnetisation was destroyed. Today with southern Madagascar situated in a magnetic latitude of 59°S the granitised rocks display mainly positive magnetic anomalies caused by induced magnetisation whilst the original remanent magnetisation is still dominant within the meta-sedimentary rocks.

It is possible that many of the assumptions made in this interpretation particularly as to the relationship between magnetic response and lithology will subsequently be found, after more detailed mapping on the ground, to be inexact and require modification. This is to be expected and nearly always occurs where the geological control is limited. It should be possible to modify and improve this basic magnetic interpretation as more information becomes available.

It is recommended that particular attention be given to determining which are the more magnetic rock types in the area. This may be achieved by collecting and measuring the magnetic susceptibility of a large number of different rock samples. In addition ground magnetometer traverses would provide detailed resolution of anomalies which is not possible from an airborne survey and should provide a valuable correlation between lithology and magnetic response.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 One of the main problems encountered in undertaking the survey was the use of 25 year old aerial photographs for both navigation, flight path recovery and interpretation. It is recommended that high priority be given to undertaking an aerial photographic survey in colour of the area at a scale of either 1:25,000 or 1:30,000 covering that portion of southeast Madagascar which possesses some uranium potential. This would permit the origin of many anomalies whose origin is at present uncertain to be determined as well as giving an immediate picture as to the extent of previous mining operations.

New photographic cover would enable the area to be rapidly and inexpensively mapped photogeologically, particularly in the north which is relatively clear of bush. It could also be utilised for general planning as well as detailed photogrammetric mapping of selected proposed mining areas, although this would require some pre-marking on the ground prior to flying the photographic survey.

6.2 The survey has been successful in identifying both known and unknown areas with a high uranium potential. Several of the first priority anomalies are associated with previous mines or their adjacent dumps and crushing plants. However many first priority anomalies exist both in areas where previous mining has and has not takenplace, but where the available evidence suggests that the anomalies originate from undisturbed bedrock sources. Some second and third priority anomalies are also coincident with known quarries though some of these may befrom phlogopite rather than uranium mines. If it can be established that potentially economic uranium mineralisation is associated with second and third priority anomalies then this demands that virtually all anomalies warrant further investigation. (Some of the dangers of selecting anomalies using anomaly amplitude as a significant parameter are discussed in sections 3.3., 4.2.3, and 4.2.5.)

6.3 The majority of linear anomalies, particularly those associated with previous mining operations have been interpreted as being produced by the mineral urano-thorianite occurring within a layered pyroxenite sequence. It is significant that the strike lengths of such anomalies are often several kilometres in length and are frequently terminated by faulting. The apparent quality of long linear anomalies is usually variable, as indicated on the interpretation maps. This suggests that

the spectrometer survey has been successful in mapping individual mineralised pyroxenite layers as well as indicating those areas where the concentration of urano-thorianite increases locally. It is probable that the extensive strike length of many anomalies has not been fully appreciated with the result that in the past the full potential of several known mines has neither been completely investigated nor developed.

6.4 A detailed listing of 'Selected Spectrometric Anomalies' is given in Appendix 1 and a discussion of major spectrometric zones and major linear anomalies is given in section 4.5. It is recommended that these sections can be greatly improved by establishing the true origin of all anomalies directly by field checking and sampling. This would enable all major anomalies to be placed in a reliable order of priority based on geological as well as geophysical considerations. At this stage consideration could then be given to the ease of access, the degree of contamination as well as to estimated ore grades and estimated tonnages.

6.5 The chief problem encountered in the flying of the survey was the presence of extremely high ground on both the western and eastern edges of the survey area. At times this resulted in the aircraft having to fly well above the prescribed 150 metres in order to clear an approaching mountain range. This prevented complete spectrometric coverage in certain areas. For an initial survey it is not considered that this was a serious fault and that the amount of data lost was small.

However for any future spectrometric flying it is recommended that consideration be given to a helicopter mounted spectrometer for the flying of mountainous areas. A helicopter has the advantage of being able to fly slower and maintain height more accurately than a fixed wing aircraft.

6.6 The magnetic results generally indicate that the best spectrometric anomalies are located in specific and easily recognisable magnetic zones (usually M2C and M3C), although from the airborne magnetic results there is rarely any distinct magnetic anomaly associated directly with a spectrometric anomaly. This may be because the pyroxenite layers occur close together and produce a relatively weak magnetic response which prevents individual layers from being resolved from the air.

It is possible that by undertaking detailed ground magnetic surveys over anomalous pyroxenite zones it may be possible to obtain a definite magnetic response from pyroxenite beds. This would be invaluable in the detailed investigation of specific anomalies prior to either drilling or mining developments, particularly in those areas where the overburden prevents radioactivity being detected.

If this method of ground magnetic investigation proves successful then consideration should be given to using a helicopter magnetic survey for rapid and detailed mapping of potential mining areas.

PART 2

OPERATIONS REPORT

1. INTRODUCTION

The airborne geophysical survey described in this report was carried out by Hunting Geology and Geophysics Limited on behalf of the Office Militaire National pour les Industries Stratégique between 22nd March and 10th April, 1977.

The survey consisted of 7270 line kilometres of airborne magnetic and spectrometric flying undertaken over an approximately rectangularly shaped area of dimensions 100 km north-south by 25 km east-west whose southern edge lies 50 km west of Fort Dauphin in southeast Madagascar. Additional flying amounting to 40 line kilometres was undertaken over the Tsanerna Area, approximately 75 kilometres to the north of the northern boundary of the main area.

The flying was undertaken by our associate company Aerial Surveys Botswana (Pty.) Limited using a Douglas DC-3 aircraft registration number A2 ZFD.

The survey team comprised:

S.J. Bullock	H.G.& G.	Party Leader and Senior Geophysicist
B.W. Smithers	Aerial Surveys	Pilot/Navigator
L. Oakenfull	Aerial Surveys	Pilot/Navigator
V. Seagrave	Aerial Surveys	Aircraft Engineer
M. Harvey	H.G.& G.	Data Compiler
P. Conway	H.G.& G.	Electronics Engineer

The survey was under the overall control of Mr. Augustin Andriamahefamanana, Chef du Department Mineraux Radioactifs de l'OMNIS and Dr. C. Premoli, Geological Consultant from the International Atomic Energy Agency with whom a close liaison was maintained at all times.

2. FLYING OPERATIONS

The aircraft was based at Fort Dauphin.

The flight parameters of the survey were as follows:

Flight Line Direction	East - West
Tie Line Direction	North - South (Approximately)
Flight Line Spacing	400 metres
Tie Line Spacing	As shown on Text Figure 1
Mean Flying Height	150m above ground level
Mean Flying Speed	120-130 knots
Navigation	Visual using 1:50,000 aerial photographs plus Doppler

A brief diary of events throughout the survey period is given below:

24th March	Arrived in Fort Dauphin
25th March	Sortie 01
	F.Ls 241 - 265
	Experienced intermittent trouble with digital clock
26th March	Sortie 02 and Sortie 03
	FLs 235-228 and 227-213
	Intermittent trouble with digital clock and spectrometer
27th March	No flying - low cloud
28th March	Sortie 04
	Late departure because of bad weather
	Spectrometer fault cured
	Digital clock fault not cured
	FLs 212-201
29th March	No flying - rain
30th March	Sortie 05
	FL 188-199
	Digital clock fault located and cured
31st March	Sortie abandoned owing to bad weather
1st April	No flying - rain
2nd April	Sortie 06
	FLs 187-184; 149-174; 147-136
3rd April	Sortie 07
	FLs 135-101
4th April	Sortie 08
	FLs 100-58
5th April	No flying - bad weather
6th April	Sortie 09
	TLs 2 and 4
	FLs 1-36
7th April	Sortie 10
	TLs 1 and 6
	FLs 37-57; 175-183; plus reflies
8th April	Sortie 11
	FL.3
	FLs 271-266 and 240-236 plus reflies
	Flying of Tsanerna Area

9th April Sortie 12
Refly of FL.37
10th April Transit Fort Dauphin - Tananarive

Owing to a numbering error on the original mosaics flight line 200 was omitted.

The main problem encountered in the flying of the survey was the mountainous areas encountered at the eastern and western ends of the flight lines. This resulted in the aircraft having to exceed the 150 metre nominal flying height well before the end of the survey in order to ensure the safety of the aircraft. Following consultations with Dr. C. Premoli and Mr. A. Andriamahefamanana it was decided that where necessary the flight lines should be reduced slightly in length provided that this enabled the aircraft to fly lower for a longer period of time. The final decision as to when to end a survey line was then left to the discretion of the pilot.

3. GEOPHYSICAL AND ANCILLARY EQUIPMENT

3.1 Airborne Magnetometer

The instrument used for the survey was a digital fluxgate magnetometer which was developed by Hunting Geology and Geophysics from the original Mark III Gulf fluxgate magnetometer.

The magnetometer measures the total intensity of the Earth's magnetic field to an accuracy of ± 1 nT and was used at a sampling rate of one reading per second.

The detector head, comprising three mutually perpendicular fluxgate elements, one for measuring the Earth's field and two to orientate the measuring element in the direction of the total field, was mounted in a stinger attached to the tail of the aircraft.

The output of the magnetometer is in the form of an analogue voltage which varies continuously with the magnetic field and is measured by a digital multimeter every second. This voltage was recorded in analogue form on a twin channel Hewlett Packard 7100B recorder, and in digital form on magnetic tape as 5 B.C.D. characters. The HP 7100B was operated at a speed of 3 inches/minute and used chart paper which was 10 inches wide.

The other channel of the 7100B recorder displayed the spectrometer total count channel. The F.S.D. ranges used were:

Blue Pen -	Magnetometer	F.S.D. 1000 nT
Red Pen -	Total Count	F.S.D. 1000 counts per second (sorties 1-4)
		F.S.D. 2000 counts per second (sorties 5-12)

3.2 Gamma Ray Spectrometer

The gamma ray spectrometer used was an Exploranium DiGRS 3001 (Digital Gamma Ray Spectrometer), 4 channel differential spectrometer with nine matched thallium activated sodium iodide detecting crystals each 15.2 cm in diameter and 10.2 cm thick giving a total crystal volume of 16.68 litres. The crystals, assembled in three bins each containing three crystals together with photomultipliers and preamplifiers, were insulated, shock mounted and moisture proofed.

The system contains semi-automatic spectrum stabilisation for each bin which is achieved by monitoring the pulse height output of the mono-energetic photopeak of Caesium 137 at 0.662 MeV, a small quantity of which is contained within the crystal assembly, and adjusting accordingly the high voltage supply to the photomultiplier tubes.

The spectrometer windows were chosen to include primary photopeaks from the uranium and thorium decay series and photopeak of potassium 40. In addition the counts derived from the total useful energy spectrum were recorded. Window settings, widths and primary photopeaks, used for the survey are listed below:

Channel No.	Energy Range MeV	Primary Photopeak	Series
1	0.9 - 2.80	Total Count	
2	1.36 - 1.56	K40 (1.46 MeV)	K
3	1.65 - 2.30	Bi214 (1.76 MeV)	U
4	2.42 - 2.82	T1208 (2.62 MeV)	Th

The base setting of channel 1 at 0.9 MeV avoids the inclusion of radiation from the caesium monitor source.

The number of counts entering each channel every second was displayed visually by the spectrometer as a three digit number for each channel. These counts were recorded directly in digital (uncorrected) form on magnetic tape and after stripping of the uranium and potassium

channels in analogue form on a MARS 6 hot wire pen recorder operating at 3 inches/minute.

The recording positions and ranges used on the MARS 6 channel recorder for the majority of the survey were:

Mars Channel 1	Bottom of Chart	Total Count	0-2000 cps
Mars Channel 2		Stripped Potassium	0-200 cps
Mars Channel 3		Stripped Uranium	0-500 cps
Mars Channel 4		Thorium	0-500 cps
Mars Channel 5		Altimeter	1000-0 ft
Mars Channel 6	Top of Chart	Magnetometer	1000 nT

Precise details of the ranges used and range changes made are given below:

(i) Sortie 01 until fiducial 6370 seconds the Mars ranges were:

Total Count	0-1000 cps
Potassium	0-200 cps
Uranium	0-200 cps
Thorium	0-200 cps

(ii) Sortie 01 after fiducial 6370 seconds until Sortie 05 the Mars ranges were:

Total Count	0-1000 cps
Potassium	0-200 cps
Uranium	0-500 cps
Thorium	0-500 cps

(iii) From Sortie 05 onwards the Mars ranges were:

Total Count	0-2000 cps
Potassium	0-200 cps
Uranium	0-500 cps
Thorium	0-500 cps

The term 'stripping' is used to describe the removal of counts from the uranium channel produced by a pure thorium source and counts from the potassium channel produced by either pure sources of uranium or thorium. This unwanted leakage of energy between windows is produced partly by the window settings overlapping other photopeak energies, and partly from Compton Scattering of gamma radiation both inside and outside of the detecting crystals.

The DiGRS-3001 spectrometer possesses a built-in electronic stripping (subtraction) facility which ensures that a pure uranium source produces no response in the potassium channel and that a pure thorium source produces no response in either the uranium or potassium channels.

The adjustment of the stripping control was made whilst flying at the survey height over the sea. In practice analogue stripping is not perfect since with the window settings used there is a slight leakage upwards from the uranium channel into the thorium channel caused by the Bi214 photopeak at 2.43 MeV. Also inspection of the analogue records on completion of survey suggested the uranium channel was understripped by a factor of 0.2 of the thorium counts (i.e. on the Mars record the uranium channel counts should have subtracted from them an additional one fifth of the thorium counts). In general this is a very small correction but is necessary for any quantitative assessment of the results to be made from the analogue charts.

3.3 Digital Recording System

The digital recording system was a Static Device data acquisition system coupled to a Kennedy incremental tape recorder which is specially designed to record multi-channel geophysical data in B.C.D. form on 7 track magnetic tape. The unit incorporates a digital clock which generates fiducial data common to both the digital recorder as well as the various analogue recording devices.

The recording in the aircraft was made onto 600 ft spools of magnetic tape at 200 b.p.i. with the following format:

Block Format:

1 Block = 300 characters
= 10 scans of 1 second each
(i.e. 30 characters per scan)

Scan Format:

I3	I5	I5	I3	I4	I3	I3	I3	I1
XXX	XXXXX	XXXXX	XXX	XXXX	XXX	XXX	XXX	X
Sortie No.	Time Secs.	Magnetic Field nt	Altimeter Metres	Ch.1	Ch.2 Counts/Second		Ch3	Ch.4	Multiplying Factor

3.4 Magnetic Storm Monitor

The magnetic storm monitor was a Gulf fluxgate Magnetometer which measures changes in the total intensity of the Earth's magnetic field. The magnetometer output was recorded on an Esterline Angus strip chart analogue recorder running at a speed of 0.625 inches per hour with 250 nT being recorded over the full 4.5 inches wide chart paper.

3.5 35mm Positioning Camera

A Vinten 35mm frame-type tracking camera with secondary optics displaying the fiducial number of each frame, was used to record the aircraft's actual flight path. Individual exposures were taken at 1 second intervals which, using a 18.5mm lens at the flying height of 400 ft, gave adequate overlap between adjacent frames to ensure that complete photographic coverage was achieved along each line.

3.6 Radar Altimeter

The radar altimeter was an STR 54B with a quoted accuracy by the manufacturer of $\pm 3\%$.

3.7 Doppler Navigation

The Doppler system was a Decca Model 72. Generally the navigation for the survey was visual with the Doppler being used to monitor and correct for cross track drift whilst flying each flight.

4. GEOPHYSICAL MEASUREMENTS

4.1 Spectrometer Calibration and Controls

To ensure that the spectrometer was functioning to the manufacturers specification the following checks were made:

(a) After initially setting up and balancing each crystal using the 0.662 MeV photopeak of caesium 137 standard uranium and thorium sources were used to check the position of the spectrometer windows using a small window width and scanning manually the energy level to ensure that the window was located accurately on a photopeak.

(b) Zero and F.S.D. levels were checked at the beginning and end of each sortie.

(c) 'Castle Calibration' Checks

The castle calibration procedure consisted of exposing the spectrometer crystals to pure sources of thorium and uranium at the beginning and end of each sortie whilst the aircraft was flying over the sea at a height of 150 metres.

The average results of the calibration checks are given below:

Channel	Cosmic Background (Unstripped) Counts/Sec.	Uranium Source (Unstripped) %	Thorium Source (Unstripped) %
Total Count	500	-	-
Potassium	40	38	24
Uranium	16	59	41
Thorium	6	3	35

5. DATA COMPILATION

5.1 On-Site Compilation

On completion of each sortie the 35mm tracking film was developed and the flight path recovered in Fort Dauphin on to aerial photographs of the survey area at a scale of 1:50,000. Generally no difficulty was encountered in plotting fiducial points at approximately 3km intervals except where the bush was very thick and uniform.

This plotting established where the flight lines had been flown out of the required specification, and which lines or portions of lines required reflying.

The fiducial points were transferred for each line from the photographs used for navigation purposes onto the 1:50,000 mosaics of the survey area. These mosaic plots were left with OMNIS on completion of the survey so that selected anomalies could be located in the field prior to the submission of the final report.

Spectrometer anomalies were plotted on transparent overlays to mosaics. They were numbered to agree with anomaly numbers given on the MARS analogue record and given a classification rating for follow-up purposes.

The quality of both spectrometric and magnetic records were checked for acceptability prior to departure of the aircraft from Tananarive.

5.2 Laboratory compilation

The 1:100,000 scale topographical maps of the area were photographically enlarged to a scale of 1:50,000.

The plotted fiducial points were transferred from the aerial photographs to the enlarged topographic maps. This was achieved by identifying features common to both map and photograph and using proportional dividers to scale off distances to fiducials. By keeping a constant check on the scale relationship between map and photograph and by using features as close as possible to the fiducial points, scale errors produced by photographic distortion were mainly eliminated.

For the control of the magnetic results the intersections of the tie lines with every fifth flight line were located by direct comparison on the 35mm film. All intersections were marked on the magnetometer analogue charts by reference to the camera fiducial marks. At each intersection the tie line minus the flight line magnetic values were calculated and these errors distributed throughout the control grid on the basis of a modified least squares method. This resulted in the flight lines and tie lines being reduced to a common datum plane.

A regional correction was applied to this datum plane using the International Geomagnetic Reference Field (I.G.R.F.) supplied by the Department of Geomagnetism, Royal Greenwich Observatory.

Having produced a common datum plane, corrected for the regional field, this enabled a datum line to be drawn on each flight line.

Magnetic values (relative to the datum line) were then read from each profile at intervals of 10 nT, together with all minima, maxima and points of inflexion. These values were transcribed onto the flight line grid again by reference to camera fiducials, and contoured.

The total count and uranium contour maps were prepared from computer drawn CALCOMP profiles of each channel. The profiles of total count were drawn for each line with three point smoothing, after the

removal of cosmic background and the application of a height correction. The uranium channel profiles were plotted with five point smoothing after cosmic background, height and stripping corrections had been applied. Total count values were read at 100 cps interval and uranium values at 25 cps interval. The values were transcribed respectively onto the flight line grid and contoured.

6. MATERIALS SUPPLIED TO THE CLIENT

The following materials were supplied to OMNIS before the Hunting team left Tananarive.

1. Approximately 90% of the analogue MARS records
2. The accurate positions of the plotted flight line fiducial points plotted onto mosaics of the survey area at a scale of 1:50,000.
3. A map of selected spectrometric anomalies shown on transparent overlay to the mosaics.

The following results were sent to OMNIS prior to the submission of the final report.

1. An Interim Report and a Supplement to the Interim Report
2. Work Sheets at a scale of 1:50,000 of:
   - (i) Interpretation Maps
   - (ii) Magnetic Contour Maps
   - (iii) Uranium Contour Map
   - (iv) Total Count Contour Map
3. ANOMSEC Listings (2 copies)
4. Transparencies of the topographical maps at a scale of 1:50,000.

The following material will have been supplied following compilation and interpretation.

Five copies of the final report in French

1 Durafilm copy of each final magnetic contour sheet @1:100,000 scale

1 Oza-loft copy of each final magnetic contour sheet
@ 1:50,000 scale

1 Durafilm copy of each spectrometric total count contour sheet
@ 1:50,000 scale

1 Durafilm copy of each spectrometric uranium contour sheet
@ 1:50,000 scale

1 Oza-loft copy of each interpretation map
@ 1:50,000 scale

1 Durafilm copy of each interpretation map
@ 1:100,000 scale

7. PROFESSIONAL SECRECY

Hunting Geology and Geophysics Limited wish to reaffirm to OMNIS its guarantee of strict professional secrecy. No information on the results of this survey will be divulged to any person without the written authority of the Client.

8. REFERENCES

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APPENDIX 1

SELECTED SPECTROMETRIC ANOMALIES

SHEETS 1 AND 2

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
1/1 - 3/2	2½	1400	600	2/6	2	M3C	No	Yes?	Pyroxenite + eluvium
1/2 - 3/3	2	1000	1000	2/5	2	M3C	No	Yes	Pyroxenite + colluvium
1/3 - 7/4	3	3000	-	4/2	3	M2A	No	Yes	Granite/Gneiss
4/5 - 6/2	3	1500	-	4/5	3	M3C	No	Yes ?	Pyroxenite + colluvium
4/6 - 14/4	2	4500	3000	11/1	1	M3C	No	Yes ?	Pyroxenite + colluvium
7/5 - 15/5	4	6300	-	-	-	M2B	No	No	Alluvium; near River Mandrare
13/4 - 15/3	3	1000	300	14/2	2	M3A	No	Yes	Granite/Greiss
17/1 - 28/4	3	4600	600	18/4	2	M2C	No	Yes	Pyroxenite
19/5 - 25/5	1½	3200	3200	24/2	1	M3C	No	Yes ?	Pyroxenite
21/1 - 27/1	4	2700	-	21/1	3	M2C	No	Yes	Pyroxenite
26/2 - 33/6	3	3800	900	30/1	2	M3C	No	Yes ?	Pyroxenite
30/2 - 33/5	4	2000	-	-	-	M3C	No	Yes	Pyroxenite
31/5 - 36/4	3	2300	-	34/4	3	M2A	No	Yes	Granite/Gneiss
41/3 - 54/2	4	2100	-	-	-	Variable	No	No	Alluvium; on River Manambolo& River Intranat
42/4 - 51/2	4	6000	-	-	-	M2A	No	Yes ?	Granite/Gneiss or Alluviu
50/5 - 53/1	3	2200	-	53/1	3	M3A	No	Yes	Granite/Gneiss
54/1 - 57/6	2½	1800	1800	55/4	1	M2C	Yes MRFD 114 116	Yes	Pyroxenite + contaminatio
55/1 - 62/1	4	3000	-	60/1	3	M3A	No	Yes	Granite/Gneiss
56/3 - 60/8	2	1900	1100	57/5	1	M2B	Yes MRFD126 MRFD122	Yes ?	Pyroxenite - close to granite ?

/Cont. .....

SHEETS 1 AND 2

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
57/4	2	200	200	57/4	2	M2B	Yes Soarano	?	Pyroxenite
57/2 - 60/2	4	1700	-	57/2	3	M2A	No	Yes ?	Granite/Gneiss
58/6 - 65/1	2½	3000	1800	59/3) 65/1)	1 1	M3B	Yes MRFD 107	Yes	Pyroxenite - close to granite ?
60/6 - 65/1	3	2100	-	63/4	3	M3B	No	Yes	Pyroxenite

SHEETS 3 AND 4

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
63/7 - 76/1	4	5500	-	68/2	3		No	No	Pegmatite
63/5 - 64/5	3	800	-	64/5	3	M3B	Yes Est Vohipaly	Yes	Pyroxenite
64/2 - 86/1	4	8600	-	69/5	3	M2A/M3B	No	Yes ?	Pegmatite
66/7 - 70/1	3	2000	-	67/6	3	M2A	No	Yes	Granite Gneiss
67/1 - 68/5	1½	900	900	67/1	1	M3B	Yes Atomiti-kisey	Yes	Pyroxenite - close to granite
70/7 - 72/9	2	1300	1300	71/2	1	M2A	No ?	No ?	Road contamination
71/3 - 77/3	2	2400	1500	75/4	1	M3B/M2A	Yes SE Vohipaly	Yes/No	Pyroxenite + contamination on anomalies 76/4 and 72/3
71/5 - 75/5	4	2000	-	73/7	3	M2B	No	Yes?	Pegmatite
71/7 - 75/9	3	2200	-	74/1	3	M2A	No	Yes	Granite Gneiss
73/3 - 76/5	2	1700	800	74/6	1	M3B	Yes	Yes	Pyroxenite
73/2 - 76/6	2.5	1300	900	74/7	2	M2A	No ?	Yes ?	Pyroxenite and/or contamination
73/1 - 84/6	2	5000	4000	79/1	1	M2C	No ?	Yes	Pyroxenite to South of 77/ Alluvium to North of 77/1
78/4	1	200	200	78/4	1	M2C	Yes	Yes	Old mine or mine workings
79/2 - 81/3	2.5	1200	800	81/3	2	M2A	Yes Marasohihy N.	Yes ?	Pyroxenite + contamination
81/1 - 83/2	3	1200	200	81/1	2	M2C	No	No ?	Alluvium ?
86/6 - 94/4	3	3500	900	92/2	2	M2C	Yes Esiva	Yes	Pyroxenite
90/4 -114/4	3	9600	800	91/2	2	Variable	No	No	Pegmatite
92/3 -100/5	3	3500	800	100/5	2	M2C	No	Yes	Pyroxenite - close to granite
97/1	1	200	200	97/1	1	M2C	Yes	Yes	Pyroxenite

SHEETS 3 AND 4

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
103/1 - 105/1	2	1000	1000	103/1	2	M2C	No	Yes	Pyroxenite (Broad Anomaly)
112/2 - 114/1	2½	900	200	112/2	2	M3B	Yes	Yes	Pyroxenite
112/3	2	200	200	112/3	2	M3B	No	?	Pyroxenite - close to granite
116/4 - 120/6	3	1900	600	117/1	2	M2C	No	Yes ?	Pyroxenite or alluvium
118/4 - 123/1	3	2200	-	123/1	3	M2C	No	Yes	Pyroxenite - close to granite
119/4 - 126/4	3	3500	800	125/4	2	M2B	No	Yes	Pyroxenite - close to granite
125/1 - 127/1	2	1000	1000	125/1	1	M2C	Yes Analalava	Yes	Pyroxenite + contamination
128/4 - 132/5	2	2000	1600	129/3	1	M3C	Yes Ambindndrakomba	Yes	Pyroxenite + contamination
129/1 - 130/7	2	800	800	130/7	2	M3C	Yes Androtsabo I	Yes	Pyroxenite + contamination
133/1 - 136/5	1	1700	1700	131/1	1	M3C	No ?	Yes	Pyroxenite + contamination

Incidents in Chemical Industry	Average Priority	Active Cases		Root Causes			Hazards Involved	Mode Associations	Controversial Well Behaved	Referred Diffuse/Zoology
Incident No.		Level (Degree)	Not 2 Sub Priority (Degree)	Answer No.	Priority		Info.			
1087/1 - 1047/1	2	1200	1200	1247/1	2		Fix	No	Yes	Pyrazoles (Pyrid) Anhydr
1123/2 - 1147/1	44	300	1147/2	2	1237		Yes		Yes	Pyrazoles
1137/3	1	120	300	1147/3	2	1237	Yes	No	?	Pyrazoles - Glycerin Amines
1147/4 - 1237/1	4	1200	900	1171/1	2	1237	No	No	Yes ?	Pyrazoles or alkylene
1147/5 - 1237/2	2	1200	-	1237/1	1	1237		No	Yes	Pyrazoles - glycol in amines
1147/6 - 1237/3	2	1200	600	1237/2	2	1237	Yes	No	Yes	Pyrazoles - glycol or amines
1147/7 - 1237/4	2	1200	1000	1237/3	1	1237	Yes Adsorbers		Yes	Pyrazoles + Cyclohexylamine
1147/8 - 1237/5	2	Cash	1000	1237/4	1	1237	Yes Adsorbers		Yes	Pyrazoles + Cyclohexylamine
1237/1 - 1237/6	1	120	800	1247/1	2	1237	Yes Adsorbers		Yes	Pyrazoles + neutralization
1237/2 - 1247/1	2	1200	1200	1247/2	1	1237	No		Yes	Pyrazoles + neutralization

SHEETS 5 AND 6

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
138/3	1	200	200	138/3	1	M3C	Yes	No ?	Contamination or quarry
135/1 - 141/2	2	2700	2700	138/4	1	M3C	No ?	Yes ?	Pyroxenite + contamination
140/4 - 142/3	2	1600	800	141/3	2	M3C	No ?	Yes ?	Pyroxenite + contamination
143/2 - 146/3	2	1400	1000	144/1	1	M3C	No ?	No ?	Pyroxenite + contamination
143/3 - 150/2	3	2700	400	45/2	2	M2A	No	Yes	Pyroxenite/Granite (close to Betroky River)
150/3 - 159/3	3	4200	1400	159/3	2	M3C	Yes Valipaly Ouest Morafeno	Yes ?	Pyroxenite + contamination
150/1 - 152/1	1½	1000	1000	150/1	1	?	Yes Androt-saks ?	Yes ?	Pyroxenite + contamination
154/1	2	200	200	154/1	2	?	No ?	?	Possible contamination
155/1	2	200	200	155/1	2	?	No ?	?	Possible contamination
159/1 - 162/1	2	1700	1300	162/1	2	M2B	Yes Ilapalita	No ?	Pyroxenite - close to granite
160/2 - 161/2	2½	900	450	161/2	2	M3C	No	Yes	Possible contamination - roads
160/1 - 163/2	3	1700	200	161/1	1	M2A	Yes Amboan-emba	Yes	Pyroxenite/Granite - close to granite
163/4 - 168/1	3	2100	200	164/3	1	M2C	Yes Andrano-kaola	Yes ?	Pyroxenite - close to granite
163/7 - 166/1	2	1400	1400	164/1	2	M3A	No	Yes	Granite/Gneiss
164/7 - 175/1	2½	4500	2500	172/6	2	M2C ?	Yes Milatsaha	No ?	Pyroxenite
166/3 - 167/4	2½	800	400	167/4	2	M2C	No	Yes	Pyroxenite
170/4	2	200	200	170/4	2	M1C	No	?	Bedrock

/Cont. .....

SHEETS 5 AND 6

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
172/3 - 173/3	3	800	-	-	-	M2B	No	No ?	Bedrock
175/2 - 178/1	4	1400	-	176/1	3	M2C	No	No ?	Alluvium
175/4 - 178/2	2½	1000	500	175/4	2	M2B	No	Yes ?	Pyroxenite
176/2 - 181/3	4	2300	-	178/2	4	M2C	No	No	Contamination along road
180/3 - 185/5	3	2000	-	182/3	3	M3C	No	Yes	Bedrock
180/2 - 186/1	3½	2200	-	186/1	3	M2C	No	Yes	Bedrock
182/1 - 185/3	2½	1300	400	184/2	2	M2C	Yes Ampopasy	No	Mainly contamination
183/3 - 185/2	2½	1000	200	184/1	2	M2C	Yes	No	Mainly contamination
187/2 - 194/6	2	3500	3000	192/3	1	M2C	Yes Amboasar-ikely	Yes/No	Pyroxenite + alluvium + contamination
187/3 - 194/7	3	2900	600	189/3	2	M3B	No	Yes	Pyroxenite
190/1 - 194/9	3	1600	-	-	-	M1B	No	Yes	Bedrock
190/6 - 204/4	3	5900	400	190/6	2	M2C	No	Yes/No	N of 194/5 Pyroxenite S of 194/5 Alluvium
191/4 - 191/5	2	-	-	191/4	2	M2C	No	No	East-West strike - contamination ?
197/2 - 199/2	2	1000	1000	198/8	2	M2C	No	Yes ?	Pyroxenite and/or alluvium
198/10- 205/6	3	4000	200	199/1	2	M3C	No	No	Alluvium/Eluvium ? Broad anomaly
199/5 - 212/7	2½	5500	3400	210/7	2	M3B	No	Yes ?	Pyroxenite and/or alluvium
207/5 - 213/4	3	2400	200	213/4	2	M3C	No	No	Bedrock
207/6 - 208/2	2½	800	400	207/6	2	M3C	Yes Bevah.Est.	Yes ?	Pyroxenite + contamination

SHEETS 7 AND 8

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/ Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
215/7-228/9	3	6300	-	223/8	3	M3C	No	No	Broad Anomaly Eluvium ?
216/6 - 224/9	3	3100	200	219/1	2	M3C	No	Yes	Bedrock
217/5 - 225/3	2	4000	3000	221/6	1	M3C	Yes	Yes ?	Pyroxemite + contamination
217/7 - 221/6	3	2300	-	219/5	3	M2C	Yes	Yes	Bedrock
217/8 - 228/7	3	4400	200	223/6	2	M2C	Yes Antsatra	Yes	Pyroxemite + contamination
220/2 - 225/7	3	2800	400	223/7	2	M3C	No	Yes ?	Bedrock
222/9 - 228/12	2	2700	1200	225/9	1	M2C	No	Yes	Pyroxenite
224/7 - 228/4	3	1800	400	225/4	2	M3C	No	Yes ?	Bedrock
226/4 - 242/10	3	7000	1000	230/7	2	M2C	No	Yes ?	Pyroxenite + road or other contamination
227/2 - 233/1	3	3000	200	228/11	2	M2C	No	Yes ?	Pyroxenite ?
227/9 - 232/3	3	2000	200	230/2	2	M3C	No	No ?	Bedrock
227/10-234/1	3	2500	-	232/3	3	M3C	No	No ?	Bedrock
228/6 - 242/6	3	6400	-	232/6	3	M2C	No	Yes	N of 234/3 - Bedrock S of 234/3 - Alluvium ?
230/3 - 237/4	3	3700	200	230/3	2	M3C	No	No ?	Mainly alluvium ?
235/1 - 241/1	3	3000	-	240/1	3	M2C	No	Yes	Bedrock + contamination on road
237/3 - 245/3	3	4000	200	244/3	2	M2C	No	No ?	Mainly alluvium in river
236/8 - 241/8	3	2500	-	-	-	M2C	No	No	Mainly alluvium in river
238/9 - 249/2	3	5600	-	-	-	M2C	No	No ?	Mainly alluvium in river
242/3 - 243/6	3	400	-	-	-	M2C	No	No	Mainly alluvium in river

/Cont. .....

Anomaly or Linear Anomaly No.	Average Priority	Strike Length		Best Quality Anomaly		Magnetic Zone	Mine Association	Conformable With Bedrock	Inferred Origin/Geology
		Total (Metres)	1st & 2nd Priority (Metres)	Anomsec No.	Priority				
247/7 - 248/1	2	600	600	248/1	2	M3C	No	Yes ?	In zone S6 - eluvium/ alluvium or bedrock
247/5 - 249/4	2	1000	1000	248/3	1	M3C	No	Yes	In zone 56 - eluvium/ alluvium or bedrock
251/2 - 257/2	3	3500	-	257/2	3	M1B	No	No	Bedrock
252/3 - 254/4	2	800	400	252/3	1	M3C	Yes Ikatefa N	Yes ?	Pyroxenite + contamination
256/2 - 262/2	2	2750	1500	259/2	1	M1B	Yes Ikatefa S	Yes ?	Pyroxenite + colluvium
259/1 - 263/1	2½	2000	900	263/1	2	M1B	No	Yes ?	Bedrock
265/1 - 266/3	2	800	800	266/3	2	M1B	No	Yes	Bedrock

APPENDIX 2

FLIGHT LINE INDEX

RÉGION DE FORT DAUPHIN

Flt. Line No.	Date	Sortie	Direction	Extent TLs	Flt. Line No.	Date	Sortie	Direction	Extent TLs
1/1	6. 4.77	9	E	4 - 2	32/1	6. 4.77	9	W	6 - 4
2/1	6. 4.77	9	W	2 - 4	33/1	6. 4.77	9	E	4 - 6
3/1	6. 4.77	9	E	4 - 2	34/1	6. 4.77	9	W	6 - 4
4/1	6. 4.77	9	W	2 - 4	35/1	6. 4.77	9	E	4 - 6
5/1	6. 4.77	9	E	4 - 2	36/1	6. 4.77	9	W	6 - 4
6/1	6. 4.77	9	W	2 - 4	37/1	7. 4.77	10	E	4 - 6
7/1	6. 4.77	9	E	4 - 2	37/2	9. 4.77	12	E	4 - 2
8/1	6. 4.77	9	W	2 - 4	38/1	7. 4.77	10	W	6 - 4
9/1	6. 4.77	9	E	4 - 2	39/1	7. 4.77	10	E	4 - 6
10/1	6. 4.77	9	W	2 - 4	40/1	7. 4.77	10	W	6 - 4
11/1	6. 4.77	9	E	4 - 2	41/1	7. 4.77	10	E	4 - 6
12/1	6. 4.77	9	W	2 - 4	42/1	7. 4.77	10	W	6 - 4
13/1	6. 4.77	9	E	4 - 2	43/1	7. 4.77	10	E	4 - 6
14/1	6. 4.77	9	W	2 - 4	44/1	7. 4.77	10	W	6 - 4
15/1	6. 4.77	9	E	4 - 2	45/1	7. 4.77	10	E	4 - 6
16/1	6. 4.77	9	W	2 - 4	46/1	7. 4.77	10	W	6 - 4
17/1	6. 4.77	9	E	4 - 2	47/1	7. 4.77	10	E	4 - 6
18/1	6. 4.77	9	W	2 - 4	48/1	7. 4.77	10	W	6 - 4
19/1	6. 4.77	9	E	4 - 6	49/1	7. 4.77	10	E	4 - 6
20/1	6. 4.77	9	W	6 - 4	50/1	7. 4.77	10	W	6 - 4
21/1	6. 4.77	9	E	4 - 6	51/1	7. 4.77	10	E	4 - 6
22/1	6. 4.77	9	W	6 - 4	52/1	7. 4.77	10	W	6 - 4
23/1	6. 4.77	9	E	4 - 6	53/1	7. 4.77	10	E	4 - 6
24/1	6. 4.77	9	W	6 - 4	54/1	7. 4.77	10	W	6 - 4
25/1	6. 4.77	9	E	4 - 6	55/1	7. 4.77	10	E	4 - 6
26/1	6. 4.77	9	W	6 - 4	56/1	7. 4.77	10	W	6 - 4
27/1	6. 4.77	9	E	4 - 6	57/1	7. 4.77	10	E	4 - 6
28/1	6. 4.77	9	W	6 - 4	58/1	4. 4.77	8	E	4 - 6
29/1	6. 4.77	9	E	4 - 6	59/1	4. 4.77	8	W	6 - 4
30/1	6. 4.77	9	W	6 - 4	60/1	4. 4.77	8	E	4 - 6
31/1	6. 4.77	9	E	4 - 6	61/1	4. 4.77	8	W	6 - 4

/Cont. .....

Flt Line No.	Date	Sortie	Direction	Extent TLs	Flt. Line No.	Date	Sortie	Direction	Extent TLs
61/2	8. 4.77	11	W	6 - 4	91/1	4. 4.77	8	E	4 - 6
62/1	4. 4.77	8	E	4 - 6	92/1	4.4.77	8	E	4 - 6
63/1	4. 4.77	8	W	6 - 4	93/1	4. 4.77	8	W	6 - 4
64/1	4. 4.77	8	E	4 - 6	94/1	4. 4.77	8	E	4 - 6
65/1	4. 4.77	8	W	6 - 4	95/1	4. 4.77	8	W	6 - 4
66/1	4. 4.77	8	E	4 - 6	96/1	4. 4.77	8	E	4 - 6
66/2	8. 4.77	11	E	4 - 6	97/1	4. 4.77	8	W	6 - 4
67/1	4. 4.77	8	W	6 - 4	98/1	4. 4.77	8	E	4 - 6
68/1	4. 4.77	8	E	4 - 6	99/1	4. 4.77	8	W	6 - 4
69/1	4. 4.77	8	W	6 - 4	100/1	4. 4.77	8	E	4 - 6
70/1	4. 4.77	8	E	4 - 6	101/1	3. 4.77	7	W	6 - 4
71/1	4. 4.77	8	W	6 - 4	102/1	3. 4.77	7	E	4 - 6
72/1	4. 4.77	8	E	4 - 6	103/1	3. 4.77	7	W	6 - 4
73/1	4. 4.77	8	W	6 - 4	104/1	3. 4.77	7	E	4 - 6
74/1	4. 4.77	8	E	4 - 6	105/1	3. 4.77	7	W	6 - 4
75/1	4. 4.77	8	W	6 - 4	106/1	3. 4.77	7	E	4 - 2
76/1	4. 4.77	8	E	4 -6	107/1	3. 4.77	7	W	2 - 4
77/1	4. 4.77	8	W	6 - 4	108/1	3. 4.77	7	E	4 - 2
78/1	4. 4.77	8	E	4 - 6	109/1	3. 4.77	7	W	2 - 4
79/1	4. 4.77	8	W	6 - 4	110/1	3. 4.77	7	E	4 - 2
80/1	4. 4.77	8	E	4 - 6	111/1	3. 4.77	7	W	2 - 4
81/1	4. 4.77	8	W	6 - 4	112/1	3. 4.77	7	E	4 - 2
82/1	4. 4.77	8	E	4 - 6	113/1	3. 4.77	7	W	2 - 4
83/1	4. 4.77	8	W	6 - 4	114/1	3. 4.77	7	E	4 - 2
84/1	4. 4.77	8	E	4 - 6	115/1	3. 4.77	7	W	2 - 4
85/1	4. 4.77	8	W	6 - 4	116/1	3. 4.77	7	E	4 - 2
86/1	4. 4.77	8	E	4 - 6	117/1	3. 4.77	7	W	2 - 4
87/1	4. 4.77	8	W	6 - 4	118/1	3. 4.77	7	E	4 - 2
88/1	4. 4.77	8	E	4 - 6	119/1	3. 4.77	7	W	2 - 4
89/1	4. 4.77	8	W	6 - 4	120/1	3. 4.77	7	E	4 - 2
90/1	4. 4.77	8	E	4 - 6	121/1	3. 4.77	7	W	2 - 4

/Cont. .....

2177551 FORT DAUPHIN

FLIGHT LINE INDEX

Flt. Line No.	Date	Sortie	Direction	Extent TLs
122/1	3. 4.77	7	E	4 - 2
123/1	3. 4.77	7	W	2 - 4
124/1	3. 4.77	7	E	4 - 2
125/1	3. 4.77	7	W	2 - 4
126/1	3. 4.77	7	E	4 - 2
127/1	3. 4.77	7	W	2 - 4
128/1	3. 4.77	7	E	4 - 2
129/1	3. 4.77	7	W	2 - 4
130/1	3. 4.77	7	E	4 - 2
131/1	3. 4.77	7	W	2 - 4
132/1	3. 4.77	7	E	4 - 2
133/1	3. 4.77	7	W	2 - 4
134/1	3. 4.77	7	E	4 - 2
135/1	3. 4.77	7	W	2 - 4
136/1	2. 4.77	6	E	4 - 2
137/1	2. 4.77	6	W	2 - 4
138/1	2. 4.77	6	E	4 - 2
139/1	2. 4.77	6	W	2 - 4
140/1	2. 4.77	6	E	4 - 2
141/1	2. 4.77	6	W	2 - 4
142/1	2. 4.77	6	E	4 - 2
143/1	2. 4.77	6	W	2 - 4
144/1	2. 4.77	6	W	2 - 4
145/1	2. 4.77	6	E	4 - 2
145/2	8. 4.77	11	W	2 - 4
146/1	2. 4.77	6	E	4 - 2
147/1	2. 4.77	6	W	2 - 4
149/1	2. 4.77	6	E	4 - 2
150/1	2. 4.77	6	W	2 - 4
150/2	8. 4.77	11	W	2 - 4
151/1	2. 4.77	6	E	4 - 2
152/1	2. 4.77	6	W	2 - 4
153/1	2. 4.77	6	E	4 - 2
154/1	2. 4.77	6	W	2 - 4
155/1	2. 4.77	6	E	4 - 2
156/1	2. 4.77	6	W	2 - 4
157/1	2. 4.77	6	E	4 - 2
158/1	2. 4.77	6	W	2 - 4
159/1	2. 4.77	6	E	4 - 2
160/1	8. 4.77	11	W	2 - 4
161/1	2. 4.77	6	W	2 - 4
162/1	2. 4.77	6	E	4 - 2
163/1	2. 4.77	6	W	2 - 4
164/1	2. 4.77	6	E	4 - 2
165/1	2. 4.77	6	W	2 - 4
166/1	2. 4.77	6	E	4 - 2
167/1	2. 4.77	6	W	2 - 4
168/1	2. 4.77	6	E	4 - 2
169/1	2. 4.77	6	W	2 - 4
170/1	2. 4.77	6	E	4 - 2
171/1	2. 4.77	6	W	2 - 4
172/1	2. 4.77	6	E	4 - 2
173/1	2. 4.77	6	W	2 - 4
174/1	2. 4.77	6	E	4 - 2
175/1	7. 4.77	10	W	2 - 4
176/1	7. 4.77	10	W	2 - 4
177/1	7. 4.77	10	E	4 - 2
178/1	7. 4.77	10	W	2 - 4
179/1	7. 4.77	10	E	4 - 2
180/1	7. 4.77	10	W	2 - 4
181/1	7. 4.77	10	E	4 - 2

/Cont. .....

2177551 FORT DAUPHIN

FLIGHT LINE INDEX

Flt. Line No.	Date	Sortie	Direction	Extent TLs
182/1	7. 4.77	10	W	2 - 4
183/1	7. 4.77	10	E	4 - 2
184/1	7. 4.77	10	W	2 - 4
185/1	2. 4.77	6	W	2 - 4
186/1	2. 4.77	6	E	4 - 2
187/1	2. 4.77	6	W	2 - 4
188/1	30. 3.77	5	E	4 - 2
189/1	30. 3.77	5	W	2 - 4
189/2	7. 4.77	10	W	2 - 4
190/1	30. 3.77	5	E	4 - 2
190/2	7. 4.77	10	E	4 - 2
191/1	30. 3.77	5	E	4 - 2
192/1	30. 3.77	5	W	2 - 4
193/1	30. 3.77	5	E	4 - 2
194/1	30. 3.77	5	W	1 - 4
195/1	30. 3.77	5	E	4 - 1
196/1	30. 3.77	5	W	1 - 4
197/1	30. 3.77	5	E	4 - 1
198/1	30. 3.77	5	W	1 - 4
199/1	30. 3.77	5	E	4 - 1
201/1	28. 3.77	4	W	1 - 4
202/1	28. 3.77	4	E	4 - 1
203/1	28. 3.77	4	W	1 - 4
204/1	28. 4.77	4	E	4 - 1
205/1	28. 3.77	4	W	1 - 4
206/1	28. 3.77	4	E	4 - 1
207/1	28. 3.77	4	W	1 - 4
208/1	28. 3.77	4	E	4 - 1
208/2	7. 4.77	10	E	4 - 1
209/1	28. 3.77	4	W	1 - 4
210/1	28. 3.77	4	E	4 - 1
211/1	28. 4.77	4	W	1 - 4
212/1	28. 4.77	4	E	4 - 1
213/1	26. 3.77	3	W	1 - 4
213/2	7. 4.77	10	W	1 - 4
214/1	26. 3.77	3	E	4 - 1
215/1	26. 3.77	3	W	2 - 4
216/1	26. 3.77	3	E	4 - 2
217/1	26. 3.77	3	W	2 - 4
218/1	26. 3.77	3	E	4 - 2
219/1	26. 3.77	3	W	2 - 4
220/1	26. 3.77	3	E	4 - 2
221/1	26. 3.77	3	W	2 - 4
221/2	7. 4.77	10	E	4 - 2
222/1	26. 3.77	3	E	4 - 2
222/2	7. 4.77	10	W	2 - 4
223/1	26. 3.77	3	W	2 - 4
224/1	26. 3.77	3	E	4 - 2
225/1	26. 3.77	3	W	2 - 4
226/1	26. 3.77	3	E	4 - 2
227/1	26. 3.77	3	E	4 - 2
227/2	8. 4.77	11	E	4 - 2
228/1	26. 3.77	3	W	2 - 4
229/1	26. 3.77	3	E	4 - 2
230/1	26. 3.77	3	W	2 - 4
231/1	26. 3.77	3	E	4 - 2
232/1	26. 3.77	3	W	2 - 4
233/1	26. 3.77	3	E	4 - 2
234/1	26. 3.77	3	W	2 - 4
235/1	26. 3.77	3	E	4 - 2
236/1	8. 4.77	11	E	4 - 2
237/1	8. 4.77	11	W	2 - 4

/Cont. .....

2177551 FORT DAUPHIN

FLIGHT LINE INDEX

Flt. Line No.	Date	Sortie	Direction	Extent
				TLs
238/1	8. 4.77	11	E	4 - 2
239/1	8. 4.77	11	W	2 - 4
240/1	8. 4.77	11	E	4 - 2
241/1	25. 3.77	1	E	4 - 2
242/1	25. 3.77	1	W	2 - 4
243/1	25. 3.77	1	E	3 - 2
244/1	25. 3.77	1	W	2 - 3
245/1	25. 3.77	1	E	3 - 2
246/1	25. 3.77	1	E	3 - 2
247/1	25. 3.77	1	W	2 - 3
248/1	25. 3.77	1	E	3 - 2
249/1	25. 3.77	1	W	2 - 3
250/1	25. 3.77	1	E	3 - 2
251/1	25. 3.77	1	W	2 - 3
252/1	25. 3.77	1	E	3 - 2
253/1	25. 3.77	1	W	2 - 3
254/1	25. 3.77	1	E	3 - 2
255/1	25. 3.77	1	W	2 - 3
256/1	25. 3.77	1	E	3 - 2
257/1	25. 3.77	1	W	2 - 3
258/1	-5. 3.77	1	E	3 - 2
259/1	25. 3.77	1	W	2 - 3
260/1	25. 3.77	1	E	3 - 2
261/1	25. 3.77	1	W	2 - 3
262/1	25. 3.77	1	E	3 - 2
263/1	25. 3.77	1	E	3 - 2
264/1	25. 3.77	1	W	2 - 3
265/1	25. 3.77	1	E	3 - 2
266/1	8. 4.77	11	E	3 - 2
267/1	8. 4.77	11	W	2 - 3
268/1	8. 4.77	11	E	3 - 2
269/1	8. 4.77	11	W	2 - 3
270/1	8. 4.77	11	E	3 - 2
271/1	8. 4.77	11	W	2 - 3
				FLs
TL 1	7. 4.77	10	S	194-214
TL 2	6. 4.77	9	S	1 -271
TL 3	8. 4.77	11	N	271- 1
TL 4	6. 4.77	9	N	242- 1
TL 6	7. 4.77	10	S	18 -106

2177551 TSANERENA

FLIGHT LINE INDEX

Flt. Line No.	Date	Sortie	Direction	Extent	Flt. Line No.	Date	Sortie	Direction	Extent
				TLs					
300	8. 4.77	11	E	309-308					
301	8. 4.77	11	W	308-309					
302	8. 4.77	11	W	308-309					
303	8. 4.77	11	E	309-308					
304	8. 4.77	11	E	309-308					
305	8. 4.77	11	W	308-309					
306	8. 4.77	11	E	309-308					
307	8. 4.77	11	W	308-309					
308	8. 4.77	11	N	FL 307-300					
TL 309	8. 4.77	11	N	FL 307-300					

APPENDIX 3

TSANERNA AREA

TSANERNA AREA

The Tsanerna area, lying approximately 75 kilometres north of the northern boundary of the Fort Dauphin survey, was flown on the 8th April, 1977 and formed a part of flying undertaken during Sortie 11. A total of approximately 40 km of flying was completed.

The purpose of the survey was to investigate a known spectrometric anomaly which had been located by a previous radiometric survey.

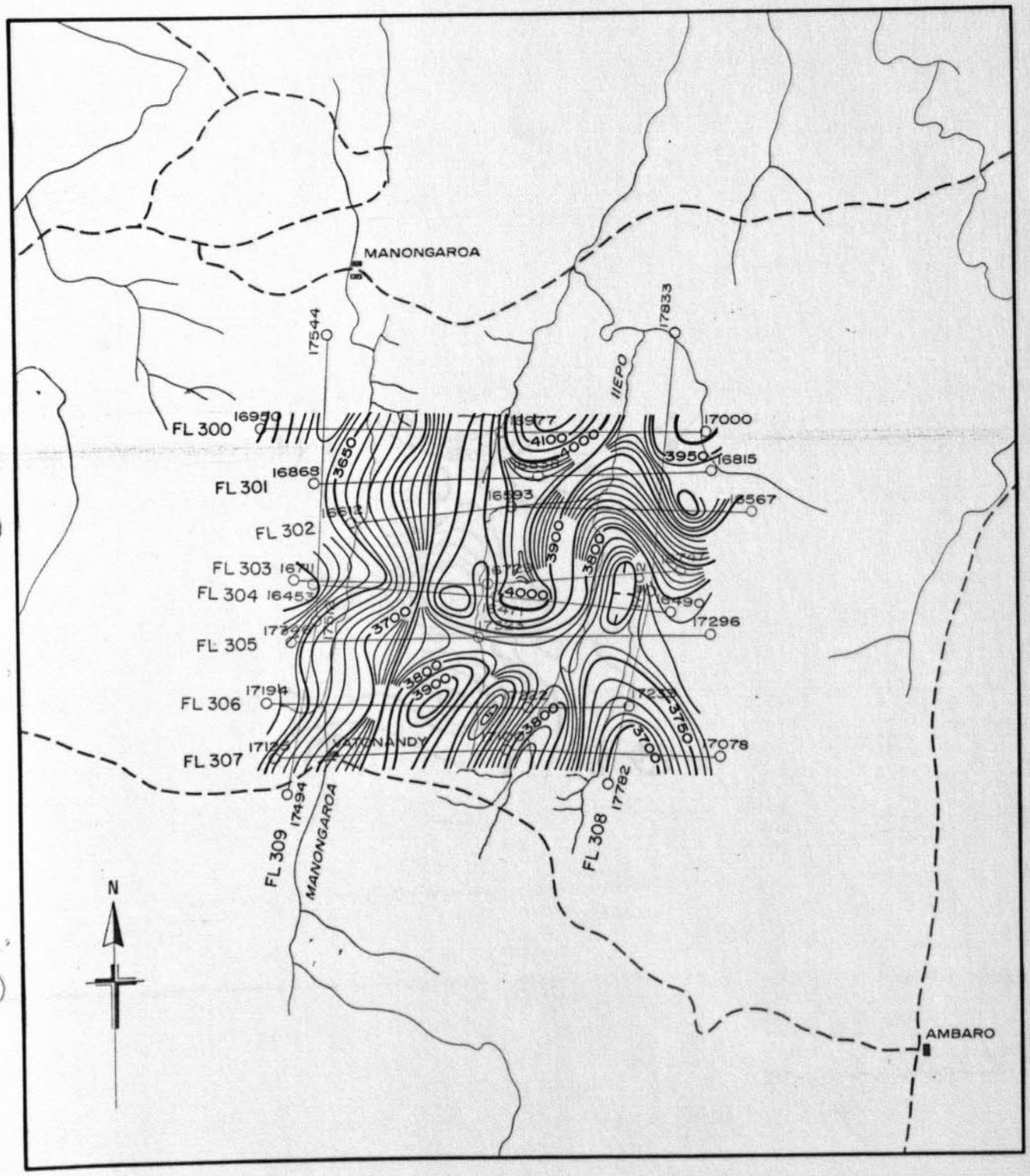
The results of the survey are presented in the form of magnetic, total count, and uranium contour maps at scales of 1:50,000 together with a selected anomaly map. These were compiled using the same principles as the Fort Dauphin Survey.

Considerable difficulty was experienced in getting good quality spectrometric results in an extremely mountainous area.

At the time of the survey some difficulty was experienced in actually locating the anomaly. The final results clearly show the existence of a radiometric zone coinciding with the ridge known as Analamitranga. Based on the interpretation criteria used for the main survey this zone warrants a fourth priority anomaly rating with the anomaly on FL.303 and 304 justifying a third priority rating.

The magnetics results suggest that an east-west striking fault or shear zone may exist along flight line 305.

ZONE DE TSANERENA

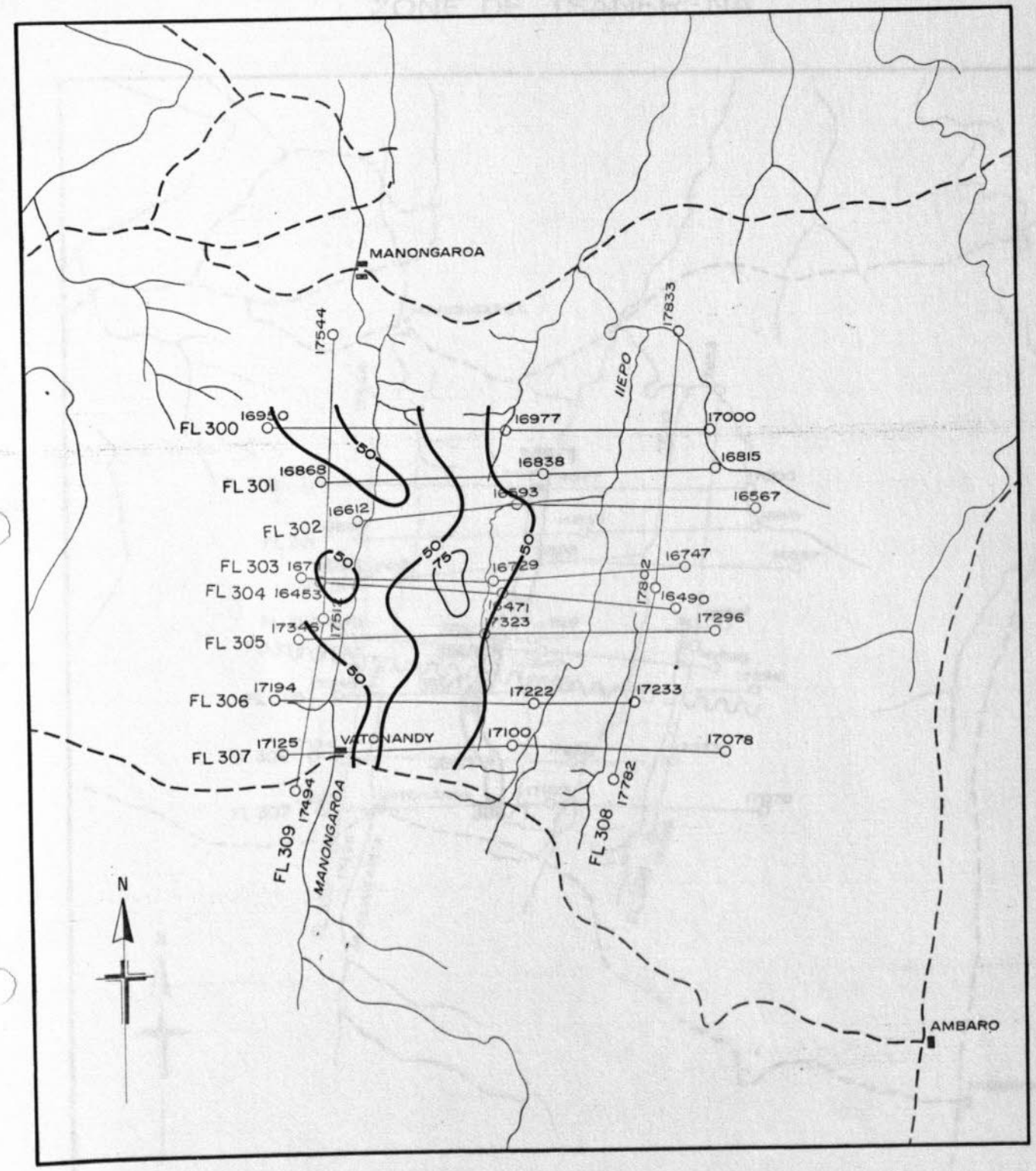


ECHELLE 1:50,000 APPROX

Km1 0 1 2 3 4 5Km

CARTE DES CONTOURS DU CHAMP MAGNETIQUE TOTAL

ZONE DE TSANERENA

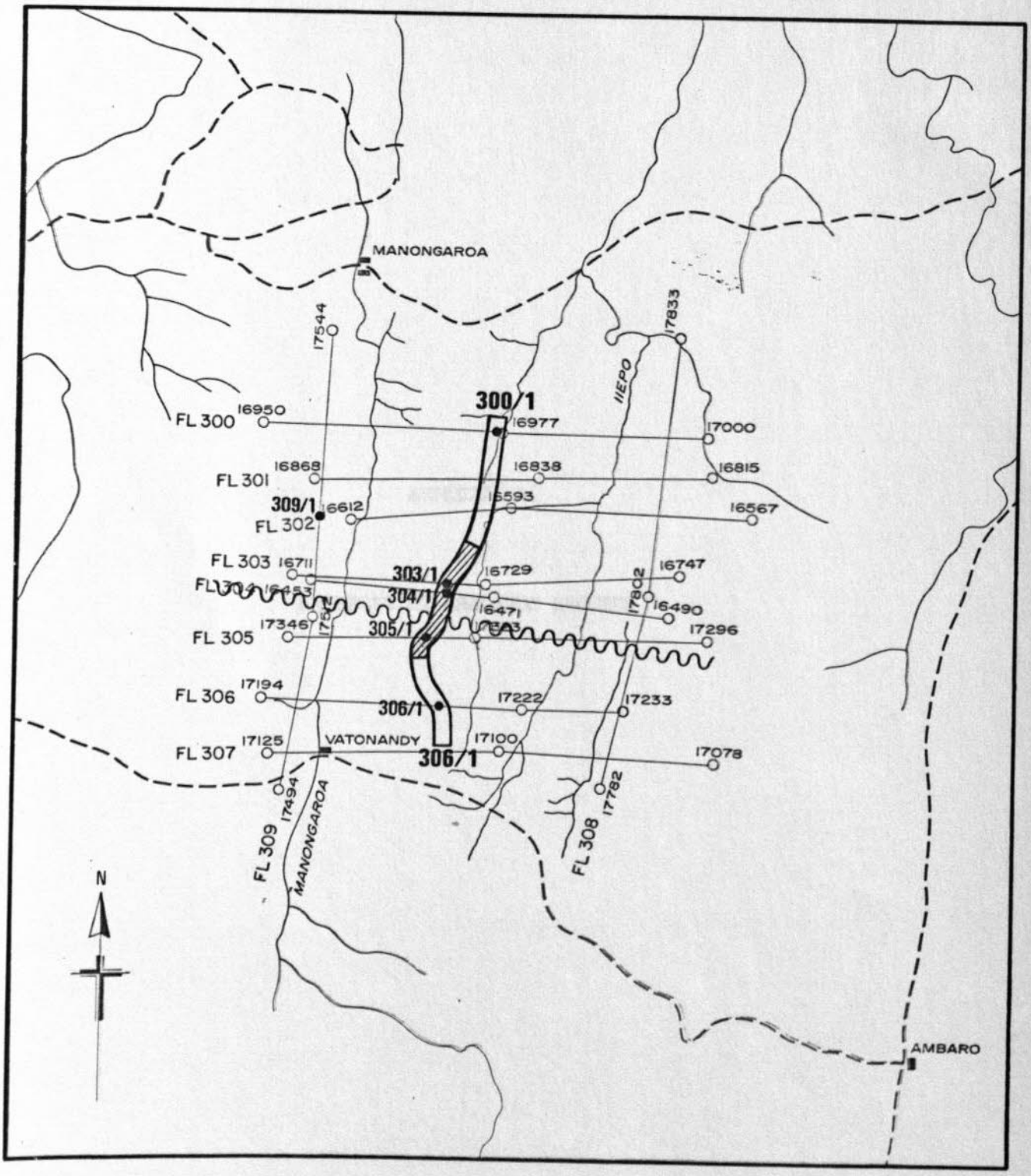


ECHELLE 1:50,000 APPROX

Km 1 0 1 2 3 4 5 Km

CARTE DES CONTOURS D'URAINIUM

ZONE DE TSANERENA



SCALE 1:50,000 APPROX

Km1 0 1 2 3 4 5Km

CARTE D'INTERPRETATION

APPENDIX 4

EXAMPLES OF ANALOGUE RECORDS