MINES GEOPHYSICAL SERVICES

16 VICTORIA STREET,
KALGOORLIE,
WESTERN AUSTRALIA 6430.

Telephone/facsimile 61 8 9021 6970

BONDI MINING LTD

MURPHY: RESULTS FROM GEOTEM AIRBORNE ELECTROMAGNETIC SURVEY OCTOBER 2010

J H COGGON

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SUMMARY

The Geotem survey at Murphy was planned with the objective of detecting conductive units in the Murphy metamorphic basement with which unconformity type uranium deposits might be associated. The survey, carried out by Fugro Airborne Surveys, was completed in early October 2010. It comprised three areas: the large Murphy Main area and the smaller UC17 and UC19 areas.

Plots of individual component signals for different delay times show fairly uniform responses over much of the area, with notable regions of low response in the central-east section of the UC19 survey and toward the eastern end of the Main Murphy survey.

Approximate conversion of raw data to conductivity versus depth has been completed in order to prepare conductivity quasi-sections and depth slices. These show that most of the surveyed area is covered by a thin conductive layer. This presumably reflects soil and shallow weathering. In the UC19, UC17 and eastern Main Murphy areas the distribution of shallow Antrim Plateau basalts, as indicated by magnetic patterns, influences the near surface conductivity. The conductance of the shallow conductive layer is not sufficient to mask responses from buried good conductors. Inspection of the sections and slices failed to locate clear anomalies indicative of good conductors.

Conductivity quasi-sections from the west Main Murphy area indicate a thick weakly conductive sequence lying over more resistive material. Information from drilling shows the conductive layer corresponds to Cambrian limestone, Antrim Plateau basalt and Westmoreland sandstone etc. while the resistive material is probably Murphy Inlier basement. Variations in depth evident from the Geotem data show that the basement unconformity undulates, is probably faulted in places, and varies in the western area from around 300 m to at least 550 m below the ground surface. There are variations also in the conductivity of the cover sediments, with relatively more conductive areas at shallow depths in the north central area (several km northeast from hole MURD012), possibly associated with inferred faults.

The Geotem survey has given more information on the disposition of the Westmoreland and Cambrian deposits in the west Murphy area, and there may be scope to develop other uranium targets within these rocks. However, no good conductors have been found below the basement unconformity in any of the areas surveyed.

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INTRODUCTION

An airborne electromagnetic survey was planned at Murphy with the primary objective of detecting conductive units in the Murphy metamorphic basement. Carbonaceous horizons that may have played a significant role in deposition of uranium at the unconformity above the basement are expected to be conductive, especially if metamorphism was sufficient to have converted carbon to graphite. Three areas were nominated for the survey, as shown in the diagram below.

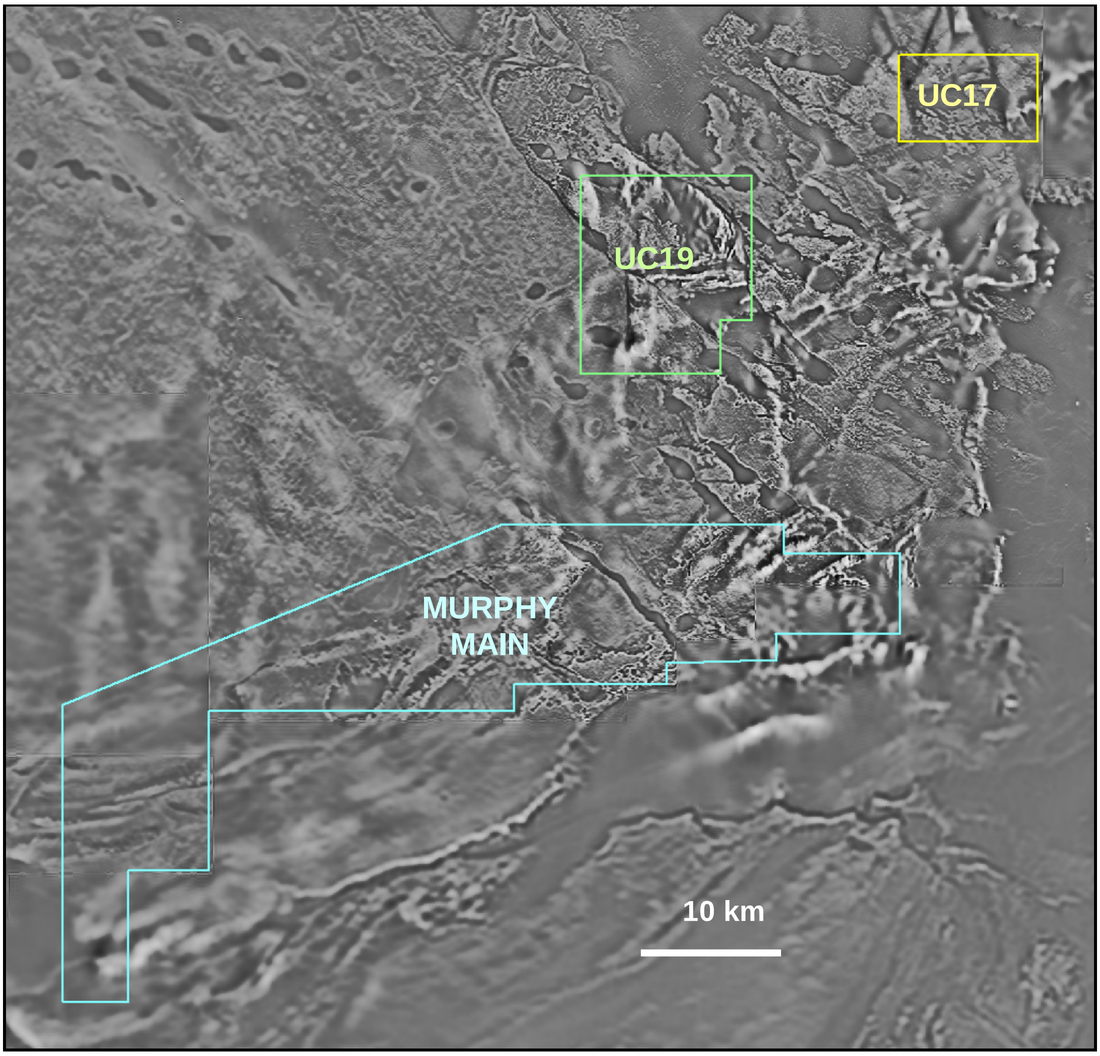

Figure 1: Outlines of Geotem survey areas, on image of first vertical derivative of magnetic intensity reduced to the pole.

Both the UC17 and UC19 areas had been selected as prospective unconformity targets from magnetic interpretation and drilling had shown anomalous uranium. The basement unconformity was expected to be deeper in the Murphy Main area, with little known about structure as the magnetic responses are dominated by the effects of overlying Antrim Plateau Volcanics of Permian age.

The Geotem towed bird time domain system was chosen for the survey as it was considered the most suitable of those available for detecting relatively large conductors at depths to about 300 m. Flight lines were laid out north-south with 500 m spacing in the Main area, north-south with 300 m spacing in the UC19 area and east-west with 300 m spacing in the UC17 area. Fugro Airborne Surveys were contracted to fly the survey, which was completed in early October 2010. The images of electromagnetic signals in this report (Plans 1-4) are based on preliminary-final grids provided by Fugro at the end of October while the remaining plans are derived from preliminary located data provided in mid October.

GENERAL RESULTS

The Geotem system employs a horizontal transmit loop mounted on the aircraft and a receiver towed at the end of a cable. For the Murphy survey the horizontal transmitter-receiver separation was 125 m and the vertical separation was 38 m, while the aircraft altitude was 120 m.

The receiver measures the vertical (Z) and two horizontal (X in the flight direction and Y perpendicular to this) components of the time derivative of the magnetic field (units nT/s) arising from electric currents in the transmitter and induced in the ground. Measurements are made in 4 time windows while the transmit current is on (a half-sine pulse 4.1 ms long) and in 16 time windows from 0.50 ms to 14.5 ms after turnoff. Raw data may be integrated with respect to time to give magnetic field (units pT), which is useful when examining responses from better conductors.

The X component is generally used for seeking steeply dipping conductors as anomalies appear as peaks when the receiver passes over the tops of such conductors. Currents induced in the ground by the transmitter decay rapidly where the conductivity is low, but last longer in good conductors, so that anomalies from good conductors show up best in late time window signals.

Plans 1-3 display the X component responses in nT/s for all the survey areas for time windows at 0.66 ms (‘early’), 2.76 ms and 9.64 ms (‘late’) and Plan 4 shows the Z component in pT at 9.64 ms. The Z component signal is usually larger than the X component signal where the ground is mildly conductive and displays higher signal/noise ratios at late delay times.

At early time (Plan 1) the most obvious features are the regions of low response at the east end of the Murphy Main area and in the centre and east of the UC19 area.

Northwest-southeast trending features in these areas correspond to magnetic anomalies interpreted as faults. Otherwise the patterns show a rather irregular or blotchy appearance that is common from areas of weak near-surface conductivity.
The responses at mid times (Plan 2) are similar. Local areas of higher response seen in Plan 1 persist. The signals at UC17 appear higher overall than in the other two areas.

At late time (Plan 3) noise is evident, with only a few areas (eg northeast corner of UC19, southern east corner of Main area) standing out with a strong response. The Z component (Plan 4) appears less noisy and otherwise displays the same patterns as the X component.

No obvious anomalies stand out at late time. The places where there are stronger responses also have large signals at early time. Further analysis is needed to help discriminate between conductive zones.

CONDUCTIVITY DEPTH RESULTS

The basic signals measured at each point have been converted to a set of conductivity-depth values. The basis of the procedure is to calculate from the observed magnetic field signal for each time window the depth of an image that represents the eddy current in the ground. The rate of propagation of the current pattern varies inversely as the conductance, so from the image movement the conductivity structure of the ground may be estimated. Although the results are ***approximate*** and valid only for horizontally layered ground, they provide for discrimination of conductors on the basis of depth. Local buried conductors also appear buried, with inverted cup shapes over their tops if they are steeply dipping.

(a) Sections

Conductivity quasi-sections for the Main Murphy area are plotted in Plan 5, those for UC19 are shown in Plan 6 and sections for UC17 are presented in Plan 7. In all these plans the sections are shown in their correct positions, with the tops at the flight line locations. Each section is 400 m deep, with no vertical exaggeration. For the UC17 and UC19 surveys the plans have been stretched so that the sections do not overlap. In some places, especially at UC19, the observed decays were too short for a reliable conversion to conductivity-depth. This occurs when the ground is very resistive. These areas are shown in grey in the sections. The sections have also been calculated for the full length of each flight line, and there are some spurious effects at the ends of lines where the aircraft might not have been in correct level flight.

Nearly all the sections show the presence of a conductive layer at the surface. This layer is virtually absent is a few areas, such as central-east UC19 and the eastern part of the Main area. The shallow conductive layer probably corresponds to soil plus the weathered zone. The Geotem system does not provide very early time measurements and so does not give information on the details of the structure in the topmost several tens of metres.

Below the conductive surface layer the conductivities everywhere are significantly lower. No clear anomalies indicative of a buried good conductor have been found.

In the western part of the Main Murphy area (Plan 5A) there area significant areas where the conductivity below the surface layer is above 0.03 S/m (yellow colour in the sections). This indicates a resistivity of about 30 ohm m or less, which is probably reasonable for moderately porous basin sediments. Conductivities are much lower at depth toward the eastern end of the Main area, however (Plan 5B). There are localised areas where the surficial layer is highly conductive and these partly mask responses from the ground beneath, as seen by the very low apparent conductivities beneath them. The areas of high response seen in the channel plots (Plans 1-4) are all seen in the sections to correspond to more conductive surficial zones.

Highly conductive shallow material is also evident in the northeast and northern central parts of the UC19 area and accounts for the higher responses at all delay times. There are very weak conductivity trends across the central area of resistive terrain, reflecting the east-west trending sediments and dykes here.

At UC17 the conductive surface layer is present everywhere (Plan 7). There are variations in the conductivity beneath this, but the sections are noisy (flying conditions for this area were turbulent on each occasion it was flown) and the values are low.

(b) Conductivity slices

The conductivity has also been averaged for several depth intervals, with the results plotted in Plan 8 (for 0-100 m), Plan 9 (100-200 m), Plan 10 (200-400 m) and Plan 11 (400-600 m). The colour legend for each of these plans is the same (with a nearly logarithmic transform) to illustrate the variation in conductivities with depth.

The slice for 0-100 m effectively maps the conductance of the near-surface conductive layer seen in the sections. Many of the patterns visible in this slice in the UC17, UC19 and eastern Main areas correlate with those seen in the magnetic anomalies (see Figure 2 on the next page). However, there is not a consistent relation between magnetic indications of Antrim Plateau basalts and conductivity. Commonly, interpreted areas of shallow basalt appear to be relatively conductive, but apparent ‘windows’ in the basalts may be even more conductive, while some areas of basalt are resistive. The northwest and north-northwest trending faults evident in the magnetic patterns at UC19 and UC17 also show up in the conductivity patterns. In the UC19 area the higher conductivities to the southwest and northeast suggest these sections are downthrown, giving greater thicknesses of the sediment and basalt sequence. In the cental and western parts of the Main Murphy survey area there is little relation between magnetic anomalies and shallow conductivity. This is consistent with the basalts being at greater depth.

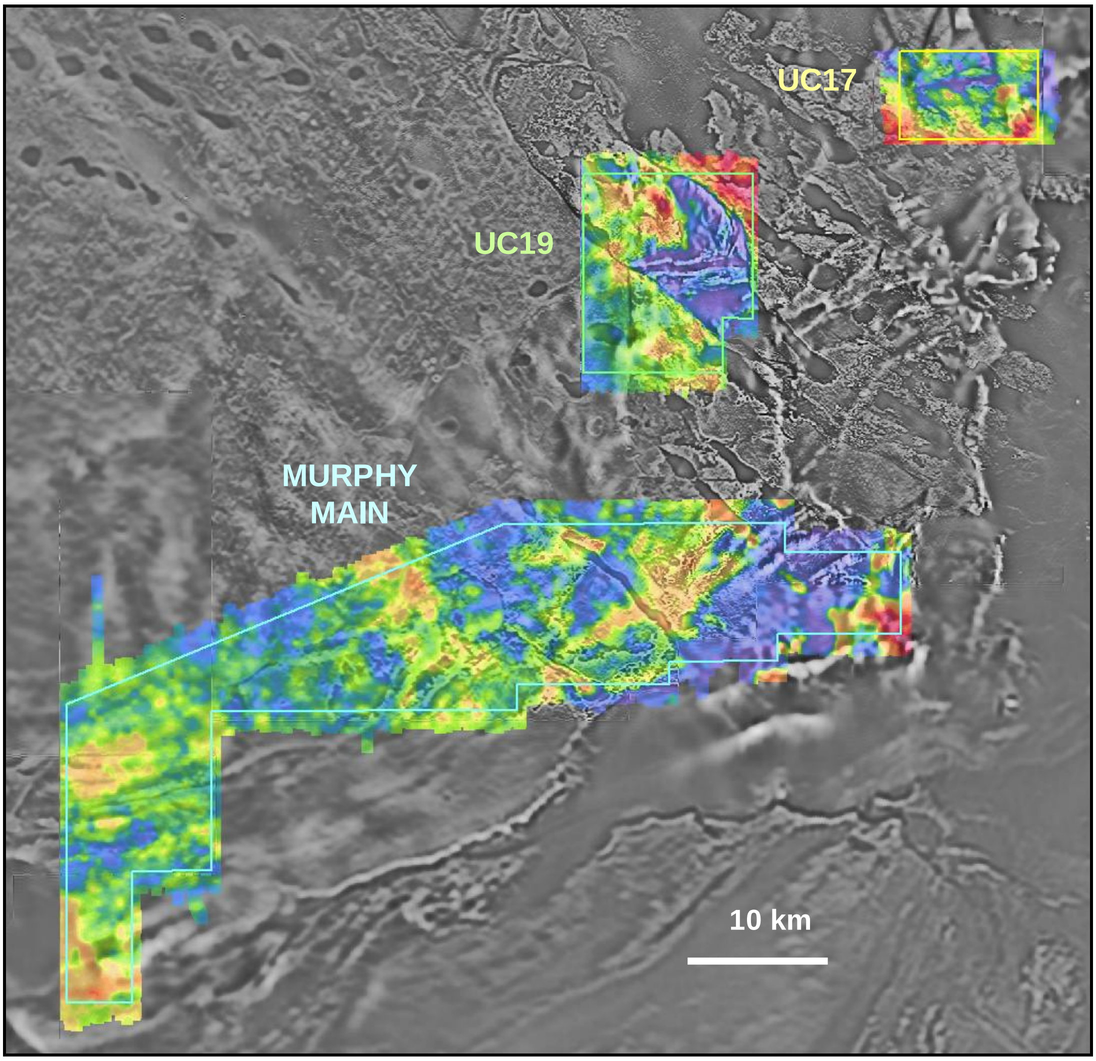

Figure 2: Conductivity for 0-100 m depth in colour (high is red, low is blue) on grey image of first vertical derivative of magnetic intensity reduced to the pole.

The slice for 100-200 m (Plan 9) shows a clear division between areas of moderate conductivity (green-yellow-orange) and areas of very low conductivity (violet). It should be noted that the conductivity values in the low areas are probably ‘too low’ as the conductivity-depth processing tends to ‘overshoot’ and actually give some negative values immediately beneath a very conductive layer.

At UC19 the boundaries correspond mainly to the two northwest trending faults. In the eastern section of the Main area moderate conductivity gives way going eastwards to low conductivity along a rather irregular boundary that trends southwest-northeast. The areas of moderate conductivity are interpreted as representing basin sediments and the more resistive rocks are probably mainly Murphy Inlier basement. Further cover sediments are indicated toward the southeastern corner of the Main survey area (these may be Cainozoic?). The UC17 area appears to be almost entirely covered by relatively conductive basin sediments, at this level (100-200 m).

The next slice, for 200-400 m (Plan 10) is similar to the one for 100-200 m, but values in the areas of low conductivity have risen a little (recovering from the ‘overshoot’ mentioned above). In the Main survey area the boundaries evident in the eastern section of the 100-200 m slice are recognisable but more gradual. There is a broad tendency for the average conductivity to decrease from west to east. At the ends of some of the flight lines there are spurious effects, as the aircraft leaves and approaches each line. The pattern for the UC17 area appears noisy with no significant trends. At UC19, however, the northwest trending faults display some edge effects - narrow high conductivity anomalies adjacent to the sharp margins of horizontal conductive sheets.

The deepest slice, for 400-600 m, is shown in Plan 11. Generally the conductivity values are low, with more noise evident (the data come from the late time measurements). Patches of very low conductivity (blue-violet) in all survey areas often correspond to masking by patches of shallow high conductivity. The patterns evident at shallower depths at UC19 have virtually disappeared, suggesting that the responses are from relatively resistive rocks beneath any basin cover. The patterns at UC17 are also noisy and give little information. In the Main survey area most of the area shows low conductivity, with irregular noisy variations. If these responses reflect the rocks beneath the sequence of basin sediments, there is no sign of any conductive units that may reveal structural or lithological trends. In the northwest section and central west sections of the Main area, however, the conductivities are higher and comparable to those in the same areas in the slice above (200-400 m). This suggests that the same rocks, inferred to be basin sediments, are present below 400 m here.

If there are any significant good conductors just below the basement-cover unconformity they should be evident in the deeper conductivity slices. Figure 3 on the next page shows conductivity slices for the three areas. There are no local anomalies evident in the UC19 area. In both the UC17 and Main areas there are some local possible anomalies. These are all small in area (each evident on only one line), lack any consistent local trend, and from closer study have been judged to be spurious (ie noise or edge effects from breaks in the cover) or insignificant. Further examination of the deep higher conductivities in the western part of the Main survey is discussed in the next section.

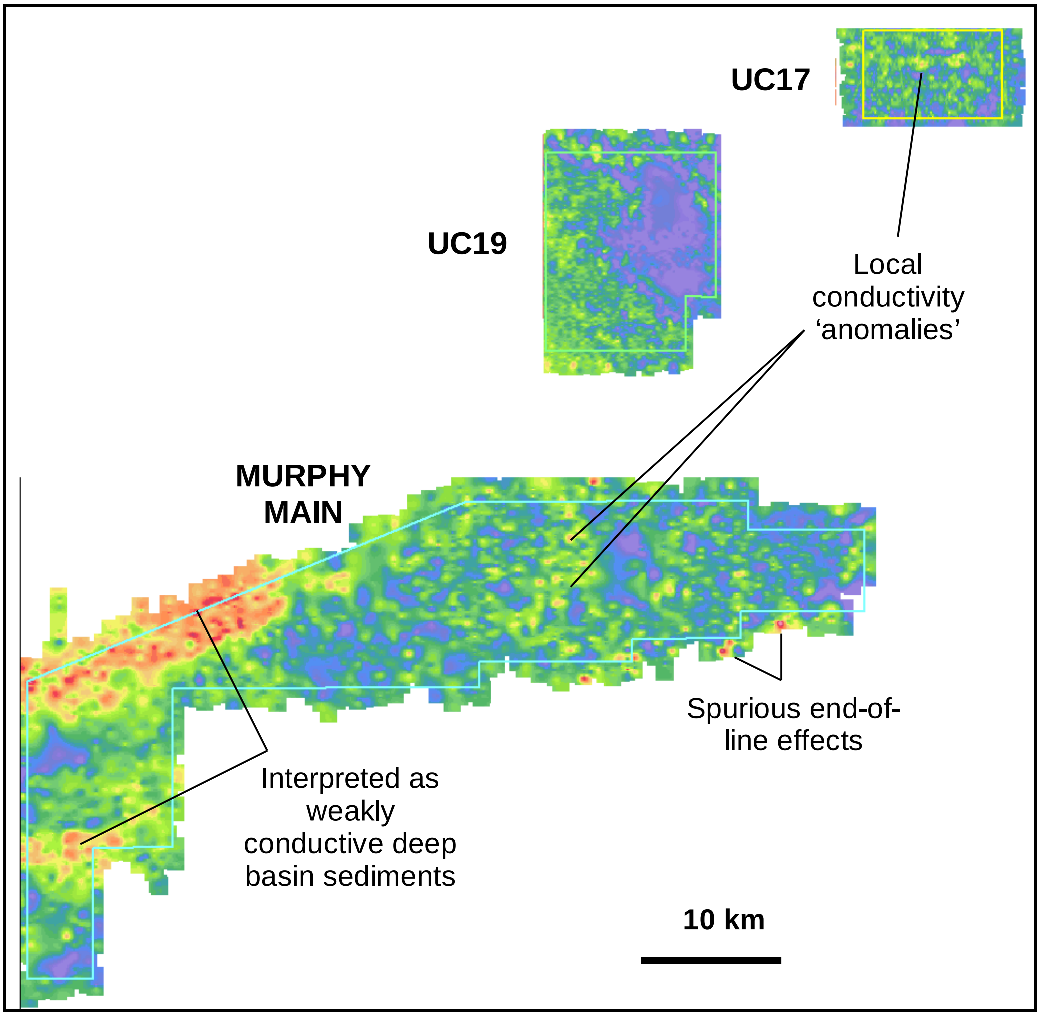

Figure 3: Conductivity for 200-400 m depth for UC17 and UC19 areas, and for 400-600 m depth for Murphy Main area. High is red, low is blue.

MURPHY WEST BASIN COVER

Drill holes MURD011, MURD012 and MURD013 have provided some widely spaced information on the sequence in the Murphy west area that assists with the interpretation of the conductivity data here.

Plan 12 is a section at 605250E (about 250 m east of MURD011) that shows conductivity versus depth, smoothed along the line with a moving average filter about 800 m long. Also drawn in the section is a smoothed estimate of the depth at which the conductivity falls to 0.007 S/m. This was chosen to give an indication of the depth of resistive basement or other resistive rocks. Additionally a smoothed estimate of the depth of maximum conductivity below 120 m is plotted. This was picked to help map the variation in depth of the most conductive rocks in the sequence, below the surficial cover. From comparison with the results in MURD011 the 0.007 S/m level appears to be a reasonable indicator here of the depth to the Murphy basement/cover unconformity. Both this and the peak conductivity profiles suggest that the unconformity is gently undulating, with probably a fault close to 7997500N that shows uplift on the northern side. The depth of basement appears to be greater (at least 500 m) just south of this fault, to be at about 400 m north of the fault and at MURD011, and then to increase steadily toward the northern margin of the survey. Conductivity sections (Plan 5A) suggest that the fault continues to the east, but eventually dies out.

Plan 13 is a section at 619250E. There is no drilling on this section, but the conductivity section indicates that the most conductive part of the cover sequence drops quite sharply at 80110000-801200N. By extrapolation the depth to the unconformity would be expected to be about 700 m in the area north of here.

The section at 623250E, 250 m east of MURD012, is shown in Plan 14.The depth to basement appears to be relatively constant at 300-350 m along the length of this section.

Plan 15 shows the section at 638250E, about 250 m east of MURD013. The hole intersected dolerite beneath the basin sequence of limestone, basalt and sandstone. The cover sequence here appears to be less conductive than further west and it is more difficult to trace it and to distinguish a more resistive substrate. However the rough estimate for the base using the 0.007 S/m value is consistent with the drill hole information.

An estimate for depth to the Murphy basement in the west Murphy area is plotted in Plan 16. This is simply a smoothed grid of depths to where conductivity drops to 0.007 S/m. The blank areas on the northern margin of the survey west of MURD012 and within the survey about 5 km south of MURD011 are where the basement appears deeper than detectable from the data. (the deepest value recovered is about 550 m).

Variations in the depth to the most conductive section of the cover rocks are shown in Plan 17. From comparison with the rocks intersected in the drill holes, this section may correspond to the upper part of the sandstone unit (Westmoreland) lying above the basement. Relatively sharp and linear offsets in depth seen in Plan 17 probably indicate faults. East or east-northeast trending faults are suggested near 7998000N about 3 km south of MURD011 (south side down; see also Plan 12) and in the area 2-6 km west of MURD012 (northwest side down; see also Plan 13). A north-northwest trending fault is suggested midway between MURD012 and MURD013 – this appears to have a smaller offset, with the west side up. There is also a north-northwest trending step to the north-northwest of MURD012, perhaps a transcurrent fault offsetting the east-northeast trending structure here.

The more conductive section of the cover sequence also varies in conductivity over the area. Plan 18 is an image of the peak conductivity in the cover, overlain with contours of the depth (cf Plan 17). The significance of these variations in conductivity is uncertain. They may be related to thickness variations and/or to facies changes. Higher conductivity regions near faults (eg 2-5 km north and 7-8 km northeast from MURD012) might reflect alteration associated with fluid movement within fault systems.

The Geotem survey has provided more data on the cover and its thickness in the Murphy west area, suggesting undulations and faulting. Depth estimates to Murphy basement suggest that the basement is probably more than 300 m deep in nearly all the area west of MURD013 (Plan 16). No anomalies indicative of localised good conductors have been found. Zones of mildly higher conductivity that have been recognised appear to lie within the cover and not within the basement.

CONCLUSIONS

The UC19 area contains a central region lying between two northwest trending faults (Fig 2 and Plan 6). This central area appears to be uplifted and Westmoreland sediments and dolerite dykes are exposed. The electromagnetic responses here are low and indicate negligible surficial cover. Two east-west trending dykes exhibit slightly greater conductivity, probably from weathering.

In the northwestern part of the central area the magnetic responses suggest there is shallow Antrim Plateau basalt. Here the electromagnetic data show a conductive surface layer with resistive material below. Incipient clay alteration (weathering) of the basalts may be responsible for some of the shallow high conductivities.

In the northeast, across the NW trending fault, there is also very conductive shallow cover. Below this the conductivities are slightly higher than in the northwestern area at similar depths. Again the magnetic patterns indicate the presence of shallow basalt. The moderate conductivities inferred beneath suggest there are sediments here that are more conductive than the basal Westmoreland unit.

To the southwest, across the other NW trending fault, the EM data suggest a similar situation to that in the northeast, although generally the surficial material is not as conductive.

The thin cover where present does not mask the underlying rocks, and the Geotem data show no indications of there being any localised good conductors anywhere in the UC19 area.

The UC17 area has a conductive surface layer everywhere. This tends to be more conductive (or thicker) toward the south and in the southwest and southeast (Fig 2 and Plan 7). As at UC19 there is some correlation between basalts as indicated by the magnetic patterns and shallow conductivity. The central section of the UC17 area lies between two north-northeast trending faults, according to the magnetic response, but these are only vaguely apparent from the EM data. The pattern of conductivity beneath the surface cover is irregular in general. There is, however, some correlation between deeper lower conductivities on the flight line near 801400N and an inferred east-west trending contact or fault seen in the magnetic data. No buried good conductors are evident at UC17.

The eastern part of the Main Murphy survey area (Fig 2 and Plans 5B, 8 and 9) shows features similar to those seen in the UC19 area. Some areas show little surficial cover and moderately resistive rocks. There is some correlation between features seen in the magnetic patterns (eg windows and channel structures inferred to be in basalt) and shallow conductivity. Conductive cover in the southeast corner might be related to shallow sediments rather than to weathered basalt. Moderately resistive rocks, probably Murphy inlier basement units, perhaps Westmoreland sediments, lie immediately beneath the surface layers and these show no evidence of containing any very conductive units.

The remaining section of the Main area has thin surficial cover and beneath this there is a general trend of increasing conductivity and thickness toward the west (Plans 5, 9 and 10). There is evidence of gentle folding and of faulting along both east-northeast and north-northwest trending structures. From drilling evidence the rock sequence consists of Cambrian limestone, sometimes Antrim Plateau flood basalts, and Westmoreland sandstone, above Proterozoic Murphy basement. Depths to higher resistivity rocks, probably Murphy basement, appear to increase to over well over 500 m in the northwest (Plan 12, 13 and 16). In most of the western area the inferred basement is too deep for any conductors beneath the unconformity to be detected from the Geotem survey. In the central area where depths may be 100-400 m good conductors should be detectable, but no significant conductive zones have been identified (Plans 5B, 9 and 10 and Fig 3).

The Geotem survey has given more information on the structure of the Westmoreland and Cambrian deposits in the west Murphy area, and there may be scope to develop other uranium targets within these rocks. However, no good conductors have been found below the basement unconformity in any of the areas surveyed.