THE ELECTROMAGNETIC RESPONSE OF THE DIFFERENT CONDUCTIVE PHENOMENA OF THE ATHABASCA BASIN AREA OF SASKATCHEWAN TO THE SLINGRAM COIL CONFIGURATION

By

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A RESEARCH PROJECT CONDUCTED IN CONJUNCTION WITH PERSONNEL IN THE GEOPHYSICS LABORATORY, DEPARTMENT OF PHYSICS, UNIVERSITY OF TORONTO
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ERRATA, ADDENDA AND COMMENTS

1. Page 1. The first-listed contributing company should be changed to read Canadian Occidental Petroleum Ltd and its joint venture partner, INCO Ltd.

2. Page 1a. Along the X-axis of the graph the numbers $10^0,10^1,10^2,10^3$ & $10^4$ should be changed to $10^4,10^5,10^6,10^7$ & $10^8$, respectively.

3. Page 1b. Same comments as above for the X-axis of the graph.

4. Page 1b. The values of D/S = 0.0, 0.25, 0.5 & 1.0 on the quadrature curves should be changed to 0.25, 0.5, 1.0 & 0.0, respectively.

5. Page 2. Third paragraph, eleventh line. The number 30 should be changed to 300.

6. Page 8. Second paragraph, seventh line. The comma between the words "sheet" and "can" should be deleted.


8. Page 19. Last paragraph, second line. The word "photomosaic" is misspelt.


11. Page 27. Fourth line. The word "Lines" should be inserted between the word "Flight" and the number "10080".

12. Page 30. Third paragraph, fourth line. The word "ohmmeter" is misspelt.

13. Page 31. Second last line. The word "a" should be inserted between the words "of" and "conductive".

14. Page 35. Fourth line. The word "ohmmeter" is misspelt.

15. Page 42. Second paragraph, eighth line. The word "evidenced" is misspelt.

16. Page 42. Last paragraph, first line. The word "section" should be inserted between the words "topo-geological" and "in".

17. Figure 37. The word "description" in the lower central part of the sheet is misspelt.

18. Figure 38. The word "interpreted" in the lower left part of the sheet is misspelt.

19. Figure 38. The word "projected" in the lower central part of the sheet is misspelt.

20. Figure 41. The head of the flight direction arrow for flight line 1160 is missing. The flight direction was from west to east in this case, as can be seen in the sketch on page 29.

21. Figure 41. The expression "weakly-conductive" in the lower left part of the sheet has been misspelt.

22. Figure 42. The word "projected" in the lower central part of the sheet is misspelt.

23. Figure 43. The word "MaxMin" in the upper left part of the sheet is misspelt.

24. Pages 18, 21, 24, 27, 29, 33, 36 & 41. Sketches. A common legend was made up for these eight sketches. All of the symbols shown in the common legend are not necessarily used in each sketch, however. In some cases, a feature represented by one of the symbols does not exist in the area covered by the sketch; hence, the absence of the symbol on the sketch. A compound symbol of low and high dot densities is used for a "Broad Basement Conductive Zone" without further explanation. The higher dot density represents a higher level of conductivity.

25. For the sake of convenience and reduced costs, Figures 37 through 44 were bound between the same covers as the text. This presents a measure of inconvenience in cross-refering the text and the Figures. For those with separate binding facilities, it is suggested to unbind the Figures and to put them into one or more pouches following the text. This way, each Figure can be separated from the report and viewed simultaneously with the text.
# LIST OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page #</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT &amp; ACKNOWLEDGEMENTS</td>
<td>i</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>PRESENTATION OF RESULTS</td>
<td>4</td>
</tr>
<tr>
<td>DISCUSSION OF THE SCALED MODELLING RESULTS</td>
<td>4</td>
</tr>
<tr>
<td>General</td>
<td>4</td>
</tr>
<tr>
<td>Figures 1 through 4</td>
<td>4</td>
</tr>
<tr>
<td>Figures 5 through 8</td>
<td>6</td>
</tr>
<tr>
<td>Figures 9 through 12</td>
<td>7</td>
</tr>
<tr>
<td>Figures 13 through 19</td>
<td>8</td>
</tr>
<tr>
<td>Figures 20 through 23</td>
<td>10</td>
</tr>
<tr>
<td>Figures 24 through 27</td>
<td>11</td>
</tr>
<tr>
<td>Figures 28 through 32</td>
<td>12</td>
</tr>
<tr>
<td>Figures 33 through 36</td>
<td>13</td>
</tr>
<tr>
<td>DISCUSSION OF THE FIELD RESULTS</td>
<td>14</td>
</tr>
<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Figure 37</td>
<td>17</td>
</tr>
<tr>
<td>Figure 38</td>
<td>20</td>
</tr>
<tr>
<td>Figure 39</td>
<td>23</td>
</tr>
<tr>
<td>Figure 40</td>
<td>26</td>
</tr>
<tr>
<td>Figure 41</td>
<td>27</td>
</tr>
<tr>
<td>Figure 42</td>
<td>30</td>
</tr>
<tr>
<td>Figure 43</td>
<td>35</td>
</tr>
<tr>
<td>Figure 44</td>
<td>41</td>
</tr>
<tr>
<td>CONCLUDING REMARKS</td>
<td>43</td>
</tr>
<tr>
<td>APPENDIX</td>
<td></td>
</tr>
<tr>
<td>REFERENCES</td>
<td></td>
</tr>
<tr>
<td>INDEX OF MODELS</td>
<td></td>
</tr>
<tr>
<td>PLOTTING SCALES FOR MODELLING RESULTS</td>
<td></td>
</tr>
<tr>
<td>MODELLING RESULTS -- Figures 1 to 36</td>
<td></td>
</tr>
<tr>
<td>FIELD RESULTS -- Figures 37 to 44</td>
<td></td>
</tr>
</tbody>
</table>
ABSTRACT

This study throws some light onto the types of conductors in the Athabasca Basin area of Saskatchewan, which respond to air and ground electromagnetic surveying systems.

By relating laboratory physical scaled modelling results to field results, for a ground EM system using the slingram or horizontal loop coil configuration, it becomes apparent that there are:

a) moderately to steeply-dipping, moderately-conductive tabular basement zones, and
b) very broad, weakly-conductive basement units -- in the overall picture.

By further relating the Input air EM results to the interpretation, based on the 'slingram' ground EM results, supported at times by drill hole information, some interpretive aids can be obtained for the Input air EM system, which to date have been rather incomplete for an environment such as the Athabasca Basin. The incompleteness of the Input interpretation has often led to improper ground follow-up procedures.

In conclusion, the results of this study will improve the quality of the interpretation for both the Input air EM system, and ground EM systems using the slingram coil configuration.

ACKNOWLEDGEMENTS

I am indebted to Dr. Gordon West for making the scaled modelling facilities in the geophysics laboratory at the University of Toronto available for this project. I am also indebted to graduate student Mr. Cesar Villegas for putting aside other projects in order to perform all of the model experiments related to this project. Without the personal interest and efforts of Mr. Villegas, this project may never have reached completion.

Equally important to the modelling results in a project like this are the field results and supportive drilling information provided by several companies working in the Athabasca Basin area of Saskatchewan. Three of the contributing companies are: Canadian Occidental Petroleum Co. Ltd., Jodi Energy Resources Ltd., and Westmin Resources Ltd.

One contributing company chose to remain anonymous.

I am thankful to Mr. K. Kahn of the University of Toronto physics department for persevering with the drafting of the great maze of field results included in the study.
INTRODUCTION

This set of laboratory scaled model experiments is based on possible deep-seated conductor geometries in the Athabasca Basin area of Saskatchewan, Canada, as seen by the slingram or horizontal loop coil configuration. The impetus behind these experiments came from the recognition in the slingram coil configuration ground EM results that not only were reasonably-confined conductive sources in play, such as, a) steeply-dipping tabular graphite zones in the basement rocks, and b) silt-filled troughs and fracture zones in the upper sandstone, but also, that very wide (e.g. \( \frac{1}{2} \) to 2 kilometers) deep-seated, weakly-conductive phenomena were in play.

It has long been known from theoretical investigations that a 'deep' conductive horizontal uni-plane or half-space will create changes in the in-phase and quadrature readings in a positive-sense from background for the slingram coil configuration. For that matter, a 'shallow', 'weakly-conductive' horizontal uni-plane, or half-space, will create changes in a positive sense from background. Only a 'shallow', 'strongly-conductive' horizontal uni-plane, or half-space, will create negative-sense changes from background.

The suites of curves on pages 1a & 1b will go toward putting into perspective the terms 'deep', 'shallow', 'weakly- & strongly-conductive' used in the preceding paragraph. These curves are made up from theoretical data\(^3\) for the slingram coil configuration over a conductive horizontal uni-plane and half-space. These curves show the manner in which the in-phase and quadrature levels vary with the product '\( \sigma.f.s \)' for a half-space and '\( \sigma.t.s.f \)' for a horizontal uni-plane, where \( \sigma \) is the specific conductivity of the conductive material in mhos/m, \( f \) is the operating frequency in Hz, \( t \) is the thickness of the plane in meters, and \( s \) is the coil spacing in meters of the 'slingram' system.

Of course, a conductive source need not be infinite in size to generate the type of background changes indicated by the suite of curves on pages 1a & 1b. A source of surficial lengths and widths of a few coil spacings would be sufficiently large to generate such changes, when the 'slingram' system is well within the boundaries of the source. As the 'slingram' system passes from inside to outside of the boundaries of a large conductive source, the background levels will change from being uniformly anomalous to uniformly non-anomalous, passing through a transition area over the edge of the source.
The nature of the change in the anomalous levels over the edge, i.e. the 'edge-effect', of a very wide, weakly-conductive source is one of the areas of investigation in this model study, because it is an anomalous phenomenon frequently encountered in the field.

Earlier model studies\textsuperscript{258} have covered the 'edge-effects' of some very wide, conductive sources, but there has been no comprehensive study for very wide, weakly-conductive sources at 'large' depths, such as in the case of the Athabasca Basin. The results of this study will help fill the gap in this information.

It can be seen in the suites of curves on pages la & lb that both shallow and deep, weakly-conductive, horizontal uni-planes and half-spaces will generate positive-sense background changes. With this, it could be asked, why the modelling study involved deep, rather than shallow, horizontal sheets and blocks. In brief, the background quadrature levels of the field results were often more positive than might be reasonably expected from a thin layer of glacial till on top of a thick layer of resistive sandstone—a statement based on plugging typical values of resistivities and thicknesses for the till and sandstone into curves based on theoretical computations\textsuperscript{3}. For example, a 10 meter-thick layer of 30 ohm-meter till, overlying a circa 200 meter-thick layer of 4000 ohm-meter sandstone, when traversed by a slingram coil configuration of an 800 ft or 250 meter spacing, would generate quadrature response levels of \(2\%P\) and \(4\%P\) at frequencies of 1777 Hz and 3555 Hz, respectively. Some of the quadrature levels seen in the case histories of this study and in many other field results, where the thickness of the sandstone is about 200 meters and the slingram coil spacing is 800 ft or 250 meters, are from 7 to \(8\%P\) at 1777 Hz and from 9 to \(10\%P\) at 3555 Hz. From this, it was assumed that there is a contribution to the anomalous picture from the basement rocks. Of course, it is possible for a 200 meter thickness of sandstone to generate a quadrature anomaly of 7 to \(8\%P\) (the theoretical maximum) at 1777 Hz, if the resistivity of the sandstone is as small as 600 ohm meters, but, such a low value of resistivity is the exception rather than the rule for the Athabasca sandstones.

Also, the small amplitude level changes of the Input air EM profiles are in keeping with deep broad, rather than shallow broad, conductive features.
Next, comes the question of the geological significance of the deeply-buried, extensive, flat-lying conductive sheets and large conductive blocks in the Athabasca Basin. A deeply-buried, flat-lying weakly-conductive sheet could be:

1a) a layer of moist clay (regolith) on top of the Precambrian basement, or

1b) a layer of intense weathering and/or fracturing in the upper basement rocks resulting in the rocks being permeated by electrolytic solutions, or

1c) a zone of clay alteration within the lower sandstone.

A deeply-buried, weakly-conductive block could be:

2a) a lithological unit containing a network of interconnected electrolyte-permeated fractures, or

2b) a lithological unit containing many parallel and sub-parallel graphite stringers, which in turn may be linked into a weakly-conductive network by oblique electrolyte-filled fractures.

The point to be remembered throughout the descriptions in the preceding paragraph is that regardless of the nature of the large weakly-conductive geological phenomenon, the conductive elements comprising it must permit the formation of large horizontal eddy current loops. Such current loops are necessary to generate the very extensive in-phase and quadrature level changes observed in the field results of the Athabasca Basin.

In addition to large deep-seated, 'weakly-conductive', horizontal sheets and blocks in the basement rocks of the Athabasca Basin, there are also steeply-dipping tabular conductive zones comprised of graphite, and sometimes sulphides. These tabular conductive zones can occur within, or near the edge of, the broad conductive sources, resulting in superimposed anomalous effects. The present model study is intended to throw some light onto these combined anomalous effects. Of particular interest in the latter regard, is the effect of a steeply-dipping tabular conductor along the edge of a wide conductive feature, because the anomalous expression of the edge of the wide feature bears some resemblance to that of the steeply-dipping tabular conductor. The superimposition of these two anomalous expressions adds to the interpretational challenge.

A total of eight conductor geometries were used for the model experiments. These geometries can be seen on the index sheet preceding the modelling profiles. The laboratory model experiments are supported by eight field case histories from the Athabasca Basin.
One type of anomalous feature not covered in these model experiments, but ever present in the field, is the shallow electrolytic conductor such as a silt-filled trough and/or a silt-filled fracture zone in the upper sandstone. There will be more on this subject in the discussion of the field results.

PRESENTATION OF RESULTS

The outcome of the scaled modelling results are shown in Figures 1 to 36 at the end of the text. They are preceded by an index and a specimen of the plotting scales. The eight field case histories are shown in Figures 37 to 44.

DISCUSSION OF SCALED MODELLING RESULTS

General

The scaled modelling experiments were centered around an equivalent field coil spacing of 250 meters—a common spacing used in the Athabasca Basin. It is an easy matter to convert the results to the other commonly used coil spacings such as 183 meters (600 ft), 200 meters, 244 meters (800 ft) and 300 meters, by making appropriate adjustments to the equivalent field conductivities and dimensions. As an example, for an equivalent field coil spacing of 300 meters, the equivalent field conductivities must be modified by a factor of 250/300, and all of the dimensions and depths of the conductive sources must be modified by a factor of 300/250.

Figures 1 through 4

Figures 1 through 4 contain 'slingram' profiles over a conductive block 890 meters wide at operating frequencies of 444, 888, 1777 & 3555 Hz.

The depths to the top of the block are 50, 100, 150, & 200 meters at all frequencies, with additional depths of 250 and 300 meters at frequencies of 888 & 3555 Hz. These greater depths were added after the original batch of experiments because, as additional field cases developed, it became apparent that thicknesses of sandstone greater than one coil spacing were encountered in the diamond drilling of some anomalous phenomena.

For the model block used in these experiments, the strike-length is equal to the width, i.e. a field equivalent of 890 meters, whereas in Nature it is nearly always greater. Alas, the choice of strike length was governed by the availability of materials and the desire to keep the weight manageable. Blocks of carbon 14 in. x 14 in. x 11 in. are readily available as stock items, and they weigh 81 lbs each—a manageable weight by the average person working alone.
One point of interest in the response of the conductive block is that the in-phase and quadrature anomaly amplitudes over the center of the block, when plotted against frequency, have a best fit to the theoretical curves (page 1a) for a half-space of an equivalent field resistivity of 525 ohm meters. The best fit between the experimental and the theoretical curves was made toward the highest laboratory frequency, where the skin depth of the electromagnetic waves is only about 0.25 of the mean block dimension. The fit is not good toward the lowest laboratory frequency, where the skin depth is about 0.75 of the mean block dimension. The equivalent field resistivity of 525 ohm meters from the best fit of the laboratory and theoretical curves is to be compared with an equivalent field resistivity of 425 ohm meters determined via a miniature Wenner array in the central region of the carbon block. In a simple sense, this difference in resistivities is understandable when it is realized that the theoretical curves are for a half-space and the reduction in dimensions from the 'infinite' to the 'finite' would have a similar effect to reducing the conductivity, or increasing the resistivity, of the half-space—in this case from 425 to 525 ohm meters.

Now for a word on the significance of the equivalent resistivities mentioned in the preceding paragraph. Generally speaking, resistivities of 425 and 525 ohm meters are very low for metamorphic basement rocks, the resistivity of which can be an order of magnitude larger. However, as stated in points 2a, b on page 3, a network of electrolyte-filled fractures—or a network formed of graphitic stringers, joined by electrolyte-filled cross fractures—could result in a marked decrease in the bulk resistivity of the rocks.

Another point of interest in the response of the conductive block is the perceptible depression in the in-phase and quadrature profiles over the edges of the block, for the block at shallow depths, i.e. down to 0.4 coil spacing or 100 meters in this case. This 'edge-effect' bears a strong resemblance to the anomalous response of a conductive sheet, dipping toward the center of the block. The perceptible depression in the profiles over the edges of the block essentially disappears, when the depth of the block exceeds 100 meters. However, it is over the edges of the block that the profile shows a maximum departure from the shortest straight line drawn between the maximum and minimum values. An example of this can be seen in Figure 4. Unfortunately, the region of maximum departure is broad, and given a little noise in the data, it would be difficult to pick the edge of the block to better than ±25
meters. Another complicating factor in Nature is that the edges may be transitional rather than sharp.

Figures 5 through 8

Figures 5 through 8 contain sliagram profiles over a weakly-conductive block as per Figures 1 through 4, flanked by a steeply-dipping tabular conductor, at operating frequencies of 444, 888, 1777 & 3555 Hz.

As in the case of Figures 1 through 4, the depths to the top of the block and flanking tabular conductor are 50, 100, 150 & 200 meters at all frequencies, with additional depths of 250 & 300 meters at frequencies of 888 & 3555 Hz.

As before, the bulk resistivity of the block is 425 ohm meters. The conductance of the flanking tabular body is 16 mhos. A conductance value of 16 mhos falls within the range of conductance estimates made by me for the graphite conductors in the Precambrian basement of the Athabasca Basin. In fact, most of the conductance estimates fall within the range of 5 to 25 mhos. This is also a common range for the formational graphite zones of northern Ontario and Quebec. Occasionally, the conductance estimates of formational graphite zones can be above this range, when the graphite is particularly well developed, or when a few thin stringers of sulphides occur within the graphite zones.

In these experiments, the steeply-dipping tabular body is in electrical contact with the block as would be the case in Nature. With this, it is reasonable to assume that there is some enhancement of the anomaly from the tabular body due to currents gathered by it from the flanking weakly-conductive block. This is a logical sequel to the observation that the anomaly from a tabular body in a completely-enveloping, weakly-conductive host medium is enhanced by the currents gathered from the medium?.

As can be seen in the profiles of Figures 5 through 8, the tabular body has a distinctive anomalous response to a depth of one coil spacing (250 meters in this case). In fact, the anomalous response of the tabular body can be seen beyond a depth of one coil spacing. But, given a noise envelope of ±1%P (the primary field strength at the receiver) in any set of field results, it might be difficult to unravel the response of the tabular body from that of the edge of the block beyond a depth of one coil spacing.

Based on a simple phasor diagram, such as shown on page 6a, the conductance of the tabular body could be as small as about 6 mhos before there would be a loss of detectibility. If the conductance
QUADRATURE (QP) vs. IN-PHASE (IP)
For Several Values of
D/S (depth/coil spacing) and
σt.s.f. (conductivity.thickness.coil spacing.frequency)

Vertical Half-Plane

OP Anomaly Amplitude (shoulder-to-trough) as %P

P = Primary Field Strength at the receiver

IP Anomaly Amplitude (shoulder-to-trough) as %P
decreases below 6 mhos, the maximum depth of detection of the body would become progressively smaller. For example, a 4 mho tabular body, flanking a weakly-conductive block, would be detectable to a depth of about 0.9 coil spacing, and a 2 mho tabular body would be detectable to about 0.75 coil spacing. These stated depths are perhaps a little conservative, but nonetheless they serve as an approximate guide line.

Not included in this suite of experiments is the experiment for a tabular conductor within the conductive block. The cutting of a slot in the carbon block to accommodate the tabular body with an all-round tight fit was not practicable within the time frame set up for these experiments.

It is left to the reader, in his mind's eye, to transfer the tabular body from the edge of the conductive block to the central region. A first order approximation of the picture can be obtained by combining the profiles of Figures 1 through 4, with either the right or left half of the profiles of Figures 20 through 23. This combination would actually give a conservative picture, because the effects of current gathering from the host medium into the tabular body would not be taken into account. In any event, it would not be far-reaching to say that the order of detectibility would be at least as good for the tabular body within the block as along the edge of the block, because the response of the tabular body would not have to stand out above the 'edge-effect' of the block.

There will be a field example of a graphite zone within a broad weakly-conductive unit in the case history of Figure 41.

**Figures 9 through 12**

Figures 9 through 12 contain the 'slingram' profiles over a 0.35 mho horizontal conductive sheet at intermediate depths, i.e. 100 & 150 meters, at operating frequencies of 444, 888, 1777 & 3555 Hz.

A horizontal zone of conductance 0.35 mho can be made up of:

- a) a 5 meter thickness of 15 ohm meter material, or
- b) a 25 meter thickness of 75 ohm meter material, to list two examples only.

Case a) would be representative of a layer of clay (regolith) on top of the Precambrian basement rocks.

Case b) would be representative of a highly-weathered, electrolyte-permeated zone in the upper basement rocks.
Although the range of depths to the horizontal sheet is limited in this set of experiments, a much wider range of depths can be had from the profiles of Figures 18 & 19. In spite of the fact that the latter two figures contain the combined effects of a horizontal conductive layer and a flanking vertical conductive zone, the picture for the horizontal layer alone can be had by ignoring the effect of the tabular conductor in the right half of the profiles and replacing the right half with the mirror image of the left half.

It can be seen by comparing the profiles of Figures 9 through 12 with those of Figures 1 through 4 that the anomalous expressions of a wide horizontal sheet is similar to that of a wide flat-topped block. One perceptible difference, however, is that the 'edge-effects' of the sheet are more prominent than those of the block. Certainly the depression in the in-phase and quadrature profiles over the edges of the horizontal sheet, can be seen to greater depths than in the case of the block, i.e. to a depth of 0.8 coil spacing for the sheet compared to 0.4 for the block.

The in-phase and quadrature anomaly amplitudes over the central part of the horizontal sheet, when plotted against frequency, have a best fit with the theoretical curves for a horizontal uni-plane (page 1b), with an equivalent field conductance of 0.3 mho. As in the case of the block, the high frequency end of the 'laboratory' curve was favoured in the best fit. This equivalent field conductance value of 0.3 mho is to be compared to the value of 0.35 mho, determined via voltage, current and thickness measurements on long narrow ribbons of aluminum foil. In a simple sense, this difference in conductances is understandable when it is remembered that the theoretical curves are for a horizontal uni-plane and the reduction in dimension from the 'infinite' to the 'finite' would have a similar effect to decreasing the conductivity (and hence conductance) of the uni-plane, e.g. from 0.35 to 0.3 mho in this case.

Figures 13 through 19

Figures 13 through 19 contain 'slingram' profiles over a conductive sheet, as per Figures 9 through 12, flanked by a steeply-dipping tabular conductor. The depths to the top of the horizontal sheet and flanking tabular conductor are 100 & 150 meters in Figures 13 through 17, and the operating frequencies used are 444, 888, 1777 & 3555 Hz.
In the case of Figures 18 & 19, the depth to the top of the horizontal sheet and flanking tabular conductor is 150, 200, 250, 300 and 350 meters, at operating frequencies of 888 & 3555 Hz. The greater depths were added after the original batch of experiments, because as additional field cases developed, it became apparent that thicknesses of sandstone greater than one coil spacing were encountered in the diamond drilling of some anomalous phenomena.

In addition to incorporating greater depths into the second batch of experiments, greater lengths of the horizontal sheet were incorporated. In the first batch of experiments (Figures 9 through 17), a horizontal sheet length equal to the width (890 meters field equivalent) was used. In the second batch (Figures 18 & 19), the sheet length was increased to a field equivalent of 1525 meters, while keeping the width at 890 meters. The reasoning behind this move was to appraise the 'end-effects' of the short sheet by comparing them with those of the long sheet, for which they presumably would be much reduced. With this, the 'end-effects' of the short block could also be estimated, and removed if necessary, from Figures 1 through 8.

As it turned out, there was little difference between the 'end-effects' of the long and short sheets. This observation was somewhat surprising in the light of other experiments\(^9\). However, this point will not be pursued further here, because it does not seriously affect the end conclusions from the overall study.

In the case of Figures 13 through 16, the steeply-dipping tabular conductor on the edge of the horizontal sheet is in electrical contact with the sheet, as would be the case in Nature. For interest sake, the tabular body was electrically insulated from the sheet in Figure 17. The profiles in the latter figure are to be directly compared with those in Figure 16, for which all parameters are the same, except the state of electrical contact between the two conductive zones. In the case of Figure 16, there was current gathering by the tabular body from the horizontal sheet, whereas in the case of Figure 17 there was none. Interestingly, the effects of current gathering tend to accentuate the positive in-phase peak from the tabular body on the sheet side of the body, and to diminish the swing toward the negative in the quadrature readings over the body.

Through a misunderstanding, the experiments for Figures 18 & 19 were carried out with no contact between the horizontal sheet and the steeply-dipping tabular body. However, the gap between conditions of no contact and contact can be fairly well bridged by comparing the
profiles of Figures 18 & 19 with those of Figures 14 & 16 for a depth of 150 meters. It is left up to the reader, in his mind's eye, to extend this comparison through the greater depths in Figures 18 & 19. Certainly, there would be an enhancement in the in-phase anomaly amplitudes over those seen in Figures 18 & 19.

Given a condition of contact between the steeply-dipping tabular body and the horizontal conductive sheet in Figures 18 & 19, it is easy to visualize in the results that a 16 mho, steeply-dipping, tabular basement conductor at the edge of a 0.35 mho regolith, or weathered layer in the basement, would be detectible to a depth of one coil spacing. The story for a tabular basement conductor of lesser conductance than 16 mhos flanking a 0.35 mho regolith unfolds much as described in the last paragraph on page 6 for a tabular basement conductor flanking a large, poorly-conductive lithological unit. Specifically, a 4 mho tabular basement conductor could be detected to a depth of about 0.9 coil spacing and a 2 mho conductor to about 0.75 coil spacing.

Missing from the suite of experiments, involving a horizontal conductive sheet, is that of a steeply-dipping tabular body under the central region of the sheet. Again, it is left up to the reader, in his mind's eye, to transfer the tabular body from the outside edge to the central region of the conductive sheet. A first order approximation of this can be had by combining the profiles of Figures 9 through 12 with those of Figures 18 & 19 (with the effects of the flanking conductor removed as per the description in the first paragraph on page 8) with either the right or left half of the profiles of Figures 20 through 23. This combination would actually give a conservative picture, because the effects of current gathering from the overlying layer into the tabular basement conductor would not have been taken into account. In any event, it would be safe to say that the depth of detection would be at least as great, for the tabular body in the central region of the sheet, as for the body along the edge of the sheet, because the response of the tabular body would not have to stand out above that of the 'edge-effect' of the sheet.

Figures 20 through 23

Figures 20 through 23 contain the slingram profiles over a model of two separate steeply-dipping tabular basement conductors separated by the same distance as exists between the edges of the wide block and horizontal sheet, i.e. 3.56 coil spacings, or 890 meters in this case.
The objective behind these experiments was to compare the amplitude of the additive effect of the positive-sense peaks of two widely-spaced, steeply-dipping tabular bodies with the amplitude of the positive-sense anomalous background over the central region of wide flat-lying sheets and blocks.

It is apparent from a comparison of the profiles of Figures 20 through 23 with those of Figures 1 through 19, that the two separate, steeply-dipping conductors do not give a central region positive-sense anomaly as large as that for the flat-lying sheets and blocks--at least for a conductor spacing as large as 3.56 coil spacings. There will be more on this point in the discussion of the case histories of Figures 42 & 43.

It is also apparent from these experiments that a large, steeply-dipping tabular body, standing in an undisturbed area, could be detected to a depth in excess of one coil spacing, given low-noise data--and this without the benefit of current gathering from the surrounding medium. With current gathering, the depth of detection could only increase. There will be field examples of steeply-dipping tabular bodies, detected at depths in excess of one coil spacing, in the case histories of Figures 42 & 43.

Figures 24 through 27

Figures 24 through 27 contain the slingram profiles over the model of a lithological system consisting of several steeply-dipping, parallel conductive stringers. These stringers exist over a width equal to that of the flat-lying sheets and blocks, i.e. 3.56 coil spacings, or 890 meters in this case. The conductive stringers have a conductance of 0.7 mho each in Figures 24 through 26 and 1.4 mho each in Figure 27.

These experiments were incorporated into the later stages of the program, because, it appeared possible from the drilling results over the broad anomalous region in the case history of Figure 43, that the anomalous region contained several steeply-dipping parallel and/or sub-parallel conductive stringers, separated by resistive rocks. It was considered possible (but not probable) that the positive-sense effect of the stringers outside of the 'slingram' system might outweigh the negative-sense effect of the stringers contained by the system, at least for deeply-buried stringers. There is a slight hint of this in the results of Figure 26, which led me to the thought that the effect might be better exemplified by increasing the conductance of the stringers. The results from doubling the conductance
of the stringers can be seen in Figure 27, and it is evident that
the positive-sense effect of the stringers outside of the slingram
coil system does not outweigh the negative-sense effect of the stringers
contained by the system, even when appreciable depths are involved.
There will be more on this subject when the case history of Figure 43
is discussed later in this study.

Due to scheduling problems, one intended set of model experiments
was not carried out. This is the case of the 'slingram' system run
parallel to, rather than across, the block of parallel conductive
stringers. However, it is not hard for me to visualize that the ano-
malous results for the 'slingram' system run parallel to the stringers
would bear a strong resemblance to those for the system run across a
flat-lying sheet or block, i.e. a prominent positive-sense anomaly
would result. This point can be reasoned quite easily, when it is
remembered that a 'slingram' system gives a positive-sense anomaly,
when run beside, and parallel to, a steeply-dipping tabular body—an
observation I have made on more than one occasion in the field. Adding
another conductive body on the other side of the system would only
accentuate the effect. Of course, a body immediately under the system
would have no effect. Therefore, the sum total effect of a series of
conductors running parallel to the line of the ground system, would be
a positive-sense anomaly.

If in the field, there is some doubt as to the cause of a broad
positive-sense anomalous effect, another traverse can be run at right
angles to the original. If a flat-lying sheet or block is in play,
the positive anomalous levels will be much the same in both directions.
This will not be the case for a series parallel stringers.

Figures 28 through 32

Figures 28 to 32 contain the 'slingram' profiles over a modelled
basement alteration zone of varying thickness, where the mean width of
the features of varying thickness is about one coil spacing, rather than
several coil spacings, as was the case with the flat-lying conductive
features behind Figures 9 to 19.

If the coil spacing is considered to be 250 meters, then the
alteration zone varies in thickness from 22 to 65 meters, and the
depths to the top of the zone are 50, 100, 150 & 200 meters. The
operating frequencies are 444, 888, 1777 & 3555 Hz. The equivalent
field resistivity of the alteration material is 210 ohm meters in
Figures 28 through 31, and 105 ohm meters in Figure 32. Both of these
resistivity values are reasonable for weathered electrolyte-permeated
basement rock.
Interestingly, the thickened region of weathering over a width of one coil spacing generates an anomaly similar in shape to that of a steeply-dipping tabular body. This phenomenon is primarily by virtue of current gathering from the thin to the thick region. A similar phenomenon has already been seen for a modelled conductive overburden of varying thickness.

There are certain tests to indicate whether or not an irregular conductive overburden (or regolith) feature is in play, rather than a bedrock (or basement) conductor. But, these tests become increasingly more difficult to apply as the depth of the conductive feature increases. However, if a 'noisy' regolith or basement weathering feature in the Athabasca Basin resembles a basement conductor in terms of anomaly shape, the apparent conductance estimate (usually less than 1 mho) will serve as an indication that an electrolytic rather than a graphitic feature is probably in the picture. In my experience, most of the proven graphitic features have had conductance estimates in excess of 2 mhos.

In any event, as far as the Athabasca Basin is concerned, the drilling of a vertical hole into the type of feature centered on Station 0+00 in Figure 32—on the assumption that a true basement conductor is being drilled—would not be a total waste, because uranium deposition is often related to intense weathering of the basement rocks.

Figures 33 through 36

Figures 33 through 36 contain the profiles over a modelled uniform basement alteration zone, overlain by a zone of clay alteration of varying thickness in the sandstone. This condition is considered favourable for uranium deposition in some circles.

The physical model is the same for these experiments as for the experiments behind Figures 28 to 32; it has simply been inverted. The range of experiments for Figures 33 to 36 is the same as for Figures 28 to 32 except that, a) the equivalent field frequency of 444 Hz has been omitted, and b) the depth measurement is to a different part of the feature. Point b) would be best understood by referring to the sketches depicting the conductor geometries immediately following the text.

Again the anomalous perturbations are due to current gathering from the thin to the thick parts of the conductive layer. The anomalous perturbations are similar to those seen in Figures 28 through 32; however, they are larger here because the thickened regions of the conductive layer are physically closer to the plane of the EM system.
DISCUSSION OF THE FIELD RESULTS

General

The reader will notice a difference between the profiles of the following case histories and the modelling profiles discussed in the preceding section. The latter profiles are quite smooth, reflecting the responses of the deep-seated features only, whereas, the profiles in the case histories contain the response of the inevitable near-surface electrolytic conductors, such as silt-filled troughs and/or silt-filled fracture zones in the upper sandstone, in addition to the response of the deep-seated sources. However, the additional anomalous activity generated by the shallow electrolytic features does not pose a major problem to interpreting the response of the deep-seated features. This is so, because, as it turns out in practice, the shallow electrolytic features predominate the quadrature results at all frequencies, while they have little effect on the in-phase results at the lower frequencies. But, these shallow features do reflect in the in-phase results at the higher frequencies--rarely predominating, but often distorting, the in-phase response from the deep-seated sources. Nonetheless, it has been observed, over many field examples involving large coil spacings, that the strong quadrature response from shallow electrolytic sources has an associated in-phase response of an amplitude 1/5 to 1/10 of that of the quadrature at the higher operating frequencies. Removing this effect from the in-phase response will leave a response which reflects the deep-seated sources. Examples of this will be shown in the case histories later in this section.

As can be gathered from the contents of the preceding paragraph, the quadrature component is more severely affected than the in-phase by shallow electrolytic conductors. For this reason, it is more difficult to use the quadrature component than the in-phase to interpret conductive basement effects; so, the in-phase component is used almost exclusively in the interpretation of the following field results--at least as far as the basement features are concerned.

Given accurate background levels of 'in-phase' and 'quadrature', or for that matter of 'in-phase' only, at several frequencies, it would be possible to construct an electrical resistivity section of the ground beneath the EM system. However with results at only two or three frequencies (typical of large reconnaissance surveys), and instrument zero levels which may be 1% to 2% of the primary field strength at the receiver.
'zero', it is difficult to be any more than semi-quantitative in interpreting the physical properties and depth of these very wide weakly-conductive basement features.

The reader will also notice that a 'regional' profile has been drawn through the in-phase results at the highest frequency in each of the following case histories. The objective of this exercise was to isolate the response of the 'confined' conductors in the sandstone and basement from the response of the broad conductive features in the basement.

Before launching into the discussion of the case histories, I will define my understanding of type A and type B herringbone patterns in the Input air EM anomalies. These expressions will come up often in the forthcoming case histories; so, they are worth clarifying now. The story is shown in the following sketch:

Type A herringbone pattern  Direction of flight  Type B herringbone pattern

In the type A herringbone pattern, the circles on the Input photomosaic, depicting negative lobes in the profiles, are displaced in the direction of flight from a mean line drawn between the circles, as shown on the left side of the above sketch. In the type B herringbone pattern, the opposite is the case, as shown on the right side of the above sketch.

The type A herringbone pattern can be explained in terms of deep, steeply-dipping tabular conductors. Briefly, the peak anomaly amplitude for a very shallow tabular conductor occurs with the receiver of the Input system roughly above the conductor and the transmitter about 300 ft. beyond, but the peak anomaly amplitude for a deep tabular conductor occurs when the entire system is a little beyond the conductor. This point is demonstrated quantitatively in Appendix I, and a brief explanation now follows: With the Input transmitter 300 feet beyond a shallow, steeply-dipping tabular conductor, the primary flux couples well with the conductor inducing a strong eddy current flow. The receiver, being directly above the conductor at this point in time, is in a position of maximum coupling with the conductor. Net result—-the strongest anomalous response. With the transmitter 300 feet beyond a deep,
steeply-dipping tabular conductor, the primary flux does not couple well with the conductor, and a weak eddy current flow is induced. The transmitter must move out further from the conductor to improve the coupling of the primary flux and increase the amplitude of the induced eddy currents. With this, the receiver will be in a less favourable coupling position with the conductor, but the decrease in receiver coupling is more than offset by the increase in transmitter coupling with the conductor. Net result—the peak anomaly amplitude moves a little past the top of the conductor in the direction of the departing aircraft. Again the reader is referred to Appendix I for a quantitative treatment of the subject.

The type B herringbone pattern may occur over a very shallow steeply-dipping tabular conductor if a little overcompensation is used for the time constant of the receiver. However, it is not possible to explain a type B herringbone pattern in terms of a deep tabular conductor, as a look at the profiles in Appendix I will reveal. The reasons for a type B pattern will become apparent during the discussion of the case histories.

A general observation which applies to all of the case histories is that many of the 'confined', near-surface electrolytic conductors—clearly visible in the high-frequency quadrature results on the ground, and of which the apparent conductance is around 0.1 mho—are not visible in the Input results. It appears that the first channel of the Input system is not early enough to capture these events.

A common denominator to all of the case histories is that the Input profiles for the flight lines straddling the ground line are shown under the ground EM profiles. All Input anomalous 'picks' are projected onto the ground traverse along the formational trends as established from the air and ground results. The 'picks' marked by the solid circles, with a letter designation, were made by the Input contractor. I have added a few 'picks' (broken circles) to round out the picture. The latter 'picks' were made both to mark the edge(s) of very broad conductive phenomena and to mark the location of confined conductive sources.
Figure 37

The coil spacing used in this example was 800 ft or 244 meters, rather than the 250 meters about which the model results revolve. Nonetheless, the difference is small enough not to complicate direct comparisons.

It is very evident in viewing the regional in-phase profile at 1777 Hz that a very wide (3000 ft) poorly conductive phenomenon exists under Line 176N between stations 114+00W and 144+00W. Any doubt about this can be dispelled by referring to the modelling profiles of Figures 1 through 4 and 9 through 12. There is obviously some sort of mechanism permitting horizontal current loops over a width of 3000 ft, in order to get the regional in-phase profile, shown in Figure 37.

A very coarse fit of the anomalous in-phase amplitudes at 1777 Hz and 444 Hz into the theoretical curves of pages 1a & lb leads to the conclusion that the broad conductive phenomenon can be a conductive 'block' in the range of D=400 ft*, ρ=1050 ohm meters* to D=600 ft, ρ=750 ohm meters. The latter interpreted depth of 600 ft corresponds quite well with the known thickness of sandstone in the area; so, presumably the latter resistivity of 750 ohm meters is fairly accurate. But, it must be remembered that great precision cannot be obtained from the results at one coil spacing and two frequencies only.

The big assumptions in the calculations in the preceding paragraph, and others upcoming in these case histories, are:

a) that the slightly anomalous background levels flanking the main anomalous areas are due to a combination of the small but finite conductivities in the overburden, sandstone and basement rocks, and

b) that the more strongly anomalous part of the profiles is due to an increase in conductivity of the basement rocks.

The anomaly amplitudes used in these calculations are the differences between the maximum and background levels. This method of making the calculations is used because it is difficult to be certain of the absolute anomalous background levels to a precision of better than ±1%, which can cause inaccuracies when trying to make calculations based on very small levels. Using the difference between the large and small anomalous levels, removes the need to know absolute values, but it gives an answer for the resistivity and depth of the more strongly anomalous source, which presumes an

* D - depth, ρ - resistivity
infinitely resistive surrounding medium. The larger the contrast in resistivity between the block and its surroundings, the more accurate will be the resistivity and depth estimates for the block. Where the resistivity contrast is not large, the estimates for the block will be rather approximate.

As described in the second paragraph on page 5, a resistivity, such as 750 ohm meters, is small for a fresh metamorphic rock, but not necessarily for a metamorphic rock containing a network of electrolyte-filled pores and fractures.

There is also an indication of a low-conductance, steeply-dipping tabular body in the ground results on the east side of the broad weakly-conductive feature. This body is at the threshold of detectibility on L-176N, but it is visible in like manner on a few other ground lines on the grid, lending credence to its existence. Rough estimates of depth and conductance are 650 to 750 ft and 2 to 3 mhos, based on plugging the anomalous amplitude difference between the smaller outside peak and central peak into the suite of in-phase curves on page 6b. There will be more on the use of these curves in the discussion of the results in Figure 41. The shallowest interpreted depth is a little greater than the known thickness of sandstone in the area, and it may simply reflect the fact that Line 176N is close to the end of the tabular basement conductor.

The quadrature response of the ground profiles reflects very strongly a near-surface current gathering feature, such as a lake bottom trough, centering around station 125+00W on Line 176N.

A plan view of the flight and ground lines is shown below:
The anomalous pattern seen in the Input profiles on Flight Lines 25 & 26 holds over several pairs of flight lines. It is not seen only on these two lines.

The overall anomalous expression on the east-flown lines, such as '25', is very broad. This point becomes very clear when a straight-edge is put on the profile for channel #1. In fact, the overall width of this anomalous activity corresponds very well with the width of the broad anomalous feature interpreted from the ground EM results. It appears that the large negative lobe toward the west side of the broad conductive phenomenon merely reflects a coupling condition of the Input system with this sort of phenomenon.

On the west-flown lines there is a double negative lobing in the Input profiles, such as seen on Flight Line 26. This could reflect a dip trend to the conductive block, but it is a little hard to comprehend how the dip of a large block could have a bearing on the readings in the central region, unless it is composed of several parallel dipping components. Then again, these components would have to be linked laterally to cause the type of anomaly observed on the ground. It is thought that this lateral linking would obliterate any dip indications for the air EM system, as it has for the ground EM system. A possible explanation is forthcoming in the next paragraph. In the meantime, it is of interest to note that the overall width of this dual-lobe phenomenon corresponds quite well with that of the broad conductive phenomenon interpreted from the ground EM results.

There is evidence in the regional in-phase profile that the eastern part of the broad conductive unit is a little more conductive and/or a little shallower than the western part. There is also evidence of a weakly-conductive tabular basement conductor on the east side of the broad unit. It is felt that the positive response between the negative lobes on the west-flown lines may reflect a rebound effect from the more highly-conductive eastern part of the broad conductive unit. Clearly, there is a need for some Input modelling on this type of phenomenon.

One important observation is that the original circles on the photomosaic, representing the large lobes in the Input profiles, form a pronounced type B herringbone pattern. This, in my view, dispels the possibility of a tabular basement conductor between the circles--especially in view of the great thickness of sandstone in this general area. The reader is referred to Appendix I for more on this point.
Certainly, the Input contractor suspected other than a tabular basement conductor as the cause of the anomalous picture, because the circles were left floating on the photomosaic with no attempt to draw a conductor axis through them.

The drill holes shown in Figure 37 were projected onto Line 176N along the formational trends, as established from the air and ground EM results. This was done, because the line on which the drill holes were spotted did not cross the eastern part of the broad conductive phenomenon. With this, the ground EM profiles for this line are not complete—only reflecting the western two thirds of the overall phenomenon. Nonetheless, the latter incomplete profiles are almost identical to those on the west half on Line 176N, leading to the conclusion that the conductive picture is essentially the same under both lines, and making the projection of the drill holes onto Line 176N more valid.

The description of the basement rocks encountered in the drill hole reads something like 'weathered meta-semipelite with disseminated pyrite and graphite' leading to the conclusion that the weathered meta-semipelite extends across the entire anomalous area marked by the ground EM results. The zone of weathering may even be complemented by a network of electrolyte-filled fractures.

Figure 38

This case history goes one further than the others, insofar as a total field magnetic profile is shown in addition to the air and ground EM and the drilling results.

It is quite clear from the 'regional' in-phase profile at 3555 Hz, that a deep, broad (about 1150 meters), weakly-conductive feature is in play in this area, extending from about 4+50S to 7+00N under Line 7E. The reader is again referred to the modelling results in Figures 1 through 4 and 9 through 12, for the basis of this conclusion. Unfortunately, the profile is a little lacking in length to permit an accurate determination of the location of the edges of the broad conductive feature. Nonetheless, this feature, interpreted from the ground EM results, coincides with a broad magnetic 'low' (about 100 gammas in amplitude), leading to such geological speculation as:

a) An intense weathering of the basement rocks, which has resulted in the broad weakly-conductive feature, has also caused a depletion of the magnetite in the region.
b) The basement rocks, most susceptible to weathering in the area of this survey, have a lesser magnetite content than the more resistive rocks.

In any event, the spatial coincidence of a broad weakly-conductive zone and a broad zone of low magnetic susceptibility exists over the entire grid, being most prominent toward the eastern end.

Although many ground lines were done on this grid, Line 7E (the most easterly) was chosen for this case history, because it is the only line on which a frequency as high as 3555 Hz was used. This frequency best brings out the effect of the broad deep-seated feature; although, it is still recognizable at the lower frequencies.

Shallow electrolytic features are very apparent in the quadrature profiles. These features are under lakes, and appear to be due to silt-filled lake bottom troughs. Of course, there is always the possibility of fracturing in the sandstone under these troughs.

A very coarse fit of the in-phase amplitudes at 3555 Hz & 888 Hz into the theoretical curves of pages 1a & 1b, leads to the conclusion that the broad conductive phenomenon can be a conductive block in the range of D=190 meters, ρ=1400 ohm meters to D=250 meters ρ=900 ohm meters. The known depth to the basement in this area is around 230 meters; so, quite probably the resistivity of the anomalous lithological unit is about 1000 ohm meters. As described in the second paragraph on page 5, such a resistivity is small for a fresh metamorphic rock, but it is not necessarily small for a metamorphic rock containing a network of electrolyte-filled pores and fractures.
A plan view of the flight and ground lines is shown on the preceding page.

It can be seen in the Input results that the low-amplitude, rather broad lobes picked by the Input contractor are part of a very broad conductive phenomenon—a point quickly revealed by placing a straight edge along the first channel profiles. This is the case on all of the flight lines on which 'picks' were made by the Input contractor. The broad anomalous effect exists on several flight lines to the west of the last line on which a 'pick' was made, but no 'picks' were made on these lines because the lobes are of smaller amplitude.

It can be seen in the profiles that the overall width of the Input anomalies corresponds quite well with that of the interpreted basement feature from the ground EM results, and it appears quite definite to me that the Input anomalies are caused by a very broad weakly-conductive basement feature, and not the 'S'-shaped conductor drawn on the photomosaic by the Input contractor. It is my feeling that the small lobes on the broad Input anomalies simply reflect a particular coupling phenomenon between the Input coil configuration and a flat-lying conductive slab. There is a need for some Input modelling on this type of phenomenon.

Further to the contents of the preceding paragraph, it can be seen that the lobes on the Input profiles occur within the broad conductive feature, and always closest to the edge first traversed by the system. Had Flight lines 10060 to 10110 been flown in the customary opposite-sense pattern for adjacent flight lines, rather than in the S-N-N-S-S-N pattern used here, the circles on the photomosaic representing the profile lobes would have formed a distinct type B herringbone pattern.

It is difficult to know the interpretation that the Input contractor would have given to the type B herringbone pattern, which would have been obtained from the customary opposite-sense flight pattern for adjacent flight lines. But, for certain, he would not have come up with the 'S'-shaped conductor shown on the photomosaic.

The original ground grid was laid out to cover the interpreted 'S'-shaped conductor and, for this reason, it was not quite large enough to cover the entire conductive phenomenon. However, some lines, including Line 7E, were later extended to complete the magnetic profiles.
The drill hole shown at station 0+75S on Line 7E was projected from the west along the formational trends as established by the air and ground EM results. This hole was drilled to the west of Line 7E, into the same shallow conductive phenomenon which centers on Station 1+00N on Line 7E. This shallow phenomenon follows the direction of a lake and it runs obliquely to the strike direction of the deep-seated feature. The drill hole was intended to investigate the possibility of fracturing in the sandstone, beneath this lake bottom trough feature, down to the weathered basement.

As can be seen in the topo-geological section, this drill hole intersected the basement at a depth of 234 meters. However, the overall geophysical and drilling results suggest that the basement becomes a little shallower from west to east; so, quite probably the basement is not as deep under Line 7E as the 234 meters shown in the topo-geological section of Figure 38.

The drill hole intersected an appreciable number of fractures and mud seams in the sandstone, and an intensely-weathered and altered gneissic rock with minor pegmatite zones and flat-angled fractures in the basement. Black material, described as 'possible graphite', and blebs and streaks of iron sulphides were also reported in the basement.

No conductivity tests were run on the drill core. But nonetheless, it is doubtful that the reported materials form part of an extensive steeply-dipping tabular conductive zone, or its presence would have been detected in the ground EM survey from a depth of about 0.9 coil spacing. The reader need only view the modelling results of Figures 20 through 23 and the field results of Figures 41, 42, 43 & 44 to appreciate this point.

The fractures and mud seams intersected in the sandstone are in keeping with the interpretation of a shallow electrolytic conductor. The highly-weathered and altered rocks, intersected in the basement, are in keeping with the interpretation of a large, deep, weakly-conductive block--assuming, of course, a very extensive area of weathering.

**Figure 39**

It is evident in the regional in-phase profile at 3555 Hz that a very wide, deep, weakly-conductive unit exists under Line 12S--extending from around 4+00E to 20+00W (2400 meters). The basis for this conclusion can be seen in Figures 1 through 4 and 9 through 12. This conductive source appears to get a little more conductive (and/or a little shallower) from east to west, as shown in the topo-geological section.
A best-fit of the positive in-phase amplitudes in the central region of the profiles, with the theoretical curves of pages 1a & 1b, leads to the interpretation that the Type 1 basement unit is a 0.28 mho layer and the Type 2 basement unit is a 0.20 mho layer, both at a depth of about 300 meters.

There are many possible combinations of resistivity and thickness to make up 0.28 and 0.2 mho layers. One likely combination is a 31 meter thickness of 110 and 160 ohm-meter material, respectively. These values of resistivity are in keeping with a highly-weathered and/or fractured, electrolyte-permeated upper basement rock.

The inevitable shallow electrolytic conductors are very visible in the quadrature profiles. The most prominent response centers around 13+00W, and it is probably due to the current-gathering effects of a silt-filled lake bottom trough. There are also some weaker responses coinciding with the two topographic 'highs' (4+50W & 18+50W) on the line. These anomalies are probably due to current gathering by electrolyte-filled fractures and/or pores in the topographic 'high' from the surrounding surficial layer. In a sense, the topographic 'high' acts much as a silt-filled valley, thickening upwards rather than downwards. The ground EM system does not really care if the weakly-conductive surficial layer thickens upwards or downwards. The main consideration is that the thickened area is capable of gathering currents from the adjacent thin areas.

A plan view of the ground and flight lines is shown below:

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Although only four flight lines are shown here, the pattern of 'two picks--no picks', for lines flown in opposite directions, exists over more than two dozen pairs of flight lines. With the Input contractor's method of making 'picks', it is obvious that if all of the lines had been flown from west to east, there would have been two 'picks' on every line. If all of the lines had been flown from east to west, there would have been no 'picks'. Clearly, the contractor's method of interpreting the profiles leaves something to be desired.
A straight edge placed on the first channel Input profiles on the lines flown from east to west reveals a low amplitude response of great width—in fact a width which corresponds quite well with that of the very broad conductive unit interpreted from the ground EM results. The same straight-edge treatment on the west-to-east profiles reveals two very broad negative lobes with a central region of small positive amplitude. Yet, the overall width of the two-lobe phenomenon corresponds quite well with that of the very broad conductive unit interpreted from the ground EM results.

The picture obtained on the four contiguous ground lines run in this area is the same, i.e. one of a deep, very broad (circa 2400 meters) weakly-conductive feature becoming a little shallower, or more conductive, from east to west. By way of explaining the nature of the Input profiles over this feature, the following possibilities come to mind:

a) The Input system is responding to a dip direction in the broad conductive phenomenon. However, a dip direction for a very broad phenomenon is hard to visualize, unless it is composed of a multitude of dipping parallel components. Yet, the ground EM results indicate that these dipping parallel components would have to be linked laterally in order to get the observed anomalous pattern, and it is thought that any lateral linking of parallel running components would wipe out the indication of dip for the Input system, as for any other EM system.

b) The strong tailwind on the east flown lines and the strong headwind on the west flown lines (as indicated by the relative profile lengths to span the same distance on the ground) may result in a different coupling condition between the Input system and the broad, essentially flat-lying source, for the different flight directions.

c) The Input system is reflecting the non-homogeneous nature of the broad conductive phenomenon. It is conceivable that the shallower and/or more highly-conductive western part of the broad phenomenon, when first traversed by the Input system, gives a prominent lobe followed by a rebound effect. When the deeper and/or more poorly-conductive side of the broad conductive phenomenon is traversed first by the Input system, there is a more gradual increase in the anomalous effect without prominent lobes and rebound effects.

Of possibilities a), b), & c) listed in the preceding paragraph, I tend to favour c) over the other two.
Some appropriate modelling for the Input system would help to clarify this matter.

Although there is room for speculation on the cause of the Input anomaly shapes, I feel that one thing is certain about these anomalies—namely, the broad negative lobes obtained on every second flight line do not relate to tabular steeply-dipping basement conductors, but they reflect a particular coupling condition between the Input system and the broad, non-uniform, poorly-conductive phenomenon interpreted from the ground EM results.

The drill hole shown in the topo-geological section was projected over a very short distance onto Line 12S. It was projected along the general formational trends as established by the air and ground EM results. The hole does not go far into the basement rocks, but the report of 'weathered granite and meta-arkose' in the bottom of the hole is in keeping with the interpretation of a broad weakly conductive layer in the upper basement rocks, assuming of course that the weathering exists over an extensive area.

**Figure 40**

The regional in-phase profile, at 3555 Hz in particular, is indicative of a very deep, wide, poorly-conductive source extending from about 1+50E to 16+00W (1750 meters) on Line C, with the part between 7+00W and 1+50E being a little more shallow and/or more highly conductive than the part to the west of 7+00W. This interpretation is supported by the results on three other ground lines in the area. Again, the reader is referred to Figures 1 through 4 and 9 through 12 to understand better this interpretation.

A best-fit of the positive in-phase levels at the different frequencies over the more prominent eastern part of the broad conductive unit leads to the interpretation that the broad basement unit is a 0.2 mho layer around a depth of 375 meters. Of course, this interpretation is very approximate in the light of the small anomalous values involved. Several combinations of resistivity and thickness can go to make a 0.2 mho layer, among which a 31 meter-thick layer of 160 ohm-meter material, or a 21 meter-thick layer of 110 ohm-meter material. Either of these combinations of thickness and resistivity is realistic for a highly weathered and/or fractured electrolyte-filled upper basement rock.

The inevitable near-surface electrolytic conductors are clearly visible in the quadrature profiles. There is a strong quadrature anomaly, centering around 16+00W on Line C, which is probably due to current gathering by a silt-filled lake bottom trough. There is also a weak
quadrature anomaly associated with a topographic 'high' centering around 7+50W.

The flight and ground lines are shown in the following sketch:

The Input anomalies on Flight 10080 & 10090 have been projected onto Line C along the formational trends as established from the air and ground EM results. It is apparent when the full width of the broad Input anomalies is taken into account, that they correspond quite well with the more prominent eastern part of the broad weakly-conductive basement unit, interpreted from the ground EM results. The western part of the basement unit is not recognizable in the Input results.

The 'picks' made by the Input contractor are not well-defined negative lobes, but are part of a very broad negative anomaly. Furthermore, these 'picks' form a type B herringbone pattern, which, in my experience, would relate to a very broad, flat-lying or block-like source rather than a narrow steeply-dipping tabular body. The latter type of body would not be detectable by either of these air or ground EM systems at a depth as great as 409 meters, the known depth to the basement in this area.

The drill hole at station 0+00 on Line C intersected 409 meters of sandstone, after which it went through 'weathered quartzite regolith' to a depth of 412 meters. The four meters of rock, intersected beneath the 'weathered quartzite regolith' were described as 'quartzite containing fractures filled with regolithic material'. Based on the EM results, it is concluded that the weathered quartzite regolith, in conjunction with these fractures, forms part of a conductive network which extends over an extensive area of the basement.

**Figure 41**

There are two conductive features apparent in the ground EM results on Line 118N.
a) a deep, very broad, weakly-conductive source extending from about 10+00E to 9+00W (about 1900 meters), as indicated by the regional in-phase profile at 1777 Hz (300 meter coil spacing).

b) a steeply-dipping tabular basement conductor centering around 1+00W, as indicated by the 'classic-looking' slingram anomaly.

The reader is referred to Figures 1 through 4, 9 through 12 and 20 through 23, and imagined combinations of these figures to appreciate the reasoning behind this interpretation.

A best fit of a plot of the positive in-phase background levels vs frequency with the theoretical curves of page 1a & 1b leads to the interpretation of a broad, flat-lying conductive phenomenon with characteristics somewhere between a 0.3 mho layer at a depth of 300 meters and a 1300 ohm meter half-space at a depth of 150 meters. The truth probably lies in a mixture of the two situations, e.g. a 150 meter thick layer of 500 ohm-meter material at a depth of 225 meters—all values being approximate.

Plugging the in-phase and quadrature anomaly amplitudes of the short-wave-length feature into a standard phasor diagram, as shown on page 6a, gives values of depth and conductance of 145 meters and 1.1 mhos at 1777 Hz, and 180 meters and 3.8 mhos at 444 Hz. Overlaying a plot of the in-phase anomaly amplitudes vs frequency onto a suite of in-phase curves, as shown on page 6b, leads to values of depth and conductance of 195 meters and 4.1 mhos.

The reason for the difference in the depth and conductance interpretation, for the different procedures used in the preceding paragraph, is primarily that there is current gathering by the tabular body from the weathered basement rocks. For the frequencies, coil spacings and ground resistivities of the present case history, the effects of current gathering go as follows:

a) a large boost to the quadrature anomaly at 1777 Hz,
b) a small boost to the in-phase anomaly at 1777 Hz,
c) a small to moderate boost to the quadrature anomaly at 444 Hz, and
d) virtually no boost to the in-phase anomaly at 444 Hz.

The net result of all of this is that the tabular basement conductor appears to be much shallower than its true depth at 1777 Hz and somewhat shallower than its true depth at 444 Hz, when using a standard phasor diagram. It appears to be a little shallower than its true depth, when using a suite of in-phase curves.
It has been found empirically that if the amplitude of the in-phase component at 1777 Hz with a large coil spacing is considered to be boosted by a factor of 1.1 to 1.2 and not boosted at all at 444 Hz, a depth estimate can be made which is very close to that encountered in the drilling. The method is simply to reduce the in-phase amplitude at 1777 Hz by a factor of 1.1 to 1.2, while leaving that at 444 Hz untouched, before making the best fit of a plot of the 'in-phase amplitudes vs. frequency' with the suite of in-phase curves shown on page 6b. In so doing, a depth of 225 meters and a conductance of 7 mhos was obtained in the present case. As the depth estimate is correct, so must the conductance estimate be close to correct.

The plan view of the flight and ground lines is shown in the following sketch:

By placing a straight edge along the Input profiles, it becomes evident that more than a deep, steeply-dipping tabular body is in the picture. The overall width of the anomalous effect as seen on both the east and west-flown lines is about 1200 meters.

Interestingly, the first part of the Input response, on both the east and west-flown lines, corresponds quite well with the edge of the broad conductive phenomenon interpreted from the ground EM results. However, the last part of the Input response corresponds with the steeply-dipping tabular conductor, rather than with the opposite edge of the broad, weakly-conductive feature. There is obviously some sort of complex coupling phenomenon occurring here, in which the rebound effect from the tabular basement conductor fairly well wipes out the remaining effect of the broad weakly-conductive unit. This pattern in the Input profiles is not peculiar
to the profiles of Figure 41, but repeats itself over many flight lines.

It can be seen that the circles on the photomosaic representing the small but definite negative lobes (in excess of the overall anomalous response) form a type A herringbone pattern. This, in my experience, is in keeping with the response of a very deep, steeply-dipping tabular body, as described in Appendix I.

The drill hole shown on the topo-geological section is located on Line 18N. It intersected weathered meta-semipelites and several stringers of graphite in the basement. These graphite stringers 'kicked' in ohmometer tests according to the oral description of the geologist in charge of the project. A few other drill holes along this interpreted tabular feature intersected the same sort of graphite stringers, forcing the conclusion that the interpreted tabular conductor is a basement zone consisting of electrically continuous stringers of graphite.

**Figure 42**

The reader should refer to Figures 5 through 8 and 13 through 19 to appreciate the reasoning behind the upcoming interpretation.

The ground EM traverses were run with both an 800 ft and a 600 ft coil spacing. The latter coil spacing was used to confirm a suspicion from the results with the former that a broad weakly-conductive unit exists between the two interpreted tabular basement conductors, which center around stations 61+00N and 85+00N.

Although the distance between the centers of the two tabular conductors is about 2400 ft, the distance between the inside edges is about 2100 ft. The latter distance is equal to about 2.6 coil spacings for a coil spacing of 800 ft. With a conductor spacing to coil spacing ratio of only 2.6, there is room to argue that the additive effect of the 'inside' anomalous peaks of these tabular conductors is the cause of the regional positive in-phase level across the gap between the conductors. This subject is treated quantitatively in the next three paragraphs.

The following diagram is a plot of

<table>
<thead>
<tr>
<th>Sum of the Inside In-phase Peaks</th>
<th>Conductor Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of the Outside In-phase Peaks</td>
<td>vs. Coil Spacing</td>
</tr>
</tbody>
</table>
for 'Depth/Coil Spacing' ratios of 0.6 and 0.8:

The above diagram was made up by using information available in the literature for conductor spacings of 1.0, 1.5 & 2.0 coil spacings in combination with the profiles of Figures 20 through 23, for which the conductor spacing is 3.56 coil spacings. The picture is reasonably complete for the 'depth to coil spacing' ratio of 0.6, but certain assumptions were made to complete the picture for a ratio of 0.8.

Now it can be seen in Figure 42 that the ratio 'Sum of the Inside In-phase Peaks/Average of the Outside In-phase Peaks' for a coil spacing of 800 ft (Conductor Spacing/Coil Spacing = 2.6) is about 2.25 at a frequency of 1777 Hz, whereas it should only be 1.8 according to the above diagram. With this, it would appear that other forces are at work between these two tabular conductors. But, the difference between the observed and the expected ratios (2.25 vs. 1.8) was judged to be small enough to warrant a further test--namely a pass with a 600 ft coil spacing.

With a coil spacing of 600 ft, the distance of 2100 ft between the inside edges of the two tabular conductors becomes 3.5 units of coil spacing, which is very close to the 3.56 units of the model experiments behind Figures 20 through 23. With this, it is immediately obvious that the elevated regional in-phase level between the two tabular conductors is much larger than the additive effect of the two 'inside' anomalous peaks. It is now difficult to avoid the conclusion that there is a mechanism permitting horizontal current loops between the two tabular conductors.

A best fit of these anomalous in-phase levels to the theoretical curves of pages 1a & 1b indicates the presence of conductive 'block' (approximating a half-space) between the tabular conductors.
The interpreted depth of this 'block' is in the 950 to 1000 ft range, and the interpreted apparent resistivity is about 425 ohm meters. The anomalous in-phase levels over the 'block' were referenced to the background in-phase levels to the south of the block, which in turn are a little lower than those to the north. However, these background levels are still somewhat anomalous, and they could render less accurate the interpretation for the 'block', in the manner described in the fifth paragraph on page 17. This point will be pursued in the following paragraph.

The interpreted depth of 950 to 1000 ft for the 'block' is somewhat greater than the depth to the basement, as established by drilling in the area. This depth is in the range of 650 to 700 ft, as can be seen in Figure 42. It is always possible that there is an increase in conductivity beneath the uppermost basement rocks, but it is thought more than likely that the discrepancy in depth interpretation relates to trying to do too much interpretation from too little data, and to over-simplified interpretational procedures, such as referred to at the end of the preceding paragraph. Even with more data, there would be inherent difficulties in interpreting the properties of the large-scale features at depth, due to the presence of the confined, more highly-conductive zones in the area.

Plugging the 'outside peak-to-central peak' in-phase anomaly amplitudes from the tabular conductors into the suite of in-phase curves shown on page 6b leads to depth and conductance estimates in the range of 675 to 725 ft and 10 to 20 mhos. It was necessary, however, to remove the effects of the shallow electrolytic conductors from the high frequency in-phase readings, as per the description in the first paragraph on page 14, before making the estimates for the deep sources. In particular, the in-phase profile for the frequency of 3555 Hz and coil spacing of 600 ft needed to have the electrolytic effects removed, because the amplitude of the in-phase anomaly from the deep source is very small and is therefore easily distorted by the effect of the shallow conductors.

The most prominent shallow electrolytic features are centered around 56+50N, 67+50N and 94+00N on Line 28E. They all occur in small topographic 'lows' and are probably caused by current gathering into overburden-filled bedrock troughs. Of course, there is always the possibility of fracturing in the sandstone under these interpreted troughs.
A plan view of the flight and ground lines is shown below:

A straight edge, placed along the Input profile on north-flown Line 14, reveals a very broad conductive phenomenon. The overall width of this phenomenon is about the same as that of the broad weakly-conductive zone interpreted from the ground EM results. Although the anomalous part of the profile stays negative over its entire width, it is possible to pick additional negative lobes along each edge. The more prominent southerly negative lobe was picked as a discrete conductive source by the Input contractor. The more subtle northerly negative lobe was picked by me.

A straight edge placed along the Input profile on south flown Line 13 reveals two prominent negative lobes with the part of the profile between them touching on the positive. These negative lobes have a width more in keeping with a deep, discrete tabular body--unlike some of the very wide lobes in the earlier case histories. Interestingly, the overall width of the two-lobe phenomenon is about equal to the width of the broad weakly-conductive zone, interpreted from the ground EM results.

The anomalous patterns seen in the Input profiles of Figure 42 are repeated on several flight lines throughout this area. They are not peculiar to the region of Figure 42. However, on some of the other flight lines, the more subtle lobes were picked in the original interpretation.

The reader will notice in the above plan view that the combination of the lobes picked by the Input contractor and myself form two type A herringbone patterns, the mean line through which corresponds to the two tabular basement conductors interpreted from the ground EM survey. The contractor's conductor interpretation is rather incomplete in this area.
Still to be explained is the difference in the Input profile shapes between the north and the south-flown lines. In this case history, the difference relates to both the dip of the tabular basement conductors and to the weakly conductive material between these tabular conductors.

A southerly dip for the entire conductive ensemble is suspected from the observation that the southern anomaly peak of the southern tabular conductor is a little larger and more extensive than the northern anomaly peak of the northern tabular conductor. This point is most readily seen in the in-phase results at the lower frequencies, because the in-phase component at the lower frequencies suffers much less distortion from the effects of near-surface electrolytic conductors than does the in-phase component at the higher frequencies.

A moderately-steep southward-dipping conductor, when traversed from north to south by the Input system, will give a prominent single negative lobe anomaly over its upper edge with a small, but noticeable, rebound effect over the hanging-wall. By comparison, the same conductor when traversed from south to north will give a less prominent negative lobe over its upper edge and a less prominent rebound effect. Also, there will be a broad weak negative lobe on the approach side of the conductor, i.e. over the hanging-wall side.

Based on the contents of the preceding paragraph, it is easy to imagine that two southward dipping conductors, spaced 2100 ft apart would give the sort of anomalous pattern seen on Flight Line 13, when traversed from north to south. However, it is not easy to imagine that the same two conductors would give the sort of anomalous pattern seen on Flight Line 14, when traversed south to north. It is felt that the central part of the anomalous area remains too strongly negative in view of the large separation of the conductors, the short time constant of the Input receiver, and the interpreted moderately steep dip of the conductors. It would require weakly conductive material between the conductors in order to generate the type of Input anomaly obtained.

The drill hole at 83+30N on the topo-geological section was drilled on Line 28E. The other holes around 61+00N were projected onto the section along the formational trends established from the air and ground EM results in the area. The latter holes were actually drilled to the west of Line 28E at the point of crossing of the deep tabular body and the electrolytic feature, which has diverged to 67+00N on Line 28E. In the case of the projected holes at 60+50N and 61+25N
and the hole located at 83+50N on Line 28E, weathered meta semi-pelites and graphite stringers were encountered in the basement. By the description of the geologist in charge of the drilling program, the graphite 'kicked' in the ohmeter tests. This description is in keeping with the interpretation of 10 to 20 mho conductive zones within the basement.

Certainly, the tabular conductors have been explained by the drilling and it can only be assumed that the appreciable weathering encountered in the basement rocks extends over the entire area between the graphite conductors. In fact, with the low apparent resistivity (425 ohm meters) interpreted for this area, there is a good possibility of extensive electrolyte-filled fracturing in the rocks between the graphite zones.

A point of interest in closing this case history: The proven depth to the graphite zones is over 600 ft in this area, and yet they were still visible in the results obtained with the 600 ft coil spacing. In other words, the graphite zones were detected at a depth in excess of one coil spacing. This is in keeping with the modelling results of Figures 6, 8, 18, 19, 21 & 23.

Figures 43

The left side of Figure 43 contains ground EM profiles at coil spacings of 400 ft and 600 ft, two sets of Input profiles and a topo-geological section, showing several drill holes for ground Line 19W. The right side of Figure 43 contains the ground EM profiles at a coil spacing of 800 ft for Line 19W, as well as the ground EM profiles at the same coil spacing for Line 12E. The latter line runs obliquely to Line 19W and crosses it in the central region. Line 12E is part of an earlier grid and it crosses the overall conductive phenomenon at about 65° rather than the ideal 90° of Line 19W. However, Line 12E is included in Figure 43, because it is longer than Line 19W, and it gives a better picture of the background levels outside of the main conductive phenomenon.

The relative positions of the ground lines and flight lines are given in the following sketch:
It was strongly suspected from the ground EM results on Line 12E that a broad, weakly-conductive region exists between the tabular conductors centering on 13+00N and 13+00S. However, in view of the fact that the shortest distance between the inside edges of the conductors is about 1800 ft and the coil spacing used on Line 12E was 800 ft, there is room to argue that the additive effect of the two 'inside' positive peaks is enough to give the strongly positive central region seen in the ground EM profiles. The same statement applies to the 800 ft-coil-spacing results on Line 19W. But, in getting sufficiently quantitative about the matter to have recourse to the diagram on page 31, there appears to be more than the additive effect of two positive shoulders involved. Specifically, a ratio of conductor spacing to coil spacing of 2.25 (1800/800) would predicate a central peak to outside peak ratio of about 2.0 in the in-phase readings. After removing the effects of the shallow electrolytic conductors from the high frequency in-phase readings, the 'central peak to average outside peak' ratio is at least 4.0, pointing rather strongly to the presence of weakly-conductive material between the large tabular conductors. In spite of this strong evidence for weakly-conductive material between the large tabular conductors, further tests were applied, as described in the following paragraph.

In an effort to come to an unequivocal conclusion about the conductive nature of the material between the two tabular conductors, Line 19W was resurveyed on the ground using both 600 ft and 400 ft coil spacings—giving conductor spacing to coil spacing ratios 3.0 and 4.5, respectively.
Given conductor to coil spacing ratios of 3.0 and 4.5 and the presence of non-conductive material between the tabular conductors, the following could be expected: A central region in-phase anomaly, equal in amplitude to the average of the outside peaks for the 600 ft coil spacing, and smaller in amplitude for the 400 ft coil spacing. A look at the high frequency in-phase profiles in Figure 43 will reveal that the foregoing predictions are far from the case. In fact, the central area is much more strongly anomalous than the outside peaks for both coil spacings, forcing the conclusion that there is conductive material in the region between the tabular conductors.

As can be seen in Figure 43, the most conductive basement 'block' exists between 1+00N and 20+00S on Line 19W. To the south, the basement is much less conductive and to the north it is somewhat less conductive. Referencing the most highly anomalous in-phase results between Stations 1+00N and 20+00S to the background in-phase levels to the south of Station 20+00S, and using the suites of curves on pages 1a & 1b, leads to the interpretation of a conductive 'block' of D=600 to 625 ft and $\rho=425$ ohm meters. As the interpreted depth to the 'block' is a little greater than the known depth, the interpreted apparent bulk resistivity is probably a little smaller than the correct value. Nonetheless, the apparent resistivity would be of the order of 500 ohm meters, which is very small for metamorphic basement rocks, unless they contain a conductive network such as described in the second paragraph on page 5.

The interpretation for the tabular conductors using the outside-peak to central-peak in-phase amplitudes in the suite of in-phase curves of page 6b leads to the interpretation of D=600 ft and $\sigma.t=3$ mhos for the northern conductor and D=600 to 625 ft and $\sigma.t=8$ mhos for the southern conductor. These interpreted depths are not far from the depth of 575 ft for the first continuous graphite encountered in the drilling.

It can be seen in the sketch on page 36 that the 'picks' made by the Input contractor form a type B herringbone pattern and no interpretation was offered on the photomosaic. However, a close look at the Input profiles revealed subtle lobes, which were picked by me. These 'picks', when combined with the contractor's 'picks', form two type A herringbone patterns corresponding to the north and south tabular conductors interpreted from the ground EM results.
The profiles from Flight Lines 11 and 12 are shown in Figure 43. The straight edge treatment on both of these profiles reveals two separate negative lobes with a rebound toward the positive in the central region. Interestingly, the first traversed of the two tabular conductors gives the prominent anomaly, and the second gives a rather subtle anomaly—subtle enough not to be picked by the Input contractor. This observation is easy to understand on Flight Line 12, because the conductor traversed first has the larger apparent conductance. But, in the case of Flight Line 11 the opposite is true. In other words, the 'weaker' conductor gives by far the 'stronger' anomaly. This is also true for other south-flown flight lines.

It would appear from the contents of the preceding paragraph that there is some sort of complex coupling phenomenon between the tabular conductors and the weakly-conductive medium between them, because in a resistive environment the tabular conductors are far enough apart to act independently from each other, as far as the Input system is concerned. With this, the conductor crossed secondly on Flight Line 11, i.e. the 'better' conductor, would have given a more prominent anomaly than was obtained.

Interestingly, the interpreted conductive medium between the tabular conductors does not announce its presence by holding the Input profiles negative between the conductors. Possibly it would have, for the north-flown lines at least, if the tabular conductors had been a little further apart, as was the case in Figure 42. In the present case, the tabular conductors predominate the visual picture, but the conductive medium between them exerts its influence by introducing some unexpected effects, as described in the second last paragraph.

Based on the original Input map with a prominent type B herringbone pattern of circles and no conductor marked on it, two different stages of investigation were required on the ground before the conductor picture was fully understood.

Of all of the drill holes shown on the topo-geological section, eight were either on or within a few feet of Line 19W. All of the others were projected onto the line from within a distance of 200 ft, with the exception of the two most southerly holes which were projected from further out; so, the geological picture should be quite accurate for Line 19W.

The interpreted tabular conductors are explained quite well by the drilling, with graphitic semi-pelites being encountered in both cases. Graphite stringers are more plentiful in the south zone than
in the north, which is in keeping with the larger conductance estimates for the south zone. By the account of the geologist in charge, the graphite stringers 'kicked' in ohmmeter tests.

The results seen in the drilling of the central region, between the steeply dipping tabular conductors, pose somewhat of an enigma. Based on the descriptions in the drilling logs, there is considerable electrically resistive material in this region. This point is difficult to reconcile with a mechanism which permits horizontal current loops. A couple of graphitic stringers were intersected around Stations 13+00S and 5+00S under Line 19W, which leads to the speculation that several other such stringers could exist in this region—being straddled by the widely-spaced drill holes.

The speculation of a block of several parallel graphitic stringers separated by resistive material, led to the 'sandwich' model of Figures 24 to 27, and discussed on pages 11 and 12. However, the results over this 'sandwich' model indicate that it alone is inadequate to give the anomalous field results obtained. In other words, a 'sandwich' of conductive stringers separated by resistive material, will not give the obtained field results, when traversed by the ground EM system at right angles to the strike of the stringers.

If the conductive graphite stringers within the anomalous block were to run parallel or sub-parallel to Line 19W, then the anomalous picture obtained in Figure 43 would be in order. But, such a strike direction for the interior stringers would be hard to reconcile with the strike direction of the two main graphite zones, which is essentially perpendicular to Line 19W. Furthermore, a traverse has been made at right angles to Line 12E, which direction is sub-parallel to the long dimension of the weakly conductive block. Although the results on this cross line are not shown in this study, the anomalous levels over the 'block' are essentially the same as those obtained on Lines 19W and 12E. This would not be possible, if the interior stringers were near-perpendicular to the cross line. So, everything seems to point to a mechanism which permits horizontal current loops in the basement between Stations 1+00N and 20+00S on Line 19W.

It can be seen in the topo-geological section of Figure 43, that the weathered basement layer has a widely changing thickness—being rather thin between Stations 8+50S and 14+50S on Line 19W. An attempt has been made to reconcile the observed anomalous results with the picture of the weathered basement layer, as revealed by the drilling.
The model results of Figure 28 through 32 were used for this, as well as other modelling\textsuperscript{3} and field\textsuperscript{1} information, for horizontal layers of varying thickness.

As positive-sense anomalies can be generated over buried resistive ridges in a conductive environment, it may be asked if the ridge of fresh basement rock between Stations 8+50S and 14+50S could generate the observed positive-sense anomaly between the two tabular zones. The answer is essentially no; otherwise, the large positive-sense in-phase readings would have dropped to a much lower level within one-half coil spacing from the edge of the ridge of fresh basement rock. As far as the northern edge of the ridge is concerned, this means that the in-phase levels should be quite 'low' by Station 6+50S for the 400 ft coil spacing, and by Station 5+50S for the 600 ft coil spacing, when moving northwards from the ridge on Line 19W. This is far from the case in the observed results, with the high in-phase levels holding until just before the northern graphite zone. So, although the ridge of fresh basement rock may make some contribution to the overall anomalous picture, it is not a major contributor.

Bearing in mind the contents of the four preceding paragraphs, I've been forced to the conclusion that in order to have the horizontal current loops necessary for the observed field results in the region between the tabular conductors, there must be either

a) a network of electrolyte-filled fracture zones, or

b) a system of electrolyte-filled fractures crossing the graphitic stringers, thus forming a conductive network.

With several hundred feet between the coils of the ground EM system and from the ground system to the basement, these fracture zones (and graphitic stringers) could be several tens of feet apart, and still form an adequately 'tight' network to generate the observed anomalous picture. With several tens of feet between the steeply-dipping fracture zones, they would not necessarily be detected by a few well-spaced drill holes.

In any event, it seems to be more than a coincidence that a uranium deposit is associated with each of the two thick graphitic zones where there is prominent anomalous ground EM activity in the region between these zones. As the anomalous activity decreases in the region between the graphite zones--along strike from this area--so does the occurrence of uranium.
Figure 44

The regional in-phase profile at the higher ground system frequency (1777 Hz) is more uneventful than in any of the other case histories. There is a very small level increase from north to south, probably reflecting a small increase in the conductivity of the basement rocks under the southern part of Line 130W. The amplitude of the anomalous effect is too close to the noise envelope of the system to attempt any sort of quantitative interpretation.

The most prominent expression in the ground EM results is that of a deep, wide, steeply-dipping tabular conductor centering around 0+75N on Line 130W.

The interpreted depth and conductance for this zone, from the standard phasor diagram on page 6a, are 180 m and 1.5 mhos at 1777 Hz and 210 m and 4.5 mhos at 444 Hz. The interpreted depth and conductance values from the suite of in-phase curves on page 6b are 240 m and 8 mhos. These interpreted depths are to be compared to the known depth of 265 to 270 meters for the conductive zone under Line 130W. As explained on page 28, in the discussion for Figure 41, current gathering plays a large role in the discrepancy between the interpreted and known depths. As the known depth of this conductive zone is somewhat greater than the maximum interpreted depth of 240 m, so must the true conductance be somewhat greater than the maximum interpreted value of 8 mhos. The estimate of 15 mhos, shown in Figure 44, is thought to be reasonably accurate.

The plan view of the flight and ground lines is shown in the following sketch:
It is immediately apparent in the preceding sketch that the Input contractor's 'picks' form a type A herringbone pattern about the conductive zone as outlined by ground geophysics and drilling. This type A herringbone pattern is in keeping with the response of a very deep, steeply-dipping tabular body, as described in Appendix I. Interestingly, the Input contractor did not draw a conductor axis on the photomosaic in this case.

The Input profiles in Figure 44 are a little curious in shape. First, the anomalous response from the confined basement conductor seemingly exists on a broad 'elevated' background in the first channel on Flight Line 1030. This effect is not apparent on Flight Line 1020; although the anomaly from the basement conductor appears to be somewhat broad for a confined conductive source—even a very deep one. It is possibly a little broad on the north side due to some sort of instrumental effect, as evidenced by the sudden drop in the profile level of channel 2 around fid 384.1. A similar drop probably increases the width of the channel 1 anomaly; although, it is a little harder to recognize in this channel due to the greater amplitude of the anomaly from the basement source.

The three drill holes shown in the topo-geological in Figure 44 all intersected stringers of graphite, which 'kicked' in ohmmeter tests, according to the geologist in charge of the drilling. Furthermore, another fence of three holes was drilled about 1000 meters along strike on the same basement conductor. All three holes again intersected stringers of graphite, which 'kicked' in ohmmeter tests. With this, there is little doubt that the cause of the airborne and ground EM anomalies is a long, reasonably-confined zone containing several graphite stringers.
CONCLUDING REMARKS

It is obvious from the foregoing field cases that the conductor geometries of the Athabasca Basin can be complex. Certainly, the Input system, which to this point has been the impetus behind most of the ground electromagnetic work in the Athabasca Basin, is sadly lacking in appropriate modelling information. On several occasions known to me, it has been necessary to expand a grid after the first survey, in order to get the complete picture. This is a situation which could have been avoided by a more complete interpretation of the Input results.

The theoretical and scaled-modelling done to date for the slingram coil configuration is obviously not complete for the Athabasca Basin. To be more complete, the host rock beyond and between the present conductor geometries would have to be modelled. There is also room for modelling somewhat more complex situations such as:

a) a horizontal layer or block with a small change in depth or conductivity from one side to the other,
b) steeply-dipping tabular conductors in the central region of flat-lying layers or blocks,
c) network conductors such as described in points 2a, b on page 3,
d) flat-lying layers of varying thickness, wherein the widths of the thick and thin parts are appreciably greater than those shown in Figures 28 to 31.

Although the modelling information at present available for the slingram coil configuration, is not complete, it does provide several building blocks on which to expand. A knowledgeable interpreter can bridge some of the gaps between these building blocks without further experiments. More pressing than the need for further 'slingram' modelling is the need for further 'Input' modelling.

Following a review of the case histories in Figures 37 to 44, the reader may come to the same conclusion as I have, that existing equipment using the slingram coil configuration is capable of locating on the ground any conductive phenomenon found from the air by the Input system--given the proper choice of coil spacing, operating frequencies, plotting scale, and one of the established methods of reducing operating noise.

END

John E. Betz
The subject matter of this appendix is intended to demonstrate quantitatively, the reason for the type A herringbone pattern obtained by the Input system. The reader is referred to pages 15 & 16 for the definition and qualitative explanation of a type A herringbone pattern.

The quantitative treatment in this appendix is only approximate because it involves certain assumptions, but the assumptions will not create first order errors in the end result—only second order errors.

Reference to the diagram on the next page will facilitate following the theoretical treatment. One set of Tx (transmitting coil) and Rx (receiving coil) positions for the Input system with respect to a vertical conductive sheet or tabular conductive body is shown in this diagram, by way of setting up the basic equations for computing the anomaly amplitude at any position of the Input system with respect to the conductive body. No attempt is made here to derive absolute anomaly amplitudes, but rather, the amplitude of the primary field at right angles to the body is normalized to that at a corresponding depth along the axis of the Tx, and the amplitude of the secondary field at the Rx is normalized to that at an equivalent height above the top of the body. The product of these normalized values for the primary and secondary fields gives a comparative amplitude of anomalous reading. These points are described more specifically in the following three paragraphs.

It is assumed that the average amplitude and coupling of the primary field, over the most effective part of the conductive body, is represented by the amplitude and coupling at point B which is at a depth of 200 ft beneath the upper edge of the body. The component of the primary field vector at right angles to the body at point B is the significant component as far as the amplitude of the induced eddy currents and contingent secondary field is concerned. If the vector amplitude at point A (a point directly beneath the Tx at the same depth as B) is considered to be unity in amplitude and $\alpha$ is the angle formed by $TxA$ and $TxB$ ($\alpha = \tan^{-1}\left(\frac{X}{(400+D+200)}\right)$), then the reduced primary field amplitude at point B, due to its increased distance from the Tx is given by the expression $(TxA/TxB)^2$ or $\cos^2\alpha$. The reduced primary field amplitude due to the position of point B with respect to the axis of the Tx is given by the expression $(1+3\cos^2\alpha)^{\sqrt{2}}$. So, the total reduced primary field amplitude at point B is given by the expression $(\cos^2\alpha) \cdot (1+3\cos^2\alpha)^{\sqrt{2}}/2$. The amplitude of the primary field at right angles to the conductive sheet is given by the preceding expression multiplied by $\cos\beta$, where $\beta$ is the angle of incidence between...
\[ \alpha = \tan^2 \left( \frac{X}{T_x A} \right) = \tan^3 \left( \frac{X}{(D+600)} \right) \]
\[ \beta = \tan^3 \left( \frac{3 \cos^2 \alpha - 1}{3 \cos \alpha \cdot \sin \alpha} \right) \]
\[ \theta = \tan^3 \left( \frac{(X-300)}{(D+150)} \right) \]
the primary field and the side of the conductive sheet. The angle \( \beta \) is derivable from the expression \( \tan^{-1} \left( \frac{3 \cos^2 \alpha - 1}{3 \cos \alpha \cdot \sin \alpha} \right) \).

As far as the secondary field is concerned, it is assumed in the first approximation to be due to a line current along the top of the conductive sheet, with an amplitude of unity at point E, which is directly above the sheet at the same height as the Rx. If the secondary field amplitude at E is considered to be unity, then the reduced amplitude at the Rx is given by the expression \( CE/CRx \), or \( \cos \theta \), where \( \theta \) is given by the expression \( \tan^{-1} \left( \frac{X-300}{D+150} \right) \). The component of the secondary field at right angles to the plane of the Rx is given by the expression \( CE/CRx \), multiplied by \( \cos \theta \), or more simply by the expression \( \cos^2 \theta \).

Comparative anomaly amplitudes along an Input profile for any channel can be derived from the expression:

\[
\cos \left( \tan^{-1} \left( \frac{3 \cos^2 \alpha - 1}{3 \cos \alpha \cdot \sin \alpha} \right) \right) \cdot \cos^3 \alpha \cdot \left( 1 + 3 \cos^2 \alpha \right)^{\frac{1}{2}} \cdot \left( \cos^2 \theta \right) / 2.
\]

Such comparative anomaly amplitudes were derived at several points along an Input traverse for three values of D (depth-to-top) of a sheet-like conductive body, using a programmable calculator. The results are shown in the suite of profiles on the following page.

It is obvious, in the suite of profiles on the following page, that the anomaly peak is essentially above the conductive body when the latter is at ground surface, and it moves away from the body in the direction of the departing aircraft as the body becomes deeper. With each adjacent flight-line flown in opposite directions, a pronounced type A herringbone pattern of anomaly peaks will result.
REFERENCES


10. Personal communication with geologists working in the Athabasca Basin area of Saskatchewan, Canada.
MODEL A1

Surface   ↓ Tx  Rx
Sandstone  D  ≈ 250 m
Basement   

Lithological unit, or system of units, containing a network of interlocked, electrolyte-filled fractures—possibly reinforced by graphitic stringers.
Width = 890 meters
Bulk resistivity = 425 Ωm

FIGURES 1 through 4

Note on modelling materials:
A1—carbon of σ = 6 x 10^8 mhos/m approx.
A2 & B—aluminum foil(s) of σ = 3.5 x 10^7 mhos/m approx.

MODEL A1+B

Surface   ↓ Tx  Rx
Sandstone  D  ≈ 250 m
Basement   

Lithological unit, or system of units, as on left.

Electrical contact exists between the lithological unit and the graphite zones in all cases.

FIGURES 5 through 8

Graphite zone σt = 16 mhos

MODEL A2

Surface   ↓ Tx  Rx
Sandstone  D  ≈ 250 m
Basement   

Layer of appreciable weathering in the upper basement.
Width = 890 meters
Conductance = 0.35 mho

FIGURES 9 through 12

MODEL A2+B

Surface   ↓ Tx  Rx
Sandstone  D  ≈ 250 m
Basement   

Layer as on left.

Electrical contact between weathered layer and graphite zone--

FIGURES 13 through 16

No electrical contact, etc.

FIGURES 17 through 19

Graphite zone σt = 16 mhos
Note on modelling materials:
A₃, A₄ & B - aluminum foils of 0 = 3.5 x 10⁻⁷ mhos/m approx.
A & Ar - carbon of 0 = 2 x 10⁻⁸ mhos/m approx.
PLOTTING SCALES FOR MODELLING RESULTS

Note: Fine scale used for conductor depths of one coil spacing and greater.

In-Phase & Quadrature as %p (primary field strength at Rx)

Figures 1 through 36

Note: Coarse scale used for conductor depths of less than one coil spacing.
MODEL A1, FF = 888 HZ, C.S. = 250 M
MODEL A1, FF = 3555 Hz, C.S. = 250 m

Region of maximum departure
Model A1+B, FF = 444 Hz, C.S. = 250 m
Model A2, FF = 444Hz, C.S. = 250 m

D = 150m

D = 100m
Model A2, $F_F = 888$ Hz, C.S. = 250 m

FIGURE 10
Model A2, FF = 3555 Hz, C.S. = 250 m
Model A2+Bc, FF = 444 Hz, C.S. = 250 m

FIGURE 13
Model A2+BC, FF = 888 Hz, C.S. = 250 m
Model A2+Bc, FF = 1777 Hz, C.S. = 250 m

D=150m
D=100m

FIGURE 15
Model A2+Bnc, FF = 3555 Hz, C.S. = 250 m
Model A2L+Bnc, FF = 3555 Hz, C.S. = 250 m

- --- inphase
- --- quadrature

D = 350m
D = 300m
D = 250m
D = 200m
D = 150m

FIGURE 19
Model A3+B, FF= 688 Hz, C.S.= 250 m

- inphase
- quadrature

D=300m
D=250m
D=200m
D=150m
D=100m
D=50m

FIGURE 21
Model A3+B, FF= 3555 Hz, C.S. = 250 m

- inphase
- quadrature

D=300m
D=250m
D=200m
D=150m
D=100m
D=50m

FIGURE 23
Model A4, FF = 3555 Hz, C.S. = 250 m

FIGURE 26
Model A4, FF = 3555 Hz, C.S. = 250 m
Model Ar, F= 888 Hz, C.S. = 250 m
INPUT, MAXMIN AND DRILLING RESULTS
WOLLASTON LAKE AREA, SASKATCHEWAN

MAXMIN II
COIL SPACING 800 ft.

FLT. LINE 26

INPUT

SCALE:

500 ppm

140W - TOPOGRAPHY
130W - LAKE
120W - LAKE BOTTOM TROUGH

INTERPRETED LIMITS OF WEAKLY-CONDUCTIVE FRACTURING IN TOPO 'HIGH'

DDH'S (PROJECTED ONTO SECTION)

INTERPRETED LIMITS OF BASEMENT CONDUCTIVE ZONE

INTERPRETED LOCATION OF WESTERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

BOTTOM OF SANDSTONE AT 586 ft or 179 m

BASEMENT

INTERPRETED OUTER LIMITS OF 2 mho BASEMENT CONDUCTIVE ZONE

INTERPRETED LOCATION OF EASTERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

FIGURE 37
INPUT, MAXMIN, PROTON MAG AND DRILLING RESULTS
BELL LAKE AREA, SASKATCHEWAN

MAXMIN II
COIL SPACING 250 METERS

LINE - 7E

FLT. LINE 10080

SCALE:
500 ppm

INPUT

INTERPRETED LIMITS OF LAKE BOTTOM TROUGH

INTERPRETED LOCATION OF NORTHERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

INTERPRETED LOCATION OF SOUTHERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

TOPOGRAPHY

SEE TEXT FOR DESCRIPTION OF BASEMENT ROCKS

DDH (PROJECTED ONTO SECTION)

BOTTOM OF SANDSTONE AT 234 m BASEMENT

FIGURE 38
INPUT, MAXMIN AND DRILLING RESULTS
RUSSELL LAKE, SASKATCHEWAN

MAXMIN II
COIL SPACING 250 METERS

IN-PHASE AND QUADRATURE AMPLITUDE
AS % PRIMARY FIELD STRENGTH AT RECEIVER

IN-PHASE
QUADRATURE
REGIONAL IN-PHASE

FLT LINE 20370

A
B
W
E

FLT. DIRN.

SCALE:
500 ppm

INPUT

TOPOGRAPHY
LAKE

VERTICAL SCALE (ft)

-350
-300
-250
-200
-150
-100
-50
0

INTERPRETED LOCATION OF WESTERN EDGE OF WEAKLY-CONDUCTIVE BASEMENT UNIT

TYPE 1 BASEMENT UNIT (WEAKLY-CONDUCTIVE)

20W

15W

10W

250 m

LAKE

LIMITS OF LAKE BOTTOM TRough

INTERPRETED LIMITS OF LAKE BOTTOM TRough

INPUT

INPUT, MAXMIN AND DRILLING RESULTS
RUSSELL LAKE, SASKATCHEWAN

MAXMIN II
COIL SPACING 250 METERS

IN-PHASE AND QUADRATURE AMPLITUDE
AS % PRIMARY FIELD STRENGTH AT RECEIVER

IN-PHASE
QUADRATURE
REGIONAL IN-PHASE

FLT LINE 20370

A
B
W
E

FLT. DIRN.

SCALE:
500 ppm

INPUT

TOPOGRAPHY
LAKE

VERTICAL SCALE (ft)

-350
-300
-250
-200
-150
-100
-50
0

INTERPRETED LOCATION OF WESTERN EDGE OF WEAKLY-CONDUCTIVE BASEMENT UNIT

TYPE 1 BASEMENT UNIT (WEAKLY-CONDUCTIVE)

20W

15W

10W

250 m

LAKE

LIMITS OF LAKE BOTTOM TRough

INTERPRETED LIMITS OF LAKE BOTTOM TRough

INPUT
THE DEPRESSION IN THE IN-PHASE PROFILE AT 444 Hz IN THIS AREA IS DUE TO LIMITATIONS IN THE METHOD OF COIL CONTROL IN ROUGH TERRAIN. IT WAS THEREFORE REMOVED FROM THE IN-PHASE PROFILES AT THE HIGHER FREQUENCIES.

INPUT SCALE:

500 ppm

181.0
180.0
173.0
178.0

TYPE 2 BASEMENT UNIT (CONDUCTIVITY BETWEEN THAT OF TYPES 1 & 3)

SEE TEXT FOR A DESCRIPTION OF THE BASEMENT ROCKS

TYPE 3 BASEMENT UNIT (VERY WEAKLY CONDUCTIVE)

INTERPRETED LOCATION OF EASTERN EDGE OF WIDE VERY WEAKLY-CONDUCTIVE BASEMENT UNIT

BOTTOM OF SANDSTONE AT 32.3 m

DDH (PROJECTED ONTO SECTION)

FLT. LINE 20380

_LINE_ 12S

444 Hz

1777 Hz

3555 Hz

LAKE
INPUT, MAXMIN AND DRILLING RESULTS
RUSSELL LAKE AREA, SASKATCHEWAN

The ripples in the in-phase profiles at 444 Hz over this area are due to limitations in the method of coil control in rough terrain, they were therefore removed from the in-phase profiles at the higher frequencies.

MAXMIN II
COIL SPACING 250 METERS

IN-PHASE AND QUADRATURE AMPLITUDE AS % PRIMARY FIELD STRENGTH AT RECEIVER

IN-PHASE
QUADRATURE
REGIONAL IN-PHASE

FLT LINE
100 90

IN
W
E
SC

FLT DIRN.
5C

19.0
18.0
170

Tx 8W

Rx

10W
250 m

6W
4W

TOPOGRAPHY
LAKE

18W
16W
14W
12W

18W
16W
14W
12W

INTERPRETED LIMITS OF LAKE BOTTOM TROUGH

TIP OF PENINSULA

INTERPRETED LOCATION OF BOUNDARY BETWEEN VERY WEAKLY-AND WEAKLY-CONDUCTIVE BASEMENT UNITS

INTERPRETED LOCATION OF WESTERN EDGE OF WIDE VERY WEAKLY-CONDUCTIVE BASEMENT UNIT.
AND DRILLING RESULTS
REA, SASKATCHEWAN

THE Ripples IN THE IN-PHASE PROFILES AT 444 Hz OVER THIS
AREA ARE DUE TO LIMITATIONS IN THE METHOD OF COIL CONTROL IN
ROUGH TERRAIN; THEY WERE THEREFORE REMOVED FROM THE IN-
PHASE PROFILES AT THE HIGHER FREQUENCIES.

FIGURE 40

INTERPRETED LOCATION OF BOUNDARY
BETWEEN VERY WEAKLY-AND WEAKLY-
CONDUCTIVE BASEMENT UNITS

BOTTOM OF SANDSTONE
AT 409 m.

SEE TEXT FOR A DESCRIPTION
OF THE BASEMENT ROCKS

INTERPRETED LOCATION OF
EASTERN EDGE OF WIDE
WEAKLY-CONDUCTIVE
BASEMENT UNIT

SCALE: 500 ppm

FLT LINE 100 90

W

LAKEx

TIP OF PENINSULA

W

LIMITS OF LAKE
1 TROUGH
INPUT, MAXMIN AND DRILLING RESULTS
CREE LAKE AREA, SASKATCHEWAN

MAXMIN II
COIL SPACING 250 METERS

MAXMIN III
COIL SPACING 300 METERS

IN-PHASE AMPLITUDE AS % PRIMARY FIELD STRENGTH AT RECEIVER

IN-PHASE AND QUADRATURE AMPLITUDE

SCALE: 500 ppm FLT. DIRN.

INTERPRETED LOCATION OF WESTERN EDGE OF WIDE WEAKLY-CONDUTIVE BASEMENT UNIT

SEE TEXT FOR A DESCRIPTION OF THE BASEMENT ROCKS

INTERPRETED LIMITS OF STEEPLY-DIPPING 7-mho BASEMENT CONDUCTO
INPUT, MAXMIN AND DRILLING RESULTS
CREE LAKE AREA, SASKATCHEWAN

MAXMIN II
COIL SPACING 250 METERS.

MAXMIN III
COIL SPACING 300 METERS.

LINE - 118 N

FLT. LINE
1160
1150

INPUT

SCALE:
500 ppm

TOPOGRAPHY
LAKE

INTERPRETED LOCATION OF WESTERN EDGE OF WIDE WEAKLY-CONDUTIVE BASEMENT UNIT

SEE TEXT FOR A DESCRIPTION OF THE BASEMENT ROCKS

BOTTOM OF SANDSTONE AT 224m

INTERPRETED LIMITS OF STEEPLY-DIPPING 300m BASEMENT CONDUCTOR

INTERPRETED LOCATION OF EASTERN EDGE OF WIDE WEAKLY-CONDUTIVE BASEMENT UNIT

FIGURE 41
INPUT, MAXMIN AND DRILLING RESULTS
WOLLASTON LAKE AREA, SASKATCHEWAN

MAXMIN II
COIL SPACING 600 ft.

MAXMIN II
COIL SPACING 800 ft.

SEE TEXT FOR AN INTERPRETATION OF THESE PROMINENT QUADRATURE ANOMALIES

INPUT
SCALE: 500 ppm

TOPOGRAPHY

INTERPRETED LOCATION OF SOUTHERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

BOTTOM OF SANDSTONE AT 660 ft (approx)

INTERPRETED LIMITS OF 10 to 15 mho BASEMENT CONDUCTOR

DDH'S (PROJETED INTO SECTION)
UT, MAXMIN AND DRILLING RESULTS

LASTON LAKE AREA, SASKATCHEWAN

MIN II
SPACING 600 ft.

MIN III
SPACING 800 ft.

SEE TEXT FOR AN INTERPRETATION OF THESE PROMINENT QUADRATURE ANOMALIES

INPUT SCALE:

-100 ppm

SEE TEXT FOR DESCRIPTION OF WEAKLY-CONDUCTIVE BASEMENT ROCKS

INTERPRETED OUTER LIMITS OF 15 to 20 mho BASEMENT CONDUCTOR

INTERPRETED LOCATION OF NORTHERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

INTERPRETED LIMITS OF 10 to 15 mho BASEMENT CONDUCTOR

BOTTOM OF SANDSTONE AT 664 ft.

DDH’S (PROJECTED ONTO SECTION)

BOTTOM OF SANDSTONE AT 660 ft (approx)

LOWER SET OF PROFILES

UPPER SET OF PROFILES

INTERPRETED LOCATION OF SOUTHERN EDGE OF WIDE WEAKLY-CONDUCTIVE BASEMENT UNIT

DDH

INTERPRETED LIMITS OF 10 to 15 mho BASEMENT CONDUCTOR

INTERPRETED OUTER LIMITS OF 15 to 20 mho BASEMENT CONDUCTOR

FIGURE 42
INPUT, MAXMIN AND DRILLING RESULTS
CREE LAKE AREA, SASKATCHEWAN

INPUT, MAXMIN AND QUADRATURE AMPLITUDE
AS % PRIMARY FIELD STRENGTH AT RECEIVER

MAXMIN II
COIL SPACING 300 METERS

IN-PHASE
QUADRATURE
REGIONAL IN-PHASE

FLT. LINE 1030

INPUT
SCALE:
FLT. DIRN.
500 ppm

FLT. LINE 1020

FL. DIRN.

15 mho BASEMENT CONDUCTOR

INTERPRETED LIMITS OF
STEEP EASTERLY DIPPING

FIGURE 44