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VLF-EM INVESTIGATIONS IN INSULAR NEWFOUNDLAND

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ABSTRACT

Two projects were initiated to investigate the use of VLF-EM as a mapping tool. The first was aimed at tracing out a drift-covered contact between the Table Head and Codroy groups on the Port au Port Peninsula. Unique in its electromagnetic signature, the contact was mappable in those areas traversed by ground work. The second project was located in the Badger area. A ground survey was undertaken to evaluate the interpretive utility of airborne VLF-EM data. It was found that conductive units, such as the Caradocian graphitic shale unit, are traceable with airborne VLF-EM.

PORT AU PORT PENINSULA, NEWFOUNDLAND

Introduction

Celestite-barite deposits are found at the contact between the Carboniferous Codroy Group and the Ordovician Table Head Group on the Port au Port Peninsula, western Newfoundland. Pb-Zn mineralization is also known to occur within this suite of rocks (Howse, 1984). A thick cover of drift blankets the area and has prevented accurate mapping of the location of the contact between the two groups.

Geochemical investigations (Davenport, *et al.*, 1975) of the stream sediments on the Port au Port Peninsula yielded anomalous values along the projected length of the contact. Therefore it was decided to test the ability of geophysical techniques in determining the contact location.

General Geology

An eroded highland runs along the southern margin of the central part of the Port au Port Peninsula (Figure 1). This escarpment consists of the Ordovician Table Head Group which strikes east-west and dips approximately 17 degrees to the north. Carboniferous rocks (limestone, shale, sandstone) of the Codroy Group onlap the Ordovician strata to the north, and form a drift-covered lowland. The area to the north (mainly Shoal Point) is underlain by Hadrynian to Middle Ordovician sedimentary rocks of the allochthonous Humber Arm Supergroup (Schillereff and Williams, 1979).

The Ordovician limestones are interpreted as having karst features prior to deposition of the Carboniferous sediments. This Carboniferous infilling outlines the topography of the Ordovician surface, which appears to be dominated by 'north trending, steep-sided, fault-controlled ... paleokarst valleys' (Knight, 1983).

Barite and celestite mineralization has been found at the contact between limestone units of the Table Head and Codroy groups in the study area. It apparently occurs as both a replacement deposit of calcareous beds (Johnson, 1954) and as space filling of cavities (Knight, 1983). Known mineral deposits (such as the Ronan) are lens shaped and concordant with the enclosing strata.

Field Work

During June, 1985, twelve north-south traverses were positioned over the projected contact location south of Shoal Point. Limited access confined these traverses to old cut lines and stream beds. VLF-EM (very low frequency - electromagnetic) measurements were taken with a Geonics EM-16 instrument. Data were recorded at 25 m intervals. Magnetic data (using a Scintrex MP-2) were also recorded over a small portion of the survey; little anomalous variation was noted in these records.

Time limitations prevented extensive line cutting and therefore a consistent line bearing was not always possible to maintain. Where vegetation or topography caused slight changes in line direction, the appropriate bearings were recorded from station to station. The collected data were later mathematically projected onto a straight line, which was determined by a method of least squares. Equidistant stations were then interpolated from the projected readings. A Fraser filter was applied to these values and depth sections of equivalent current sources were generated (Karous and Hjelt, 1983).

Figure 2 shows the investigated contact, as well as the orientation of the projected traverses. Three representative profiles of the VLF-EM data plus the calculated depth sections are shown in Figure 3.

Discussion of Results

The primary aim of this investigation was to determine if VLF-EM is capable of discerning the contact between the Table Head and Codroy groups. It was also important to see if this type of survey could distinguish between the geophysical signature of the contact and that of other geological features.

This project is a contribution to the Canada-Newfoundland Mineral Development Agreement, 1984-1989

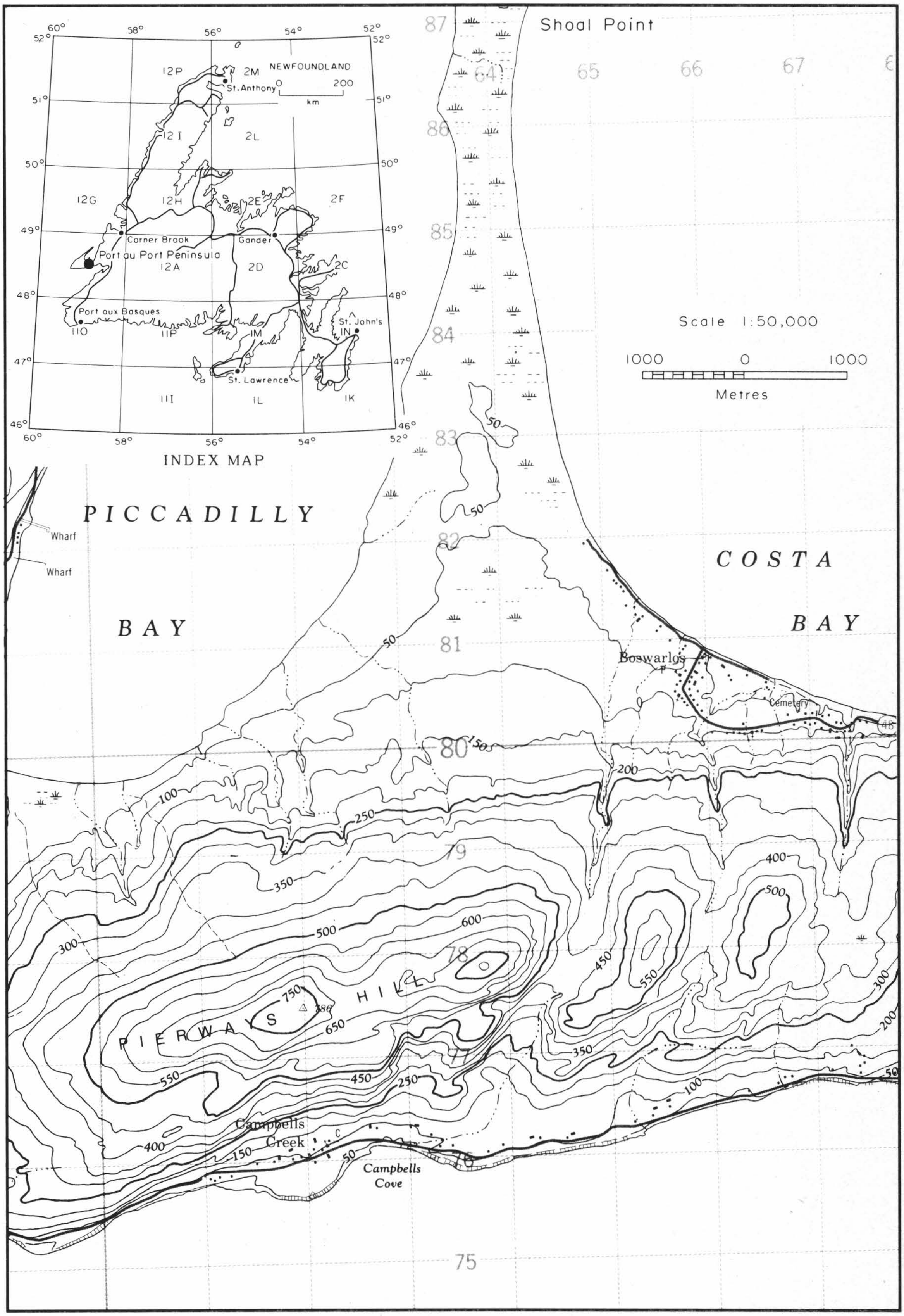

Figure 1: *Location map showing topography.*

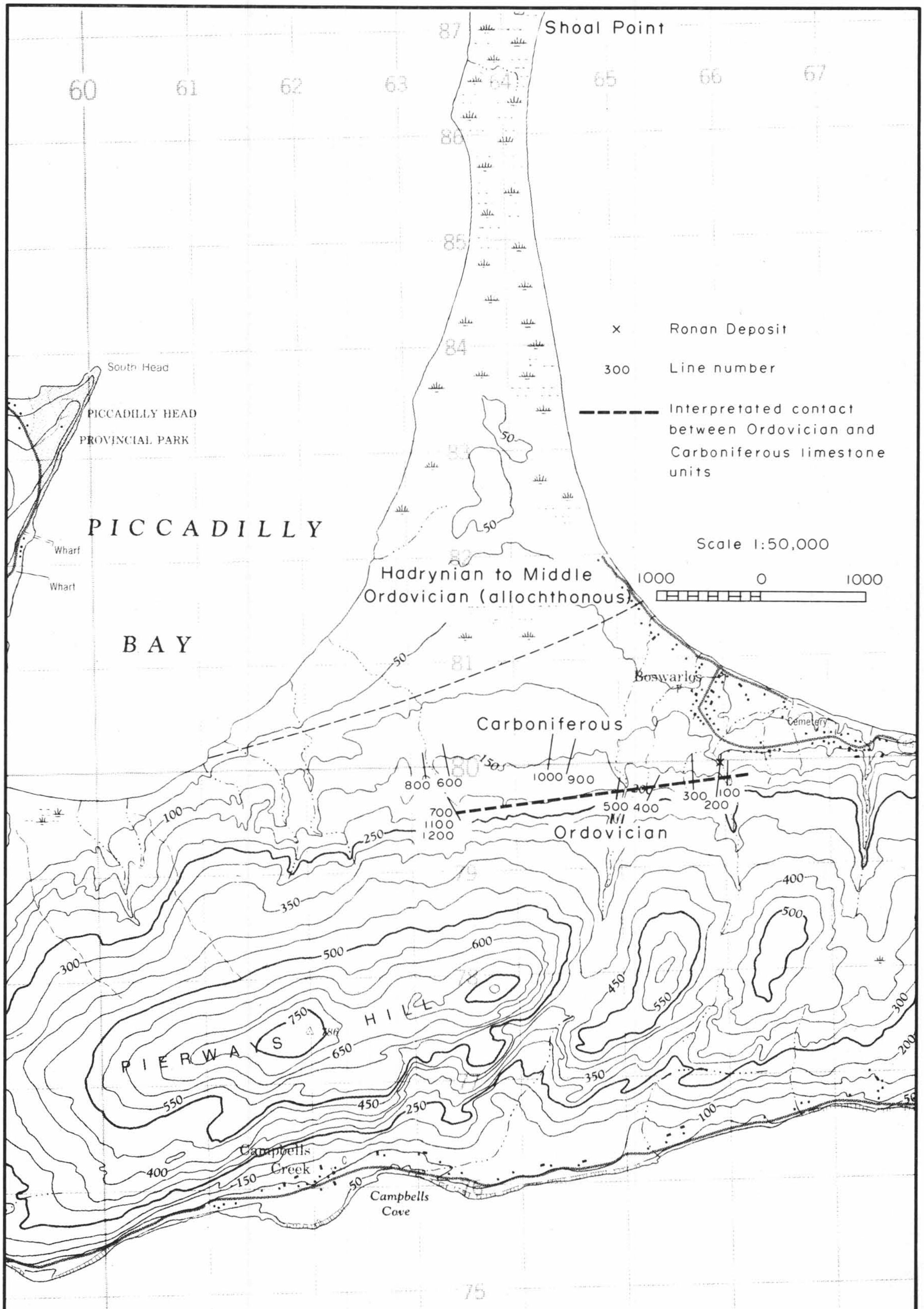

Figure 2: *Orientation and location of traverses.*

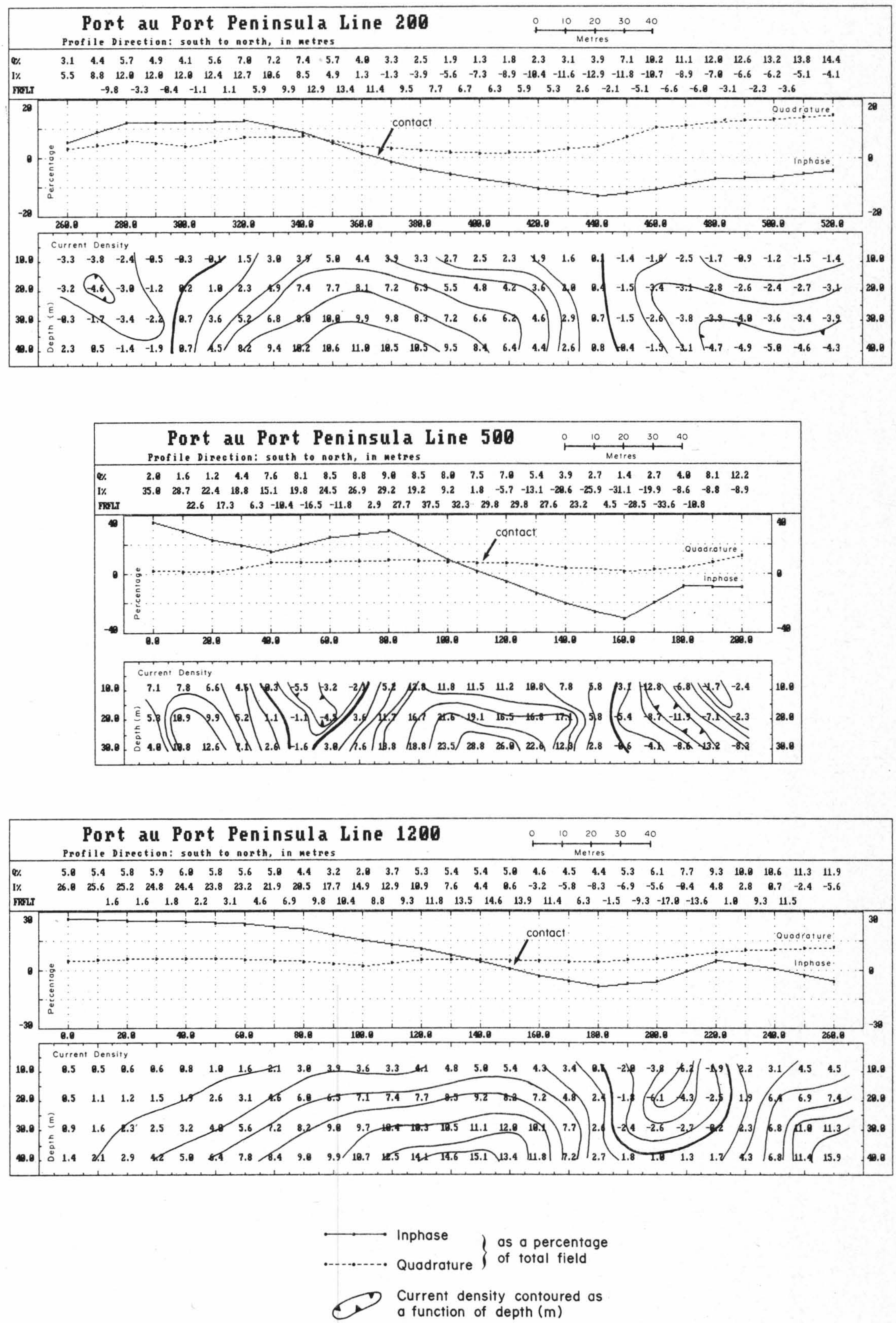

Figure 3: *VLF-EM profiles and depth sections of Lines 200, 500 and 1200.*

There is no doubt that the contact, although drift covered, is traceable using standard VLF-EM geophysical equipment. It was readily identifiable on 8 of the 12 traverses and is illustrated in Figure 3. Lines 600, 800, 900 and 1000 were positioned to the north of the target area and all four produced very flat response profiles. This supports the interpretation that the anomalies in the target area reflect the contact between the two groups.

Line 200 crosses the Ronan deposit. This barite/celestite occurrence has been thoroughly investigated by surface mapping and drilling programs, and its approximate size and location are well known. Barite and/or celestite are unlikely candidates for causing an electromagnetic anomaly as they do not have the necessary conductivity characteristics. Since there is nothing to indicate significant Pb-Zn mineralization at this locality, the VLF-EM anomaly on Line 200 would appear to be a representative contact signature.

Conclusion

An examination of the data indicates that there is very little difference in anomaly characteristics from line to line. Line 200 is a typical example of the electromagnetic response found on all the profiles. This implies that there are no positive indications of Pb-Zn mineralization; at the same time, it does not provide any information regarding celestite/barite occurrences. If two or more traverses were run over the known Pb-Zn deposits, it would provide some parameters on the magnitude of response for such mineralization. Lead Cove and Bellmans Cove are suitable sites for such a test.

The interpreted location of the contact also has a topographical expression in the area. The contact appears to follow the northern edge of a low rise that lies just to the north of, and parallel to, the hills along the south shore of the Port au Port Peninsula.

BADGER AREA

Introduction

A graphitic shale and chert unit of Caradocian age transects the central portion of the Badger (12A/16) map area (Figure 4). It delineates much of the regional folding and faulting patterns of this area, and divides the area into two major geological subdivisions. The distribution of this unit is defined by exposures of graptolite-bearing shales and a regional airborne electromagnetic survey (Kean and Jayasinghe, 1982). However, recently acquired airborne geophysical data (Geological Survey of Canada gradiometer and VLF-EM survey, 1983) suggest modifications to the assumed map pattern of the shale/chert unit.

The graphite content of the shale produces an electromagnetic anomaly that is easily detected by VLF-EM equipment. It is this characteristic which facilitated the interpretation of the airborne data (Scott, 1985) and prompted the ground followup. The magnitude of the anomalous response is proportional to graphite concentration, and depends on the acuteness of the angle between traverse orientations and strike direction. The purpose of the ground geophysical work was to assess the effectiveness of the airborne VLF-EM data as a mapping tool in this area.

General Geology

Clastic sedimentary rocks and minor intercalcated volcanic rocks underlie the middle part of the Badger map area. An extensive unit of black shale and chert containing Caradocian graptolites separates the Middle Ordovician and older Victoria Lake Group to the south from a Late Ordovician to Silurian clastic sedimentary sequence to the north. The Victoria Lake Group consists of interbedded greywacke, shale, siltstone and conglomerate with minor volcanic rocks. The overlying sedimentary rocks are typical of central Newfoundland post-Taconic greywacke and conglomerate sequences. Deformation of these rocks includes folding along northeast-trending axes and faulting along northwest- and northeast-trending faults.

Field Work

Two different areas (#1 and #2) were covered by 9 traverses. The first area lies to the south of Buchans Junction, between Highway 370 and the Exploits River (Figure 5). The airborne VLF-EM coverage indicates a well-defined anomaly to the southeast of the assumed location of the shale unit. The second area is accessible from Grand Falls and is located south of the junction between Highway 370 and Highway 98, which runs north-northwest to Millertown Junction (Figure 6). The map position of the shale unit was originally interpreted from a 1966 INPUT (Induced Pulse Transient) survey by McIntyre Porcupine Mines Ltd. The more recent Geological Survey of Canada VLF-EM data suggest two narrower units instead of the single, wider one (Scott, 1985), but the signature is not sufficiently anomalous to confirm this interpretation.

VLF-EM readings were recorded every 25 m using a Geonics EM-16 meter. As well, approximately half of the lines have magnetic coverage (using a Scintrex MP-2). Positioning of the traverses was constrained by the location of a major power line, which runs east-west through the map area. Ten rock samples were taken.

Discussion of Results

Figures 7 and 8 show the electromagnetic profiles of the traverses from both study areas. A Fraser filter was applied to the recorded values, after which depth sections of equivalent current sources were generated. These plots show four quantities: inphase response, quadrature response, Fraser filter values as a percentage of the total field, and current density as a function of depth. In general, well-defined crossovers (or changes in polarity) in the inphase readings indicate a significant change in conductivity. A summary of each traverse is given in Table 1 and interpreted locations of the shale unit are shown on each of the profiles, where applicable. Area #2 had a number of rock outcrops; identification of the collected samples is given in Table 2 (see also Figure 8).

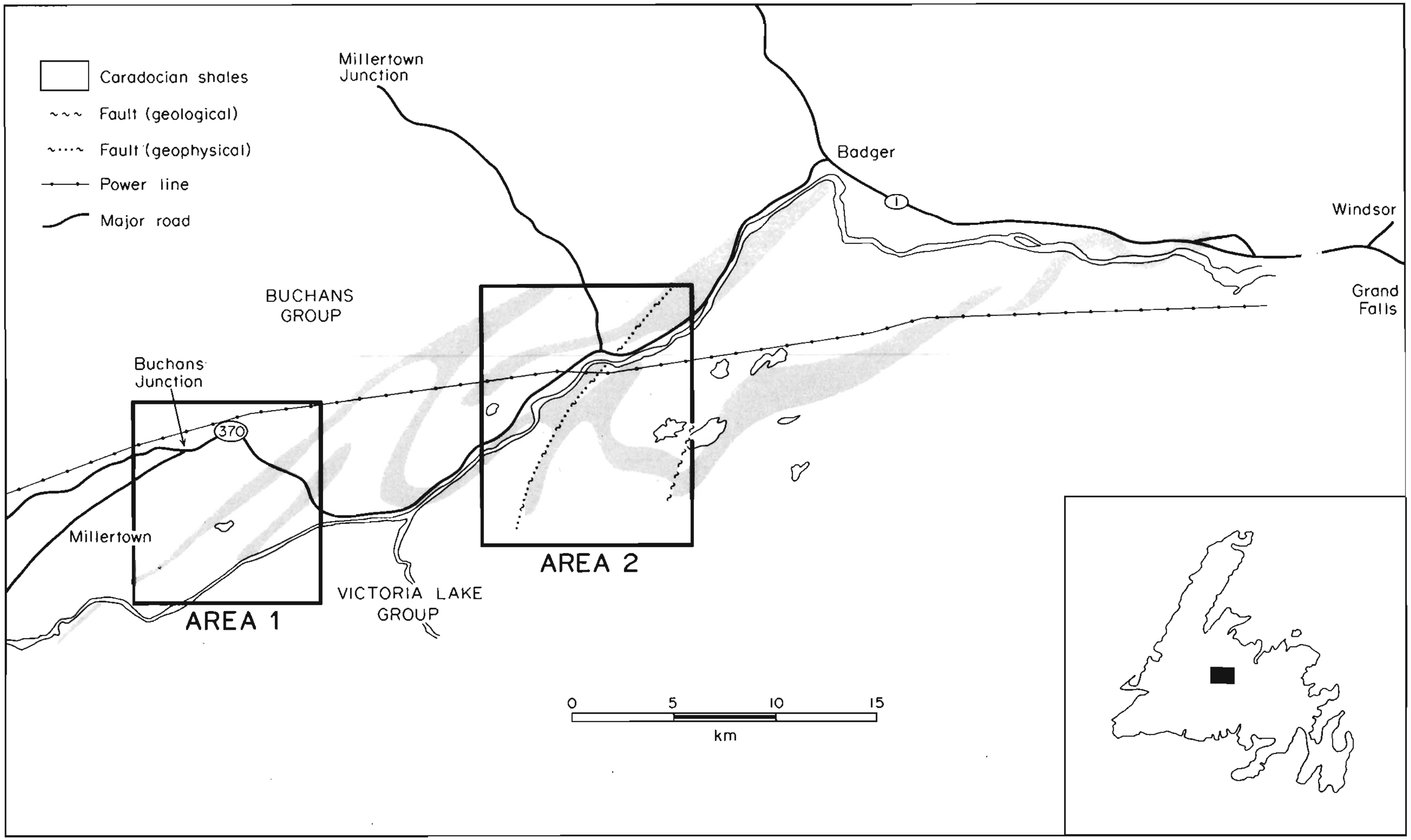

Figure 4: *Distribution of the Caradocian shale unit in the Badger map area (after Kean, 1977) and location of VLF-EM study areas.*

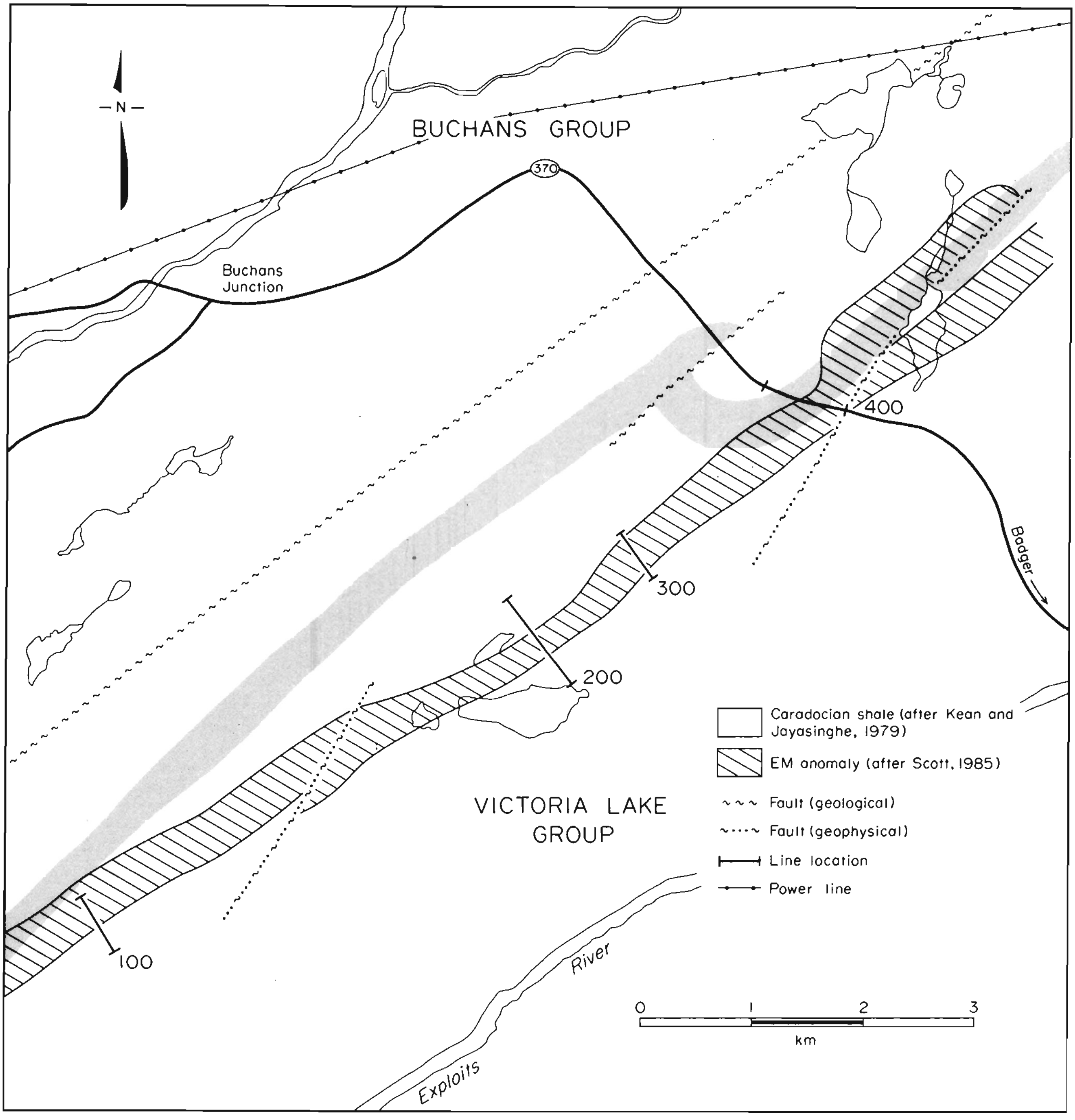

Figure 5: *Location of EM anomaly relative to mapped shale unit, showing position of ground traverses for Area #1.*

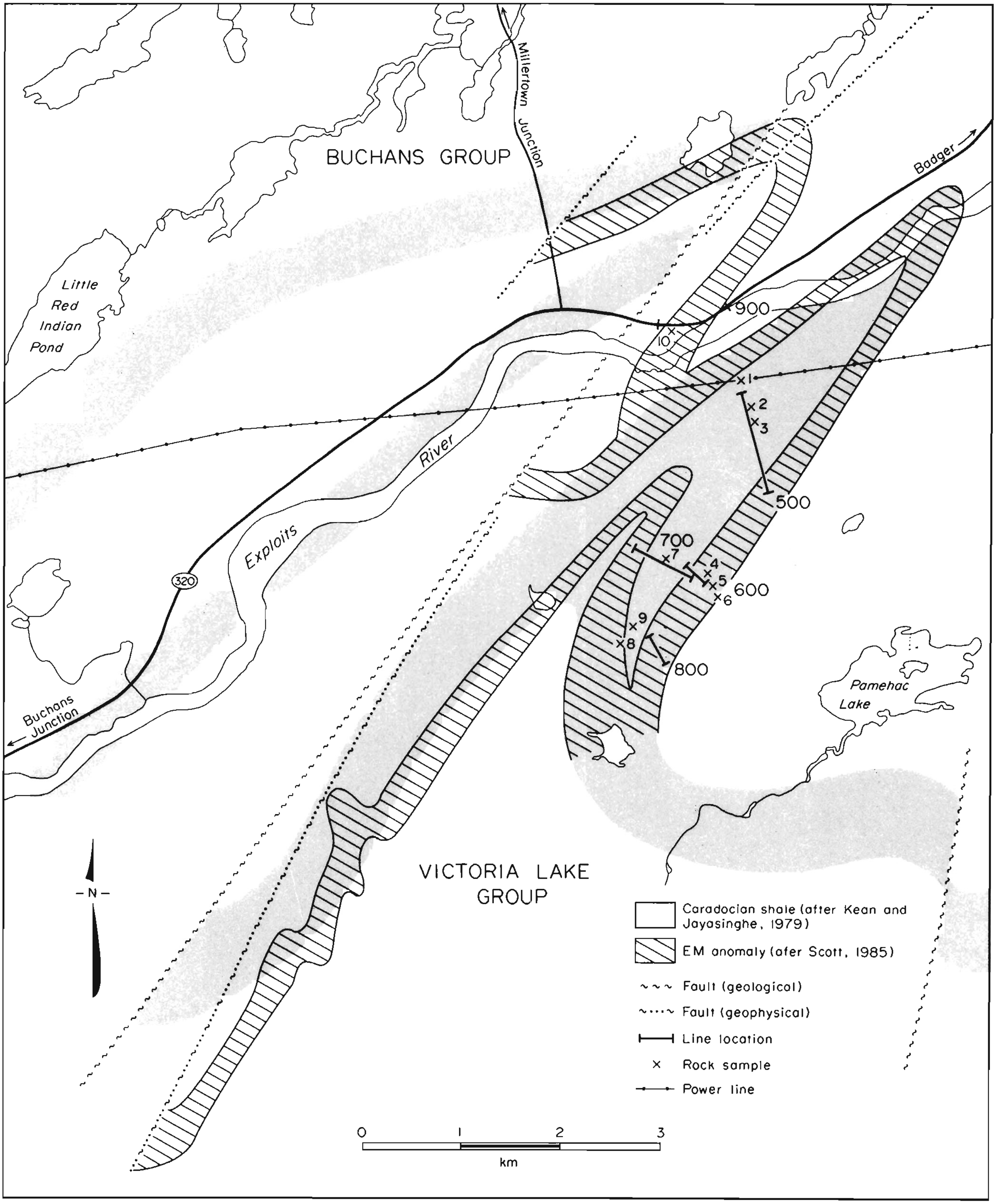

Figure 6: *Location of EM anomaly relative to mapped shale unit, showing position of ground traverses for Area #2.*

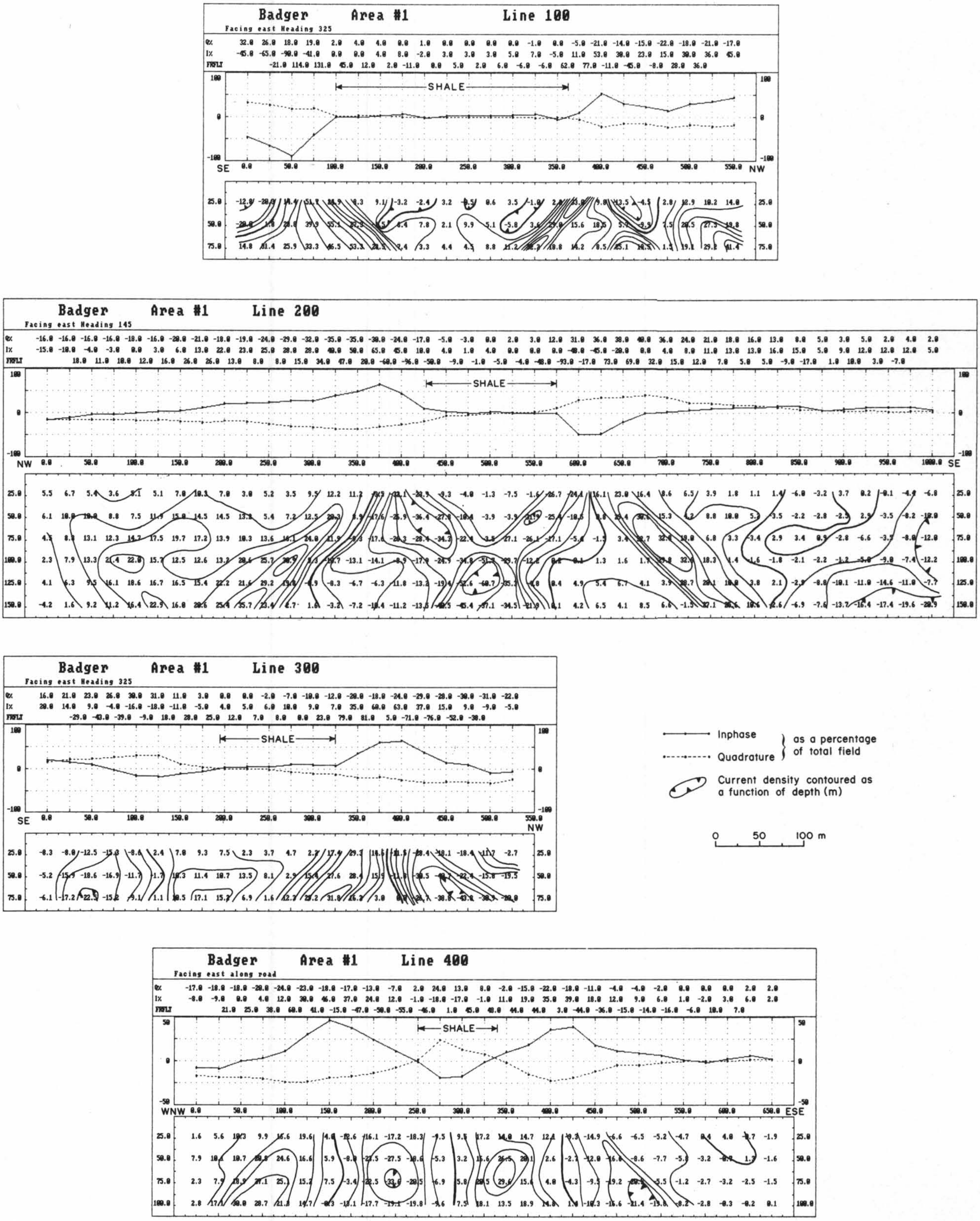

Figure 7: *Profiles of VLF-EM traverses for Area #1.*

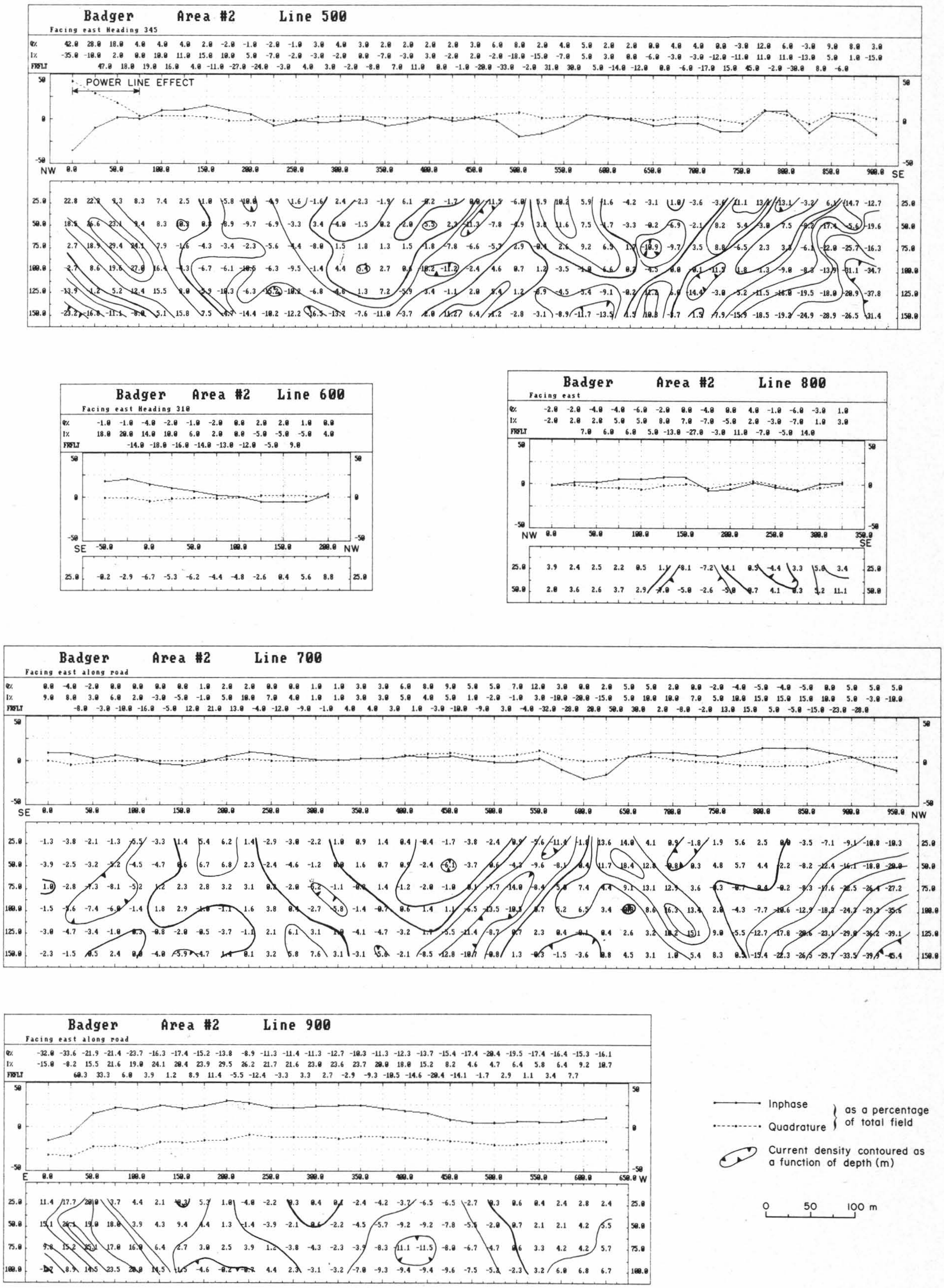

Figure 8: *Profiles of VLF-EM traverses for Area #2.*

Table 1. Summary of Traverses

Area #1

Line	Direction	Response
100	SE to NW	Graphitic shale unit between Stations 100 and 350.
200	NW to SE	Graphitic shale unit between Stations 425 and 575.
300	SE to NW	Graphitic shale unit between Stations 175 to 325.
400	WNW to ESE	Northwest edge of graphitic shale unit at Station 250; second anomaly of unknown source, centered about Station 425, masks southeast edge of unit.

Area #2

Line	Direction	Response
500	NW to SE	Power line effects from Station 00 to 75; no definitive response, but Station 775-800 may represent the northwest edge of the shale unit. Shales noted in outcrop at Station 860.
600	SE to NW	Crossover at Station 100 may correlate with shale unit boundary. There is a 100 nT magnetic anomaly at Station -25; the traverse was not extended farther due to swampy conditions.
700	SE to NW	Graphitic shale unit may exist between Stations 650 and 915 - however the response is poorly defined.
800	NW to SE	Northwest edge of shale unit appears to be located at Station 175; the traverse did not extend beyond the southeast edge.
900	E to W along road	Poor record due to obliqueness of angle between road traverse direction and strike of interpreted unit.

Table 2. Summary of Rock Samples

Sample Number	Rock Type
1	Graywacke
2	Graywacke
3	Graywacke
4	Graywacke
5	Graywacke
6	Graywacke
7	Graywacke and shale
8	Shale
9	Shale
10	Graywacke

CONCLUSIONS

The traverses conducted over Area # 1 provide definitive and positive evidence of a conductor, lying southeast of the presently indicated position of the shale unit. The stratigraphy of the Badger map area indicates rock units young to the north; however, a Llanvirnian-Llandeilian limestone unit has been identified on the northwest side of the conductor (Kean and Jayasinghe, 1982). This implies that either the conductor is not the Caradocian shale unit or that the rocks have been structurally juxtaposed such that the older limestone unit overlies the shale. Further geological field work is required to sort out this problem. As an assessment of the airborne VLF-EM data, the ground follow-up has confirmed that it is an effective tool for tracing conductive units.

Area #2 represents a much less conclusive test case, as the field work was limited by inaccessability due to power lines, swamps, and dense vegetation. However, the marginally anomalous character of the ground data supports the apparent lack of localized response on the airborne VLF-EM data. It is thought that the Caradocian interval in the western part of central Newfoundland is marked by not one, but a number of shale/chert units separated by coarse grained clastic rocks (graywacke); for further details see Kean and Jayasinghe (1982) and Dean (1978). The complexity of such a sedimentary sequence would explain the ambiguity seen in both the airborne and ground VLF-EM data.

In summary, well-defined anomalies on airborne VLF-EM data appear to be good indicators of conductive units, such as the Caradocian graphitic shale unit found in the Badger map area.

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