High-Resolution Seismic and Controlled-Source EM Studies Near Thompson, Manitoba

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ABSTRACT

High-resolution seismic reflection and deep-probing electromagnetic data were acquired near Thompson, Manitoba to map the subsurface extent of the Paleoproterozoic, Ni ore-bearing Ospwagan group. These data are supplemented by surface and borehole geology, and by laboratory measurements of density, seismic velocity and electrical conductivity which indicate that Ospwagan group rocks are generally more reflective and electrically conductive than the Archean basement rocks which envelop them. The combined seismic/EM interpretation suggests that the Thompson nappe (cored by Ospwagan group rocks) lies blind beneath the Archean basement gneisses, to the east of the sub-vertical Burntwood lineament, in a series of late recumbent folds and/or southeast-dipping reverse faults. The EM data require that the shallow-most of these fold/fault structures occur within the basement gneisses or perhaps less conductive Ospwagan group rocks. The results of this study demonstrate how seismic and deep sounding EM methods might be utilized as exploration tools in the TNB.

INTRODUCTION

The Thompson Nickel Belt (TNB) in northern Manitoba has been an important producer of nickel since the early 1960s. Known ore deposits in the belt occur without exception along distinct stratigraphic horizons within the Paleoproterozoic supracrustal Ospwagan group. The supracrustal rocks and the ore deposits they host have been subjected to medium to high-grade metamorphism and intense post-depositional, multi-episode deformation resulting in a complex interference pattern of early recumbent folds overprinted by tight, upright, doubly plunging folds. In spite of the extensive post-mineralization structural and metamorphic history, the sulphide ore-bodies have generally remained within their original host units. Thus, subsurface mapping of the structurally complex supracrustal unit is essential to future exploration within the TNB.

In an attempt to map the subsurface extent of the Ospwagan group in this complex geological environment, 19 km of high resolution seismic reflection data were acquired in 1991. In addition, 20 km of deep-probing electromagnetic (EM) sounding data were acquired to help constrain the interpretation of subsurface geological structure. Coincident controlled-source EM data and seismic reflection data have proven to be complementary in previous studies (e.g., Boerner *et al.*, 1993, 1994). Both data sets were acquired with joint funding from Inco Limited, Exploration, LITHOPROBE and the Geological Survey of Canada.

Seismic reflection methods have recently found application within a variety of geological environments in various mining camps in Canada; e.g., low-grade greenstone belts of the Abitibi Belt (Selbaie, Perron *et al.*, 1995; Matagami, Milkereit *et al.*, 1992a; Ansil Mine, Perron and Calvert 1997), the Sudbury igneous complex (Milkereit *et al.*, 1992b) and Buchans Mine, Newfoundland (Spencer *et al.*, 1992). The TNB is a distinct geological environment from these previous cases, representing a highly strained, moderately to steeply-dipping, medium to high grade Proterozoic collisional belt (cf. Weber, 1990; Bleeker 1990b; and citations therein). In this paper we present an interpretation of seismic reflection and EM sounding data from the Thompson mine study, constrained by laboratory measurements of density, seismic velocity and electrical resistivity for representative TNB lithologies. The model is also constrained by surface and borehole geology. We conclude by summarizing how these high-resolution geophysical mapping methods might be successfully utilized as exploration tools in the TNB.

GEOLOGICAL SETTING

The TNB (Figure 1) lies at the western margin of the Archean Superior Province, where it is in fault contact with the Kisseynew Domain, a part of the Paleoproterozoic Reindeer Zone of the Trans-Hudson Orogen (Hoffman, 1988). Near Thompson, Manitoba (Figure 1), the TNB comprises variably reworked Archean gneisses interleaved and infolded with the remnants of a thin Paleoproterozoic cover sequence, the Ospwagan group (Scoates *et al.*, 1977; Bleeker, 1990b). All ore deposits in the vicinity occur within the the Ospwagan group and are associated with ultramafic sills which intrude the Pipe formation of the Ospwagan group and have been variably dismembered (Bleeker, 1990a).

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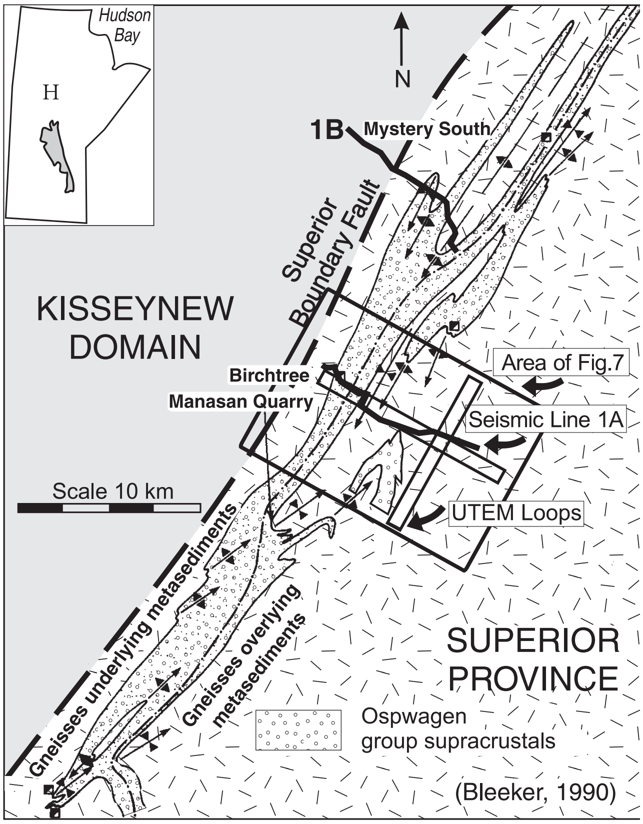

Figure 1: *Location map of the Thompson survey in northern Manitoba. High-resolution seismic and EM profiles are indicated as are mapped occurrences of the Ospwagan group. Base map from Bleeker (1990a).*

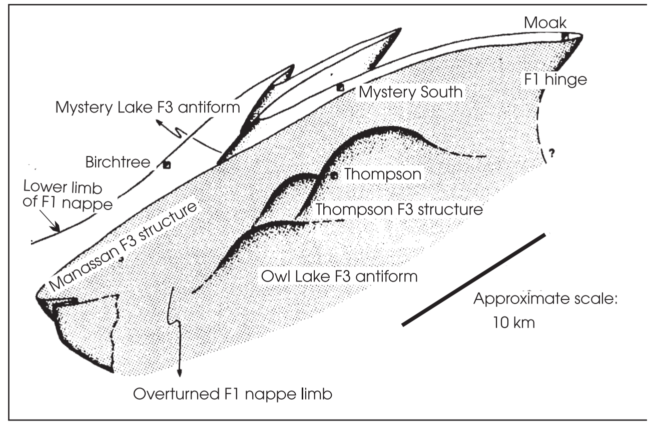

Figure 2a: *3-D sketch of the refolded Thompson nappe structure as seen from the southeast (from Bleeker 1990a). The location of the mines in the Thompson vicinity are indicated by the half-shaded boxes.*

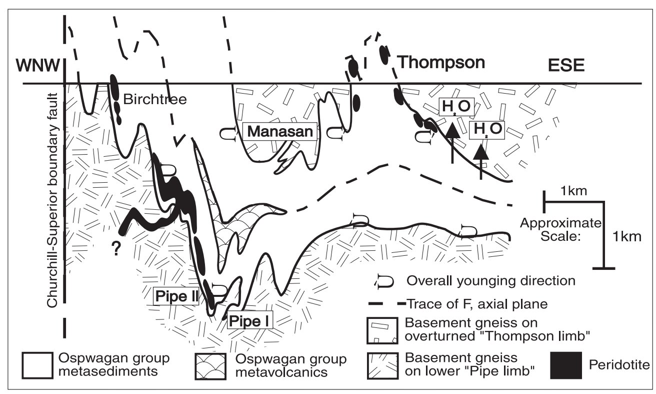

Figure 2b: *Schematic transverse section through the regional nappe structure from Bleeker (1990a). Various structural elements are projected onto the composite profile.*

Bleeker (1990a) interpreted the Thompson geology in terms of a refolded nappe structure as depicted in Figure 2. The overall geological history for the TNB, based on Bleeker (1990a), is as follows:

1. deposition of Proterozoic Ospwagan sediments on Superior Archean basement in a continental rift margin setting (ca. 2100–2000 Ma?);
2. formation of the Thompson nappe during an early (F1) deformation event (>1880 Ma);
3. F2 recumbent folding coeval with peak metamorphism (~1820 Ma);
4. refolding of the nappe structure into nearly upright, doubly plunging F3 folds;
5. late, east-side-up ductile reverse faulting, and
6. localized brittle-ductile strike-slip faulting along the boundary with the Kisseynew Domain.

Figure 2a shows the locations of mines around Thompson in relation to the regional nappe structure proposed by Bleeker (1990a). The Birchtree Mine resides on the lower limb of the nappe structure whereas the Thompson Mine and Owl antiform are F3 structures associated with the overturned limb of the nappe. This model allows for the possibility of Ospwagan metasediments in the core of the nappe lying blind beneath the overturned basement gneisses.

SEISMIC IMAGING IN A COMPLEX ENVIRONMENT

The seismic reflection method is primarily suited to imaging structures with shallow/moderate attitudes. Thus, the geological setting in the Thompson area, which comprises generally moderately/steeply oriented rock fabric, layering as well as fold and fault structures, presents a challenging environment in which to obtain useful seismic images. This limitation must be respected during seismic interpretation. For example, consider the steep fold geometry from the Thompson Mine that is shown in Figure 3a (Bleeker, 1990a). The outline of a single lithologic horizon is reproduced in Figure 3b along with the calculated seismic response prior to migration of the data (3c), and after migration (3d). The migrated seismic image fails to render the steep upright limbs of the folds, whereas the fold hinges and moderately dipping limbs are well represented. The absence of the steep fold limbs in the seismic image makes interpretation of the image non-unique. The moderately-dipping fold limb that is imaged might be interpreted as a fault plane. In this situation, surface and borehole constraints and the structural style assumed for the area are critical in interpreting the seismic images.

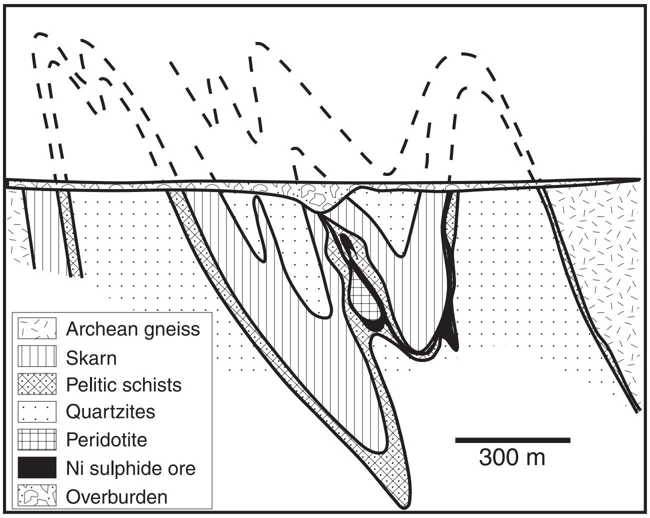

Figure 3a: *Profile through the Thompson structure, Thompson Mine, 24400 N section, looking towards the northeast (from Bleeker 1990a).*

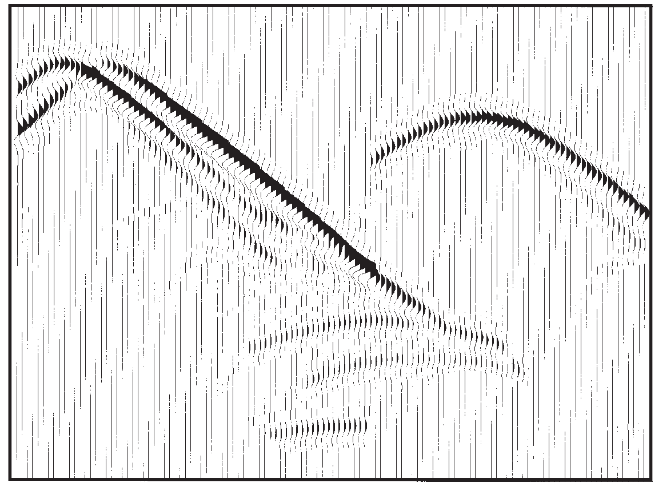

Figure 3c: *Simulated seismic vertical incidence response of the structure in (a) (unmigrated).*

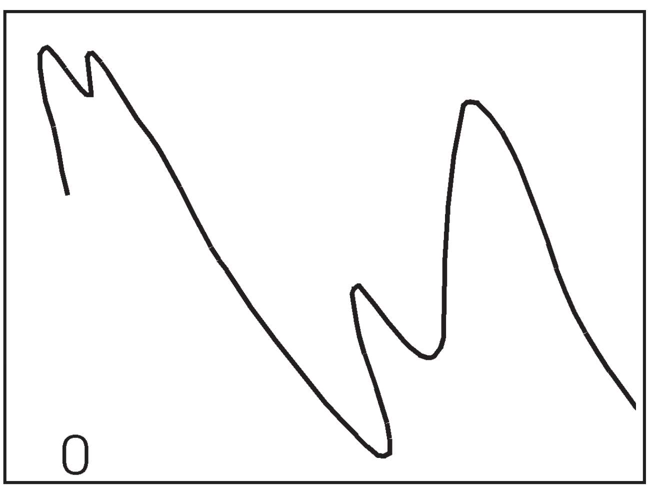

Figure 3b: *Trace of one of the "layers" from Figure 3a.*

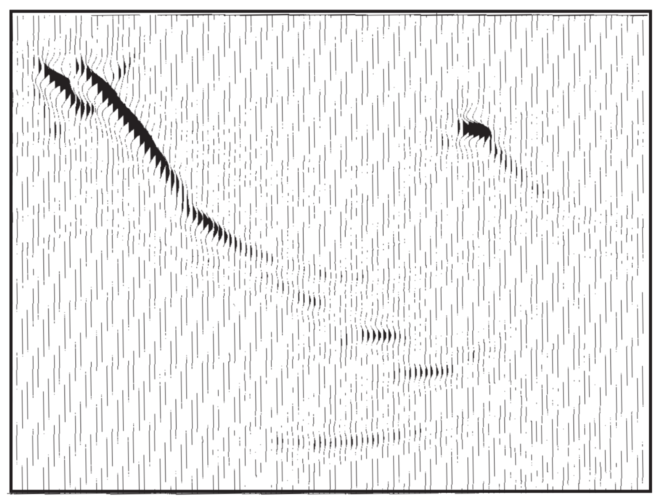

Figure 3d: *Vertical incidence response of the structure in (a) after migration of the seismic data. The Pipe formation is represented by the pelitic schist unit.*

ELECTROMAGNETIC IMAGING IN A COMPLEX ENVIRONMENT

Diffusive EM methods provide an image of the volume-averaged electrical resistivity of the subsurface. In contrast to seismic reflection methods, EM methods are ideally suited to imaging near-vertical structures. EM data provide lower spatial resolution than seismic reflection images as resistivity anomalies must have lateral dimensions roughly equivalent to their depth to be properly imaged. Intrinsically limited resolution can be a benefit in a complicated environment such as Thompson, as minor parasitic folding or limited offset faulting should not significantly disturb the EM image. Furthermore, EM methods provide a means of mapping specific lithologic units in the subsurface, as the major conductive rocks units in Thompson are generally limited to certain formations of the Ospwagan group supracrustals, whereas the Archean gneisses are resistive.

From limited rock property measurements (Katsube, pers. comm.), it appears that the Pipe formation is electrically conductive. Thus, a surface EM survey across the structure illustrated in Figure 3 would provide evidence for steeply-dipping elongated conductors wherever the Pipe formation crops out, whereas the same structure buried under one kilometer of resistive gneiss would appear as a single broad conductive zone.

THE CAUSE OF REFLECTIVITY

Rock property measurements

Compressional wave velocities (Vp) and density measurements have been made on a suite of rock samples from Thompson to assess the reflectivity of the various lithologic units. Seismic reflectivity is controlled by variations in seismic impedance (the product of velocity and density). Seismic waves are reflected from contacts between rock units with contrasting impedances when the thicknesses of the adjacent rock units are at least ¼ of a seismic wavelength (for example, 15 m for a signal with a 100 Hz dominant frequency in rocks having Vp=6.0 km/s). Case studies from other areas indicate that reflections can be caused by lithologic contacts (e.g., White *et al.* 1993), alteration zones, brittle fault zones and shear (mylonite) zones. Brittle and ductile shear zones are well documented in the Thompson area.

Vp and density measurements for a suite of rock samples are shown in Figure 4. The samples shown include velocities measured under an applied uniaxial stress of 17-25 MPa or under a hydrostatic confining pressure of 30 MPa. Relatively high impedance (Z) values (Z=18.5–21.5 $km \cdot gm \cdot s^{-1} \cdot cm^{-3}$) are observed for amphibolite, iron formation, pyroxenite and sulphide ore, as compared to the other lithologies (Z=13.0–16.5 $km \cdot gm \cdot s^{-1} \cdot cm^{-3}$). Reflection coefficients for juxtaposed high- and low-impedance lithologies range from 0.06–0.25, as compared to 0.0–0.11 for juxtaposed low-impedance lithologies. Thus the largest amplitude reflections will be associated with amphibolite, iron formation, pyroxenite and sulphide ores embedded within any of the low to medium impedance units.

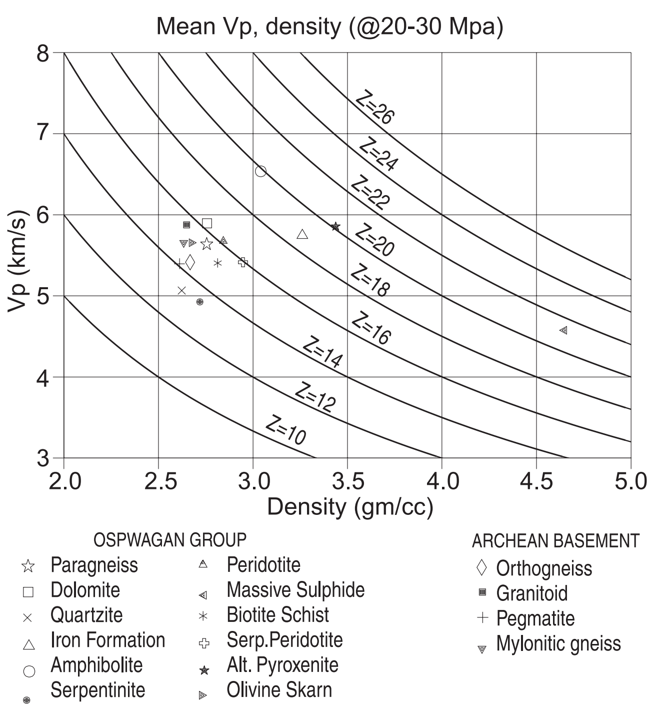

Figure 4: *Mean Vp and densities measured for a suite of rock samples from Thompson. Measurements were made on dry samples under hydrostatic pressure (30 MPa), or under an applied uniaxial stress (17–25 MPa). Note that in the absence of measurements on massive sulphides from Thompson, the Vp and density values for massive sulphide are for a pyrhotite-rich sample from Sudbury measured at a confining pressure of 200 Mpa.*

BOREHOLE LOGS

The spatial distribution of lithologies (i.e., thickness, juxtaposition sequence, lateral extent) is required to characterize the reflectivity of the subsurface. This is best done using borehole velocity and density logs in conjunction with vertical seismic profiling (VSP). However, in the absence of down-hole geophysical logging, the spatial distribution of seismic impedance down the borehole can be estimated by using the laboratory measured velocities and densities in conjunction with the borehole geological logs.

The seismic response determined in this manner for two boreholes in the vicinity of the Birchtree Mine are shown in Figure 5. Significant reflections are generated from:

1. the amphibolite bodies both within the basement gneisses (900–1500 m in borehole 86250) and the Ospwagan supracrustals (700 m and 850 m in borehole 38682-1),
2. iron formation within the Ospwagan group (1600 and 1800–2000 m in borehole 86250),
3. pyroxenite (1050 and 1150 m in borehole 38682-1),
4. serpentinite when in contact with some lithologies (at 1570 m in borehole 86250, and at 1030 m and 1150 m in borehole 38682-1),
5. schist in contact with quartzite (< 500 m in borehole 38682-1), and
6. an ore zone at 1720 m in borehole 86250.

A hypothetical 10 m thick massive sulphide zone placed within a schist host rock produces a large amplitude reflection (1300 m and 2100 m in boreholes 38682-1 and 86250, respectively).

Based on these results, we conclude that:

1. the contact of the basement gneisses and the Ospwagan supracrustals should not be a significant reflector, regionally, as the orthogneisses and paragneisses have similar impedances;
2. the reflectivity of the Ospwagan group should allow discrimination from the more homogeneous basement gneisses;
3. where amphibolite is prevalent within the basement gneisses, they will be highly reflective, making them difficult to distinguish from the Ospwagan supracrustals;
4. massive sulphide units will be reflective when they are greater than 10 m thick;
5. the reflectivity of serpentinite may provide a more useful marker for the location of massive sulphides, due to the larger dimensions of the serpentinite bodies and the genetic relation between the Ni ore deposits and ultramafic rocks at Thompson.

THE CAUSE OF CONDUCTIVITY

Surface observations of induced subsurface electrical currents cannot distinguish between the two dominant upper crustal conduction mechanisms: metallic conduction or ionic transport in fluids. However, knowledge of local geological structure allows inferences to be made about the predominant conduction mode. For example, fluids tend to

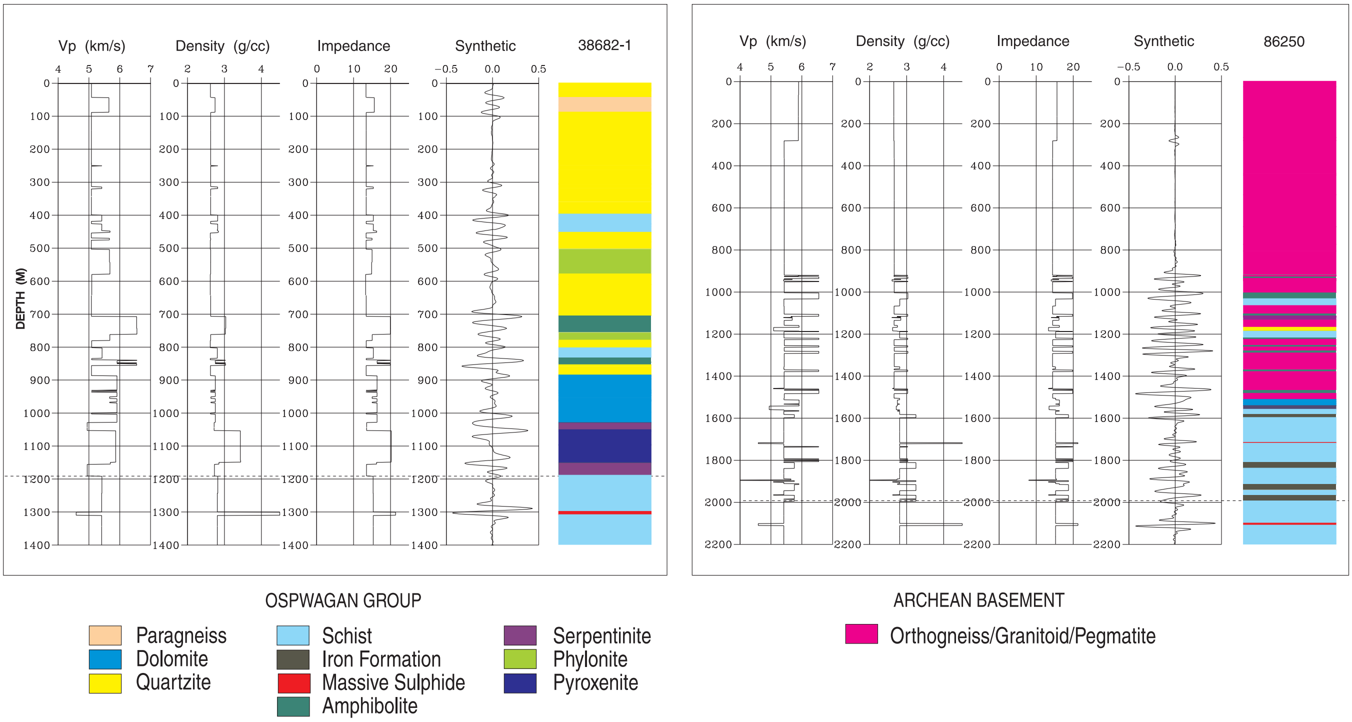

Figure 5: *Synthetic Vp, density, seismic impedance and seismic response determined for the geologic log from (**a**) borehole 38682-1 and (**b**) borehole 86250, using the rock property measurements. The seismic response is determined for the frequency range of 35–130 Hz typically used in high frequency seismic surveys. The log response for a 10 m thick massive sulphide layer embedded within a schist host rock has been added to the logs (below the dashed line) for comparison.*

produce laterally continuous, sub-horizontal conductivity anomalies unless trapped by a sealing mechanism that prevents them from migrating. Thus the presence of fluids may be a reasonable interpretation where a pervasive, subhorizontal conductive layer is observed. In contrast, solid semiconductors or conductors can attain any attitude or orientation, and thus local discrete conductors of variable attitude and orientation are likely metallic conductors.

Electrical rock property measurements

Resistivity and porosity measurements made on samples of various Thompson lithologies are plotted in Figure 6. Measurements were made at low frequency and with samples saturated with distilled water. The serpentinites and peridotites are the most conductive and porous. Moderately conductive rocks (i.e., between 100–1000 Ohm–m) include the dolomite and quartzite of the Ospwagan group. Amphibolite, biotite schist, schist and orthogneiss are all more resistive and show little porosity. This figure illustrates that any known conductive units are intimately related to the Ospwagan group.

A useful means of characterizing electrical conductivity as determined by ionic transport is through a simplified form of Archie's law

$$\rho_{Observed} = \rho_{fluid}\phi^{-m} \qquad [1]$$

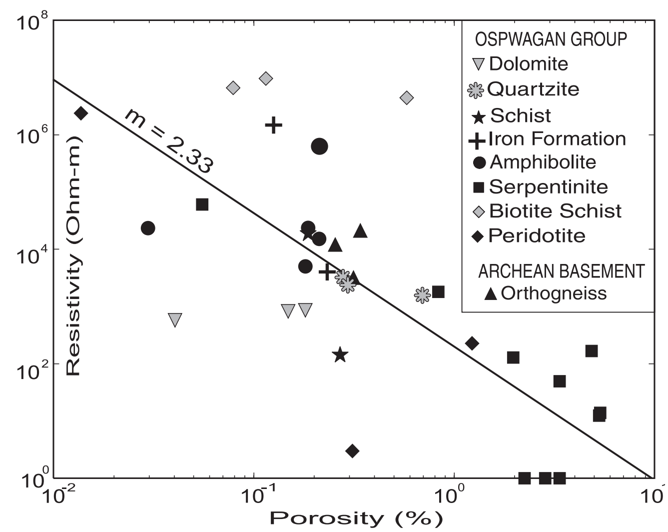

Figure 6: *Rock property results from a suite of samples provided by Inco Limited, Exploration. Plotted is the log of resistivity versus of the log of porosity to facilitate the interpretation of conductivity in terms of ionic transport (fluids) versus electronic transport (metals and semiconductors).*

where m is the saturation exponent, ϕ is the porosity, $\rho_{Observed}$ is the measured in situ resistivity and ρ_{fluid} is the resistivity of the pore fluid. The straight line plotted on Figure 6 is a best fit of Archie's law to all of the rock property data, regardless of rock type. The exponent m=2.33 is within the range of experimentally observed values (typically 1.3 to 3.). The low porosities suggest that most rocks in the Thompson area are electrically resistive. A porosity of 3% would be required to generate a resistivity of 10 Ohm·m. This porosity is at least an order of magnitude greater than that observed for the Ospwagan group and Archean gneisses, with the exception of the highly porous ultramafic rocks.

These data indicate that in general, Ospwagan group supracrustal rocks and the Archean gneiss are characterized by low porosity, and that the dolomites and quartzites are marginally conductive whereas the ultramafic rocks are highly conductive. The resistive host rocks afford deep penetration of the EM fields by virtue of limited attenuation. This observation, coupled with the association of the conductive bodies with the Ospwagan group, means that EM mapping methods are capable of delineating the subsurface extent of the supracrustal rocks, a key objective of this study.

SEISMIC AND EM SURVEY DESIGN

Figure 7 shows the location of the coincident seismic and EM profiles in relation to the Inco Birchtree mine and the outline of the Ospwagan group supracrustals. This combined profile will be referred to as Line 1A in the text that follows. Also shown is the orthogonal EM profile. The seismic/EM profile was intended to provide a complete crossing of the Ospwagan group using existing roads. Starting to the northwest of the Birchtree mine, the profile crosses the F1 synform of the Thompson nappe and continues southeast across F3 antiforms (Owl antiform) which lie along strike from the Thompson structure to the northeast (see Figure 2). The seismic data were acquired using a 240-channel telemetry acquisition system with in-field stacking, noise-rejection, and correlation capabilities. An asymmetric (80/160 channel) split-spread geophone array was used with a 20 m geophone group spacing, 10 m source group spacing, and geophones with a resonant frequency of 30 Hz. The seismic source consisted of two Heaviquip Hemi 50 vibrators sweeping twice at each shot station, using a 12 s linear upsweep from 30 to 130 Hz. Data processing applied to these data included crooked-line binning,

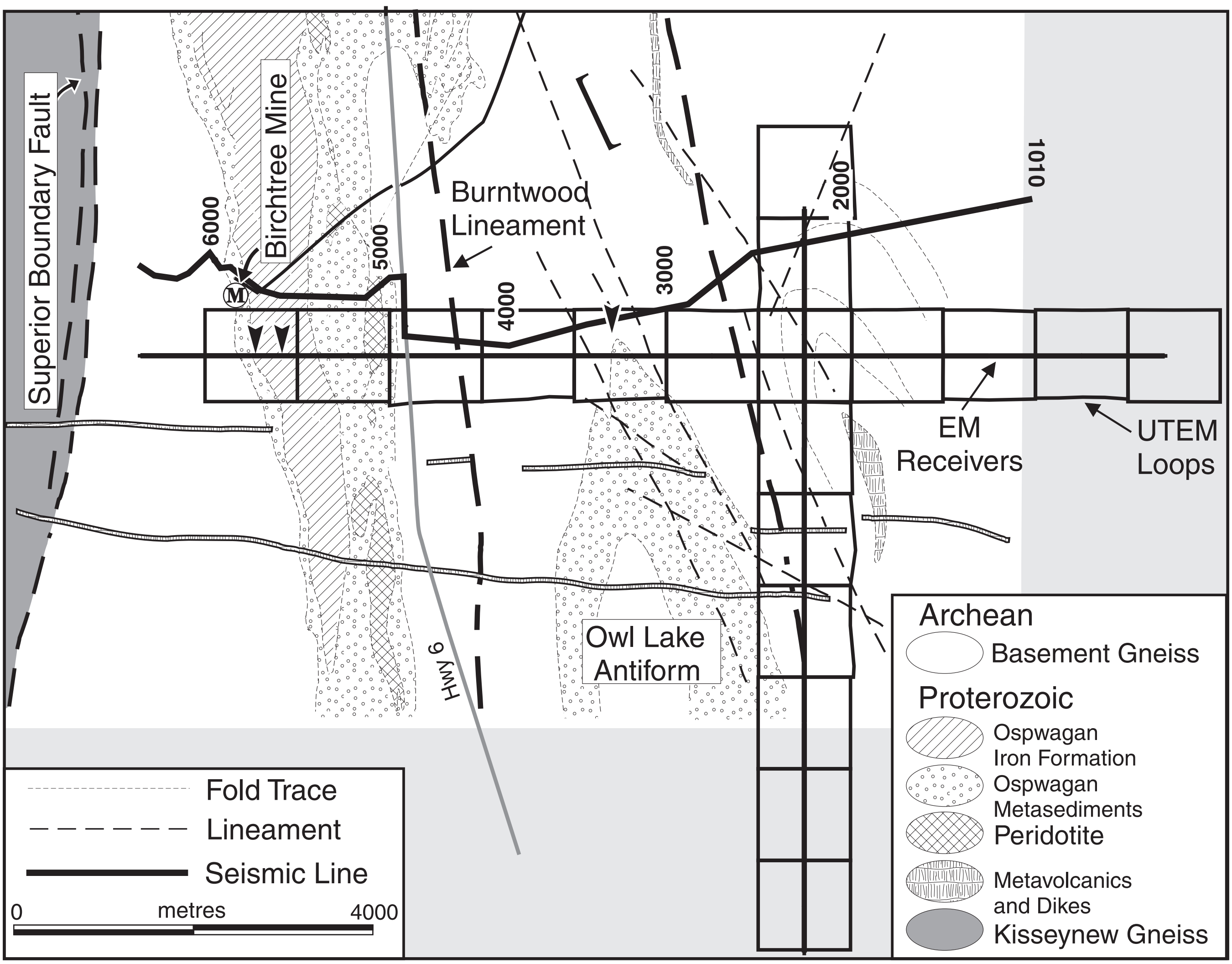

Figure 7: *Location of seismic high-resolution seismic/EM profile in the vicinity of the Birchtree mine.*

deconvolution, time-variant band-pass filtering, weathering static corrections, detailed velocity analysis, trim static corrections and constant velocity (6 km/s) f-k migration. A general description of these processes can be found in Yilmaz (1987). A hybrid of constant velocity stacks was found to be more effective in imaging the structures with highly variable dip as opposed to standard dip-moveout processing.

The EM survey design was constructed with two profiles, parallel and perpendicular to strike of the Ospwagan group, designed to constrain the true structural dip. Source loop dimensions of approximately 1×1 km ($\pm 1\%$ precision) were designed to obtain reliable information about the diffusing current system to depths of approximately 4 km. Data were collected with the UTEM system (West *et al.*, 1984) in 20-channel mode with a base frequency of 31 Hz. Receiver profiles of at least 3 km in length and centered about the loop, allow a three-fold redundancy while allowing uniform resolution in the near surface along the entire profile. The EM data were processed using the Depth Image Processing method (e.g., Macnae and Lamontagne, 1987) to convert step response data into estimates of conductivity vs. depth. Discrete, steeply-dipping conductors disrupt this processing, particularly if they are sufficiently conductive that the secondary EM field induced within them is characterized by a long time constant decay. The locations of such bodies are indicated with black arrows on Figure 7, and the imaged conductivity section is not reliably constrained by the data in these regions.

INTERPRETATION OF THE LINE 1A PROFILES

The unmigrated seismic data for Line 1A are shown in Figure 8 and the combined migrated seismic data and EM resistivity image are shown in Figure 9. Large, steeply dipping and highly conductive bodies at the west end of the line near a broad unit of exposed iron formation make the EM image west of the Burntwood lineament unreliable. Further east, there is little disturbance from near surface conductors.

Seismic interpretation

1. Based on rock property studies, zones of high reflectivity are interpreted as being associated primarily with the Ospwagan group. The highly reflective regions outline the F1 nappe folded by the upright F3 structures. The F1 structure in general dips to the

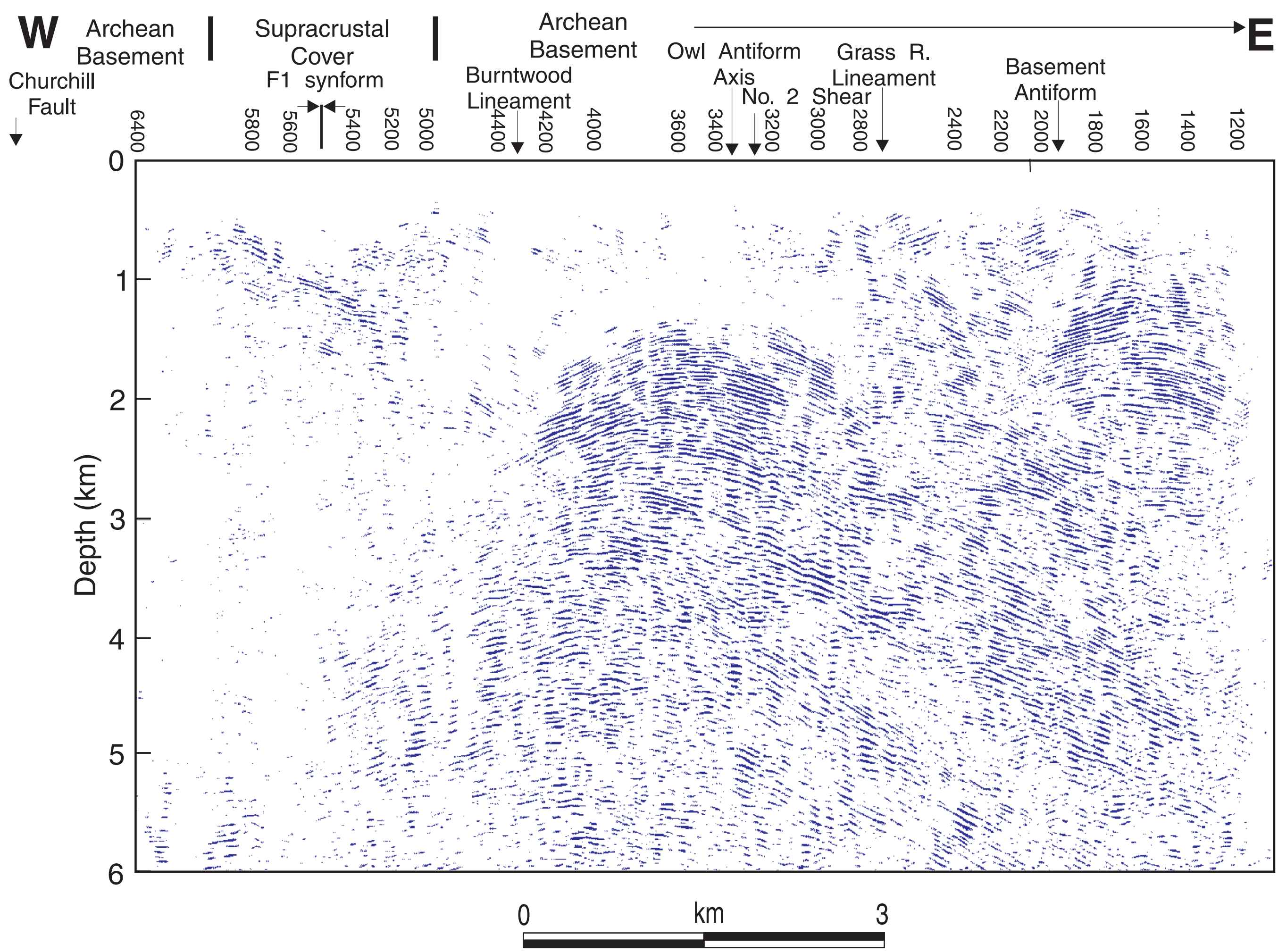

Figure 8: *Unmigrated seismic data for Line 1A. This stack was obtained by using low stacking velocities (6000 m/s).*

southeast, as do the bulk of the reflections. As the reflection data is biased towards shallower dips (<60°), the most prominent part of the overall F1 structure imaged is the crest of the F3 antiform (Owl antiform), which is approximately along strike from the F3 antiformal culmination at the Thompson mine-site (T1 shaft).

2. The depth extent of the Ospwagan group within the F1 fold structure is difficult to constrain from the seismic data alone. In areas of favorable structural attitudes (e.g., the core of the F3 Owl antiform), the seismic image is dominated by shallowly southeast-dipping reflections to at least 5 km depth. Using the thickness of the Ospwagan group rocks in the vicinity of the Birchtree Mine (~1800 m, Figure 7) as a guide, the lower limb (F1) basement-cover contact must occur within this generally reflective zone (dotted line).
3. The pattern of reflections observed to the southeast of the Owl antiform is interpreted as showing the overturned basement-cover contact imbricated along steeply southeast-dipping reverse faults that necessarily post-date F3. This interpretation implies that the overturned Ospwagan group stratigraphy (i.e., upper limb of the nappe) should be within 1 km of the surface near the southeast end of the line. A mapped antiform within basement rocks southeast of the Grass River Lineament (see Figure 7) appears to have been imaged within the hanging wall of the easternmost of the three major faults. The faults in this model can be projected to about 2–4 km depth and appear to become listric, dipping more shallowly to the southeast. It is suggested that these structures accommodate east-side-up displacement, and thus are examples of the late, ductile reverse faults found throughout the TNB (cf. Fueten and Robin 1989).
4. The Burntwood Lineament (mylonite zone) was not directly imaged on the seismic profiles, but is represented by a zone of truncated reflectivity west of the Owl antiform. The seismic signature changes dramatically across the Burntwood lineament from highly reflective in the east to non-reflective in the west, due to the westward change across the structure to steep dips.
5. West of the Burntwood lineament, the geologic sections (from borehole information) show all of the lithologic contacts dipping steeply to the west in contrast to the seismic data which are dominated by moderately east-dipping reflections. These east-dipping reflectors are interpreted as being associated with known east-dipping faults. The west-dipping lithologic contacts were not imaged for two reasons: the steep dips are difficult to image with conventional CMP-processing, and insufficient maximum offsets in the down-dip direction (west) were recorded during acquisition.

Interpretation of the EM data

The conductivity structure east of the Burntwood lineament is characterized by a resistive (10^3–10^5 Ohm·m) near-surface layer which overlies an eastward-dipping layer of high conductivity (< 100 Ohm·m). The depth to the conductive layer increases from approximately 1000 m near the Burntwood lineament to 2500 m at the east end of the line. Decay curves from adjacent loops on the east end of the line demonstrate a

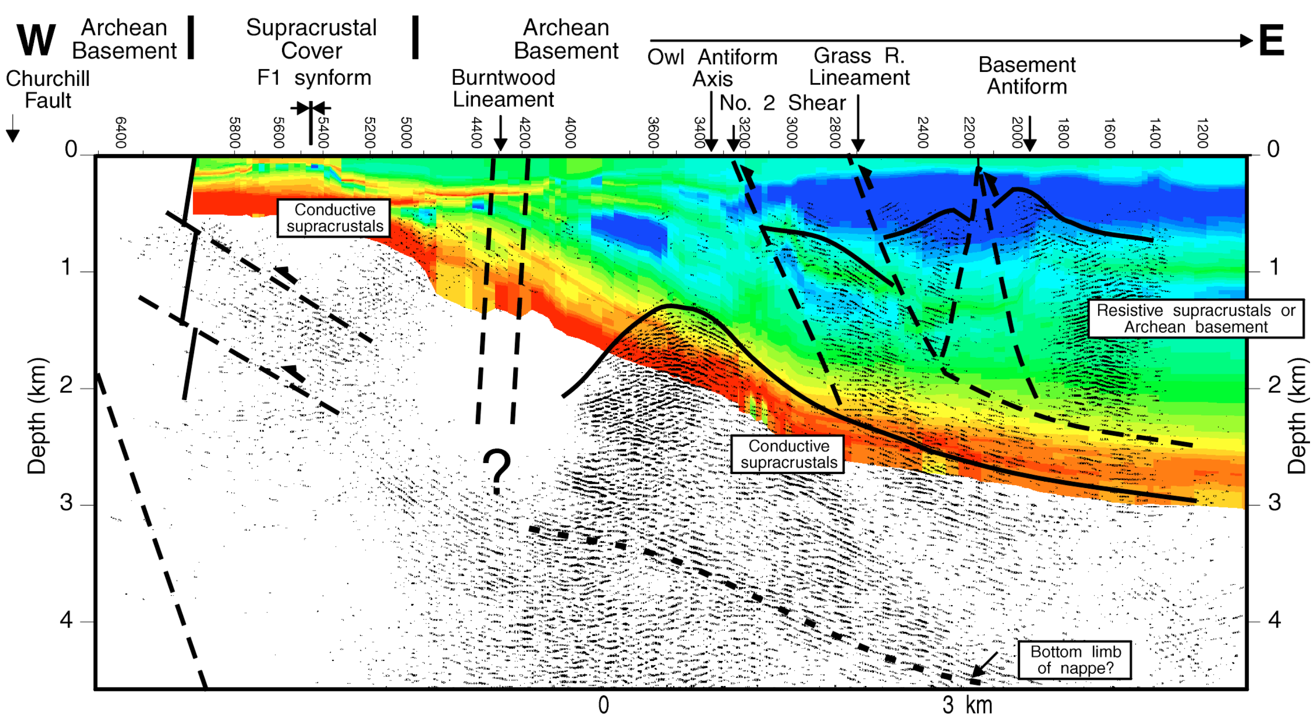

Figure 9: *Hybrid migrated seismic data for Line 1A with the resistivity versus depth image for the coincident EM profile overlain in colour.*

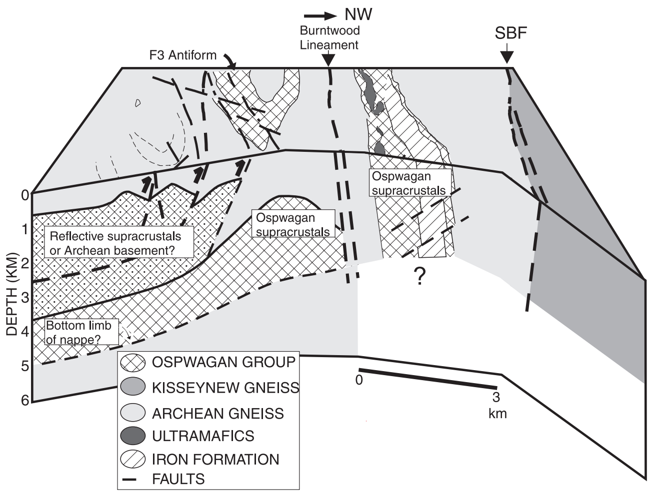

Figure 10: *Perspective view (looking from the northeast) of the combined seismic/EM interpretation.*

gradual westward slowing of the secondary magnetic field diffusion along the profile, diagnostic of a conductive layer that shallows to the west. The EM data from the perpendicular profile suggest that the conductive layer also dips gently to the north indicating a northeast true dip. The other discrete conductors identified with the surface EM survey (Figure 7) all parallel the strike of the Ospwagan supracrustal group, and dip vertically with little or no discernible plunge, although plunge is difficult to resolve with these data.

The spatial association of surficial EM anomalies with the metasediments and the results of the laboratory resistivity measurements both suggest the most plausible source of the deep conductive layer is Ospwagan group rocks. While these rocks are more porous than the basement gneiss, the conductive layer dips markedly to the northeast, making fluids an unlikely conduction mechanism. The observed anomaly is laterally continuous and thus may represent a conductive formation of the Ospwagan group. Alternatively, it may represent the cumulative response of several large discrete conductors such as peridotite/serpentinite bodies embedded within a mildly conductive matrix. The graphitic/sulfitic shale member of the Pipe formation probably contributes to the overall conductivity of the formation (Zablocki 1966).

COMBINED INTERPRETATION

A perspective view of the combined seismic/EM interpretation model is shown in Figure 10. The Burntwood lineament appears to be a sub-vertical structural discontinuity that disrupts the inferred continuity of the Thompson nappe structure (see Figure 3) between the Birchtree Mine and the Owl antiform. The significance of the Burntwood lineament is suggested by the discontinuity in the seismic signature across the lineament, the disparity in conductivity associated with Ospwagan outcrops on either side of the lineament (i.e., Birchtree vs. Owl antiform) and an increase in metamorphic grade from west to east across the fault suggesting relative east-side up movement.

Details of the interpretation model west of the Burntwood lineament are based primarily on borehole and mine geology. The seismic and EM surveys failed to provide robust subsurface images in this region due to the sub-vertical attitude of the Ospwagan group and the presence of large, strong near-surface conductors in this region (indicated by the black arrows on Fig. 7).

The Owl antiform containing Ospwagan supracrustals plunges southeast beneath the profile as suggested by surface geological observations. This is supported by spatial coincidence of 1) the antiform imaged seismically and its position on rudimentary down-plunge projections of the surface fold traced into the seismic imaging plane, and 2) the top of the conductive zone with the crest of the antiform. This interpretation is consistent with the observation that the Ospwagan group is generally conductive, but is in apparent contradiction to the resistivity image from the perpendicular EM profile which shows a reduced conductivity in the Ospwagan supracrustals within the Owl antiform relative to those west of the Burntwood lineament, and a shallow rather than steep plunge of this conductive layer to the northeast. This remains an unresolved question.

East of the Owl antiform, the seismic interpretation suggests that the overturned basement-cover contact is imbricated along a series of late steeply southeast-dipping reverse faults carrying Ospwagan supracrustals to the shallow subsurface. Although this structural interpretation is plausible, the high resistivities observed for this same zone require that the folds/faults actually lie within reflective basement gneisses or resistive supracrustal rocks. Assuming the latter, it is possible that the reflective rocks represent Ospwagan metasedimentary rocks from the overturned limb of the nappe structure (generally resistive), and that the deep conductive layer which dips to the northeast actually represents metasedimentary rocks from the basal (upright) limb of the nappe. If this is the case, the two limbs of supracrustals may not be physically connected and are perhaps separated by the Burntwood lineament.

CONCLUSIONS

The results of this combined high-resolution seismic and EM study suggest that these methods are effective in determining the subsurface configuration of the Ni ore-bearing Ospwagan supracrustal group. This conclusion is based on rock property measurements, borehole logs and correlation of the geophysical images with mapped surface geology. The Ospwagan supracrustals should generally be more seismically reflective and electrically conductive than the Archean gneisses which surround them in F1-F3 fold interference structures at Thompson.

Further work is required to substantiate this hypothesis. In particular, more rigorous ground-truthing of the geophysical images is essential. The only area along the existing profile having boreholes or mineworks to depths sufficient to correlate directly with the geophysical images is in the vicinity of the Birchtree Mine. Unfortunately, this area is where the seismic and EM images are poorly constrained due to sub-vertical lithology and strong near-surface conductors, respectively. The in situ reflectivity of the subsurface can be determined by acquiring down-hole sonic and density logs and VSP's in order to test the conclusions based on the existing rock property measurements.

The structural complexity of the Thompson nappe dictates that no single method of subsurface imaging will be effective everywhere. The existing mines in the Thompson area are located where steeply dipping nappe limbs breach the surface. In these areas, vertical seismic profiling may be a more effective means of subsurface imaging as surface seismic methods are hampered by the steep structural attitudes. However, if the nappe model is valid, much of the Ospwagan group may lie blind beneath the Archean gneisses with structural attitudes that are amenable to imaging using surface seismics (e.g., east of the Burntwood lineament). In these areas, surface seismics and EM methods may be strategically exploited. Careful survey design will be required to account for 3-D structure and ultimately 3-D surveys will be necessary to obtain accurate structural information.

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