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Alan G. Jones, Jessica Spratt, and Shane Evans

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Authors' addresses

A.G. Jones *(ajones@nrcan.gc.ca)*
Continental Geoscience Division
615 Booth Street
Ottawa, Ontario K1A 0E9

J. Spratt *(jespratt@mailbox.syr.edu)*
Department of Earth Sciences
Syracuse University, Syracuse
New York, 13244, U.S.A.

S. Evans *(evans@geoladm.geol.queensu.ca)*
Department of Geological Sciences
Queen's University
Kingston, Ontario, K7L 3N6

Central Baffin electromagnetic experiment (CBEX)

A.G. Jones, J. Spratt, and S. Evans
Continental Geoscience Division, Ottawa

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Abstract: As part of the Central Baffin Multidisciplinary Project (a collaborative effort of the Geological Survey of Canada, the Canada–Nunavut Geoscience Office, and the Polar Continental Shelf Project) a fifteen-station regional-scale magnetotelluric profile, crossing the northern margin of Trans-Hudson Orogen on Baffin Island, was acquired during the summer of 2001. The primary goal was determining the subsurface geometry of major geological boundaries, particularly between Archean Rae Craton rocks and overlying Paleoproterozoic continental-margin units. The most significant conclusion reached from preliminary analyses and modelling is that the highly conductive iron-, sulphide-, and graphite-rich Astarte River Formation, a distinctive stratigraphic marker horizon within the Paleoproterozoic Piling Group, is electrically disconnected from similar rocks found in the south. This could suggest that Archean rocks to the south are not related to Rae Craton rocks to the north, or that tectonic imbrication has disconnected northern and southern segments. Either way, the results indicate that the Piling Group rocks do not sit within a synformal basin structure.

Résumé : Dans le cadre du projet multidisciplinaire de l'île de Baffin centrale (projet en collaboration mené par la Commisssion géologique du Canada, le Bureau géoscientifique Canada-Nunavut et l'Étude du plateau continental polaire), on a réalisé à l'été 2001 un profil magnétotellurique à l'échelle régionale comptant 15 stations, qui recoupe la marge septentrionale de l'orogène transhudsonien dans l'île de Baffin. L'objectif premier de ce levé était de déterminer la géométrie en profondeur des principales limites géologiques, en particulier celle qui sépare les roches archéennes du craton de Rae des unités sus-jacentes de marge continentale du Paléoprotérozoïque. Des conclusions découlant des analyses préliminaires et de la modélisation, la plus importante est à l'effet que la Formation d'Astarte River, une unité très conductrice riche en fer, en sulfures et en graphite qui forme un horizon stratigraphique repère aux propriétés caractéristiques à l'intérieur du Groupe de Piling du Paléoprotérozoïque, n'est pas en continuité électrique avec les roches semblables présentes au sud. Ceci pourrait suggérer que les roches archéennes au sud ne sont pas associées aux roches du craton de Rae au nord, ou qu'une imbrication tectonique a brisé les liens électriques entre les segments nord et sud. D'une manière ou d'une autre, les résultats indiquent que les roches du Groupe de Piling ne gisent pas dans une structure synforme de bassin.

OVERVIEW

During July and August of 2001, magnetotelluric (MT) measurements were made at a total of 16 sites on Baffin Island as part of the Central Baffin Multidisciplinary Project (Corrigan et al., 2001; St. Onge et al., 2001). Fifteen of these sites were along an approximately 300 km long north-northwest–south-southeast profile (Fig. 1), and the sixteenth site was located at the GSC Camp, primarily for instrument testing. The sites were located to be optimally positioned as far from seawater as possible, within helicopter range, and to obtain a profile that crossed the major geological structures in the mapping area.

The primary goal of the MT survey was to determine the subsurface geometry of major geological boundaries, particularly between Archean Rae Craton rocks and overlying Paleoproterozoic continental-margin units. Within those margin units, the Piling Group, lies a sulphide-facies iron-formation, named the Astarte River Formation (Corrigan et al., 2001). Given its enhanced electrical conductivity, this formation is a particular target for electromagnetic imaging of the crustal-scale structural geometry of the Piling Group rocks and their underlying basement.

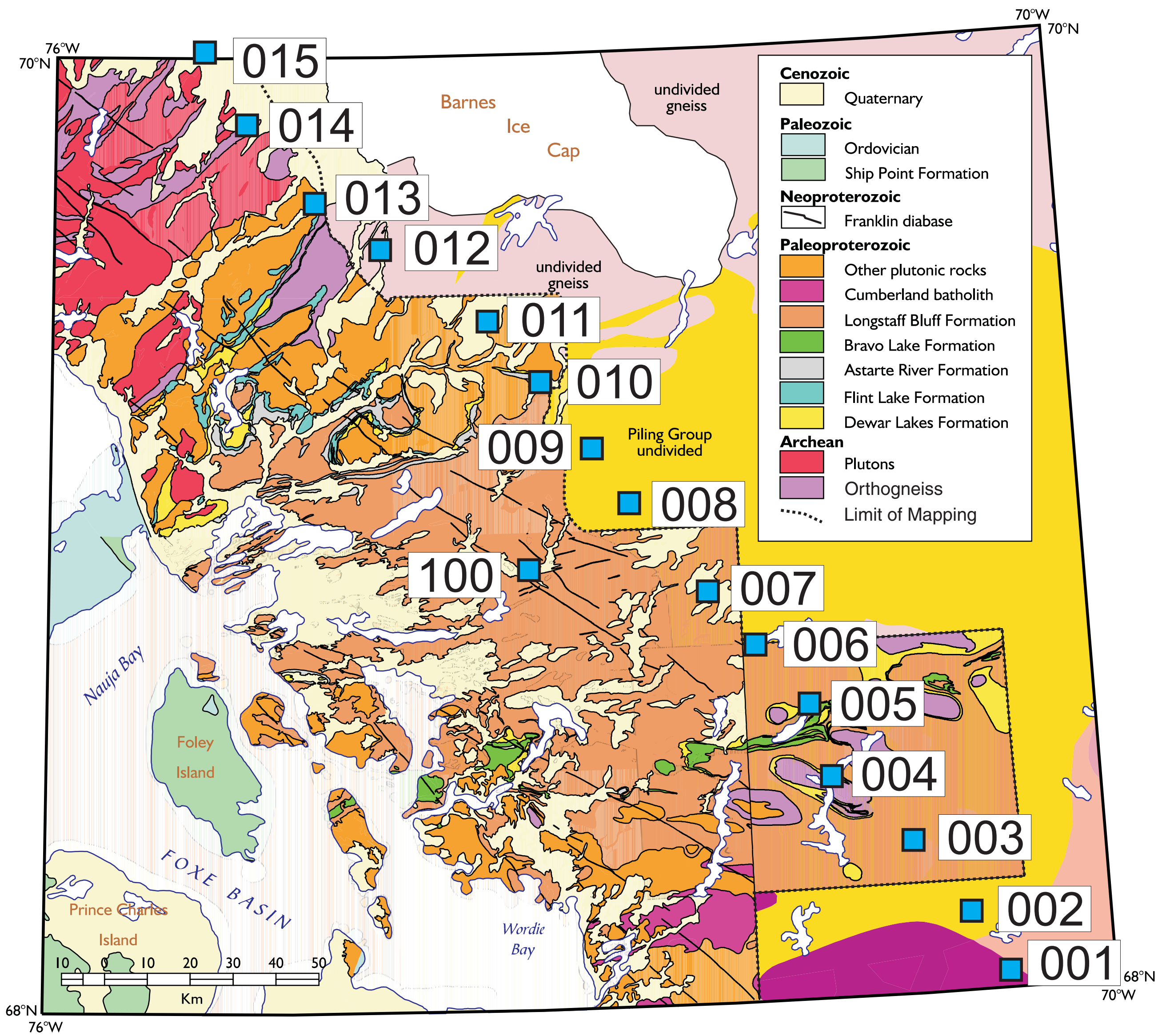

Figure 1. Regional location map of the MT sites (blue squares) in central Baffin Island. (Taken from the CD-ROM Geological Map of Canada, Wheeler et al., 1997.)

MT DATA ACQUISITION AND QUALITY

At each location, MT time-series data were acquired by two sets of instruments. For low frequencies, 0.05 to 0.0001 Hz, probing the mid-crust and upper mantle, LiMS (Long period Magnetotelluric Systems) designed by the GSC were used to record five components of the time-varying electromagnetic fields (*Ex, Ey, Hx, Hy* and *Hz*). These systems remained at each site for 4 to 5 weeks from early July to mid-August. The sites were visited where possible, depending on helicopter availability and the high-frequency systems-installation cycle (*see* below). These visits ameliorated data loss due to the actions of local wildlife — a major issue at sites 003 and 013, where wolves tore up the electrode lines frequently.

Additionally, at each location high-frequency measurements, 1000 Hz to 0.005 Hz, probing from a few kilometres to the lower crust, were made using two new Phoenix MTU V5-2000 systems with lightweight magnetometer coils specifically for helicopter-supported surveys. Due to permafrost it proved impossible to install the five-foot-long magnetometer coil sensors vertically, and accordingly only four components were recorded (*Ex, Ey, Hx* and *Hy*). The systems were installed at neighbouring sites for a period of two days, then moved successively along the profile from south to north. Even with only two days acquisition, the responses acquired were of exceptionally high quality, with error estimates of a few per cent at 100 s and below 10% at 1000 s. Examples from sites 100, 001, 005, and 010 (note different ordinates for data from this site) are shown in Fig. 2. The vertical bars signify one sigma error estimates, and are smaller than the plotting symbol for most data points.

MT DATA PROBLEMS

One problem encountered in this survey was very high electrode-contact resistances, especially at sites with little surficial cover due to the recent retreat of the Barnes Glacier . Typically, in MT we strive to have resistance between the electrodes below 10 kΩ to ensure good ground contact. The worst site was 001, located in an extensive boulder field with virtually no cover, and contact resistance was measured as greater than 2 MΩ. Such high contact resistances result in the capacitive coupling to the ground becoming important, with the consequence that the ground acts as a low-pass filter to electric signals. This can be seen on the data at site 001 (Fig. 2) with the rapid decrease of apparent resistivities and phases with decreasing period (increasing frequency) below 0.1 s. Ironically, this coupling problem was the least at sites 003 and 013, sites located in river valleys with good sediment cover, but wolves were attracted to those sites and caused some data loss.

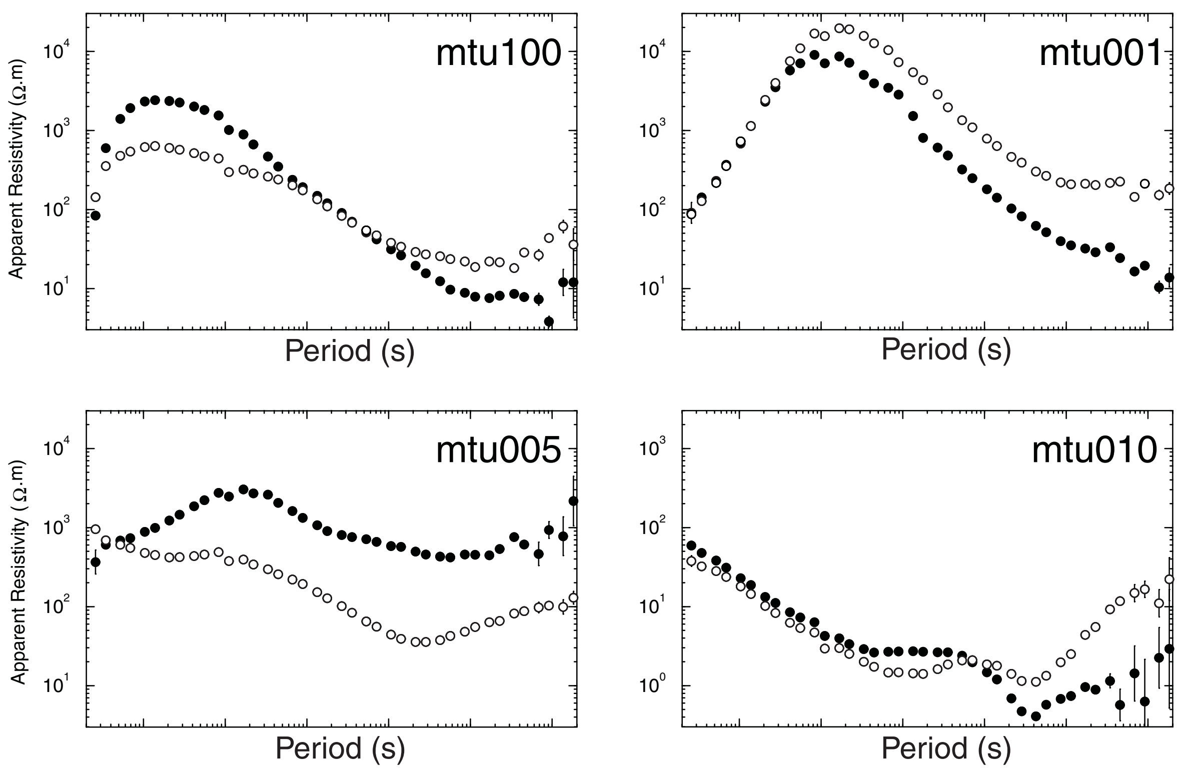

Figure 2. *Magnetotelluric apparent-resistivity responses derived from the data acquired at sites 100, 001, 005 and 010* (see *Fig. 1) using the MTU V5-2000 systems. Error bars designate one sigma errors. The filled circles are the responses for electric currents flowing perpendicular to the profile, and the open circles are the responses for currents flowing along the profile.*

This electrode-coupling problem resulted in some short-period data having to be discarded during preliminary interpretation. It is hoped that this effect can be corrected for in subsequent processing.

Electric-field distortions due to local heterogeneities were strong at some sites, and were most severe at the sites located in river valleys (003 and 013). Detailed distortion analyses will be undertaken to extract the regional responses.

PRELIMINARY MT MODEL

A preliminary model that describes much of the MT response observed along the profile is shown in Fig. 3. The hotter colours in the model (yellows to reds — upper end of spectrum) indicate regions of low resistivity, whereas the colder colours (blues — lower end of spectrum) indicate regions devoid of an interconnected conducting phase. This model fits well some parts of the total data set, but does not fit other parts. More processing, analyses, and inversions are required to obtain a better model. However, some model features appear to be robust, in that they are apparent in the data and also appear in all models obtained.

These robust features are as follows:

1. There is a marked change in crustal response between southern sites 001–004 and sites 005–006. The southern sites show rapidly dropping apparent resistivity curves with increasing period (*see* Fig. 2, site 001), indicative of decreasing resistivity with depth. In contrast, the curves from sites 005 (Fig. 2) and 006 are flatter, suggesting no middle- and lower-crustal low-resistivity layers.
2. There is another change between sites 005–006 and 007–010, again with the implication of a less resistive crust beneath the central sites. Site 100 is along-strike from site 008 (Fig. 1), and the data from site 100 (Fig. 2) are representative of 007–010.
3. Conducting material comes closer to the surface beneath sites 010 and 011. This is evident in the much lower levels of the apparent-resistivity curves (data from site 010 shown in Fig. 2; note different ordinates used for these data). These two sites are closest to the mapped outcrop of the iron-, graphite- and sulphide-rich Astarte River Formation.
4. Sites 012–015 show curves that drop as rapidly as those at the southern end of the line, but the curves are at higher levels indicative of more resistive upper crust.
5. There is the implication in the long-period data of a change in mantle resistivity from most resistive to the north (tens of thousands of Ω•m) to less resistive to the south (thousands of Ω•m). This is reminiscent of the resistivity model for the Rae–Hearne boundary (Jones et al., 2001).

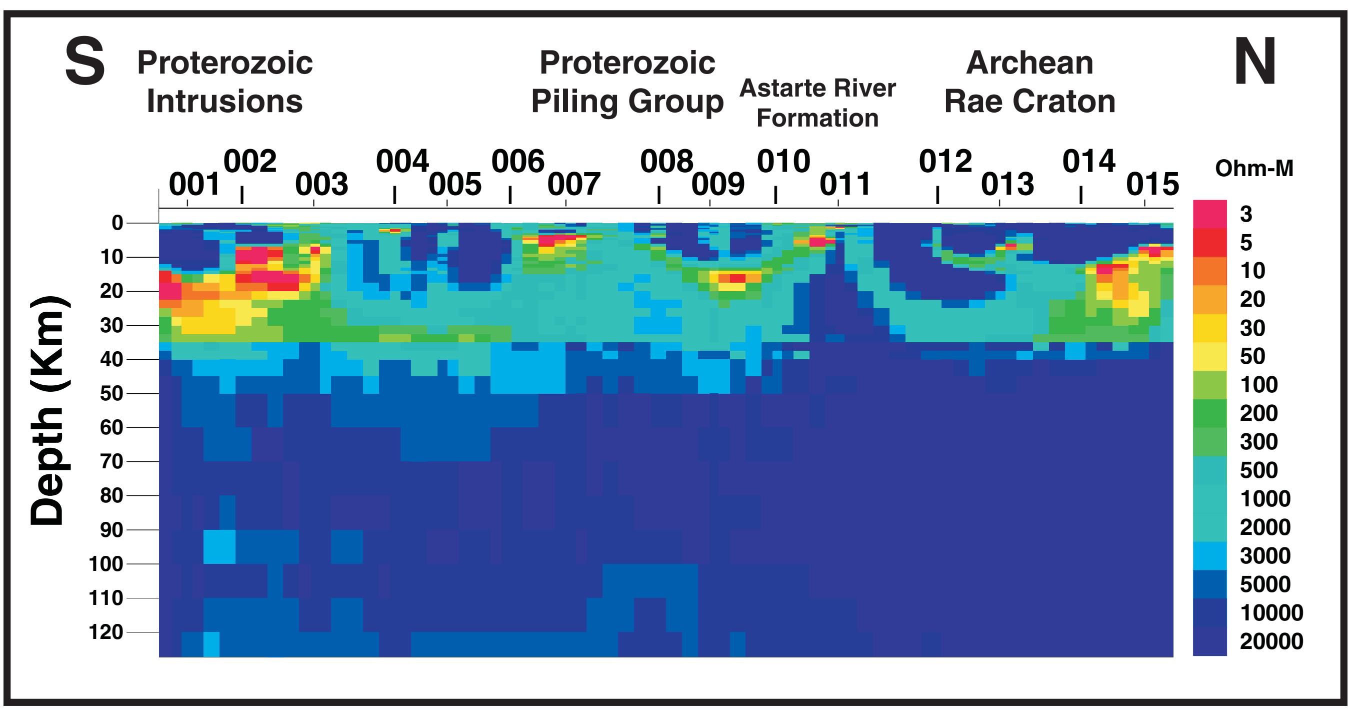

Figure 3. *Preliminary electrical-resistivity model of the MT response estimates derived. The hotter colours (top of the spectrum) designate regions of enhanced electrical conductivity (reduced resistivity), whereas the colder colours (bottom of the spectrum) designate regions where there is no interconnected conducting phase present.*

INTERPRETATION

The robust model features above infer that the conducting material beneath sites 010 and 011, which can be associated with the Astarte River Formation, is not continuous throughout the whole profile, implying that the sulphidic-graphitic rocks observed in the southern part of the mapping region may not be associated with the Astarte River Formation. This could suggest that Archean rocks to the south are not related to Rae Craton rocks to the north, or that tectonic imbrication has disconnected northern and southern segments. Either way, the results indicate that the Piling Group rocks do not sit within a synformal basin structure.

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