HuBLE-UK: Hudson Bay Lithospheric Experiment

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PROJECT OVERVIEW

We are conducting a broadband seismological experiment in Nunavut in order to understand better the origins of Hudson Bay. Our 10 remote and community based stations complement the broader "POLARIS" network of stations currently operating in the region. Our data will enable us to test hypotheses of root formation and the persistence of intra-cratonic basins via a range of broadband seismological analyses such as travel-time tomography, receiver function analyses and SKS shear wave splitting. Some of the major questions we hope to answer through HuBLE are:

- What is the structure and evolution of lithospheric roots and their dynamic interaction with mantle flow?
- How has this intra-cratonic basin formed?
- What is the lithospheric structure of the Trans-Hudson Orogen beneath Hudson Bay and the nature of the Nastapoka Arc?
- What is the nature of post glacial re-bound in Hudson Bay, and what is its effects on seismicity in this continental interior region?

Data will be available to us later this year after the first station service run. Satellite modems at our stations allow us to monitor the state of health of our stations. After a short period (~3-4 weeks) during the shortest winter days when we lost power at all stations, the network now appears to be operating well.

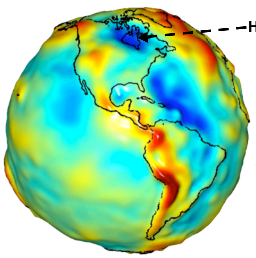
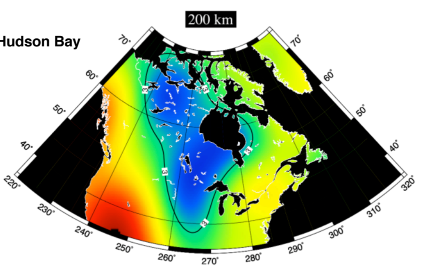


Figure 1: Gravity images from the GRACE project. Note the long wavelength anomaly that characterizes the Hudson Bay region. www.csr.utexas.edu/grace/gallery/gravity



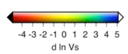


Figure 2: S-wave velocity perturbations at 200 km depth from global model SAW24B16 (Megnin & Romanowicz, 2000). The 3% contour outlines the approximate region of the tectospheric root beneath Laurentia.

INTRODUCTION AND SCIENTIFIC RATIONALE

Despite being one of the most striking features of the North America continent, the reason for the existence of Hudson Bay is obscure. It lies in the Precambrian core of North America, which is comprised of the Canadian Shield and contiguous platform regions (Laurentia: Hoffman, 1988). The region is underlain by the largest continental root on Earth and is the site of one of the largest negative geoid anomalies (Figure 1); it is also characterized by a broad high-velocity zone illuminated in global tomographic models (Figure 2). Only part of the gravity anomaly can be attributed to post-glacial isostatic rebound, however, and lithospheric instabilities (Houseman et al., 2000), plume-related lithospheric densification (Kaminski & Jaupart, 2000), the existence of an eclogite lower crust (Baird et al., 1995) and extension (Roksandic, 1987) are amongst the various mechanisms proposed to explain the field observations in Hudson Bay.

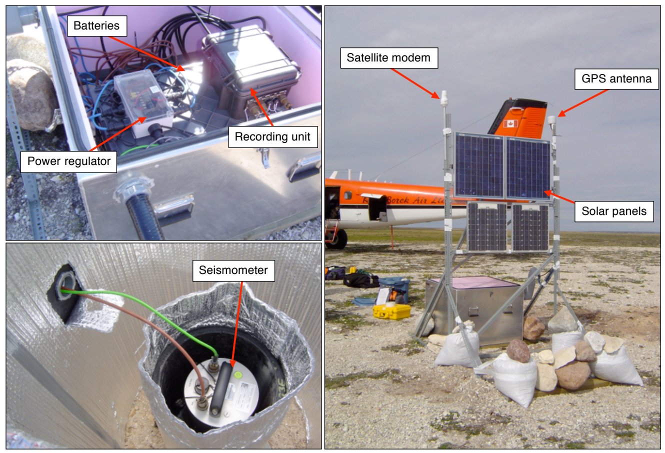
The Trans-Hudson Orogen, a vast paleo-Proterozoic orogenic belt, played an important role in the assembly of Laurentia. It is characterized by extreme salient-reentrant geometry possibly analogous to the western syntaxis of the Himalayan front, but its origins are unknown. Its geometry may reflect a primary shape of the Superior craton and its strong mantle root, but the current shape of the keel is not well resolved. In the same vicinity, the SE corner of Hudson Bay exhibits a nearly semi-circular coastline known as the Nastapoka Arc. Hypotheses for its formation range from meteorite impacts to Archean basement fabrics so we also seek observational constraints here via our experiment.

ACKNOWLEDGEMENTS

SEIS-UK have provided invaluable assistance with our field deployment and subsequent remote access of remote sites. The HuBLE-UK project was funded by NERC grant NE/D012317/1. Logistical support from the CNGO and GSC is also gratefully acknowledged.

SEISMIC STATION CONSTRUCTION

We deployed 10 broadband seismic stations during summer 2007. 4 sites are housed in secure compounds in Community locations: Pangnirtung, Cape Dorset, Kimmirut and Coral Harbour. 6 stations are in remote locations across the northern part of Hudson Bay: Southampton Island (3), Mansel Island, Coats Island, Mingo Lake and Nottingham Island. While the community stations are run by mains power, our remote sites are powered by solar panels; instrumentation are housed in secure steel containers (below).



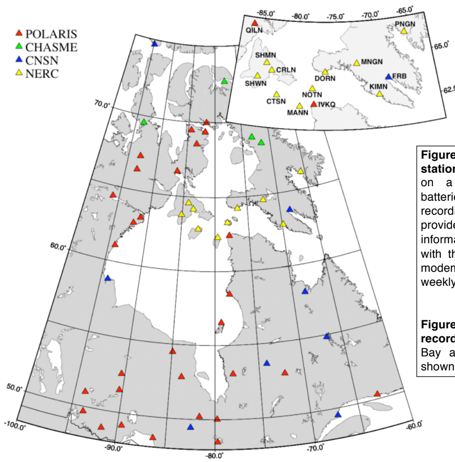


Figure 3 (above): HuBLE-UK remote station construction. 20-40W solar panels on a steel frame re-charge 3x100Ah batteries that power the seismometer and recording equipment. The GPS antenna provides continuous accurate timing information for our data. We communicate with the stations remotely via the satellite modems that are scheduled to operate twice weekly.

Figure 4 (left): Broadband seismic recording stations throughout the Hudson Bay area. HuBLE-UK stations are also shown in the inset figure.

REMOTE STATION MODEM CONNECTIONS

The satellite modem facility installed at our remote sites has proved invaluable so far. After all stations powered up after New Year power-downs due to short day-times, two stations experienced seismometer and recording equipment problems. These were rectified remotely from our UK base-station resulting in us obtaining ~10 months of extra data. Once-weekly monitoring of station power, GPS status and seismometer stability also allow us to prioritise our efforts at service runs.

RECEIVER FUNCTION ANALYSES

As we collect data from the field, we will perform multiple analyses on our seismic data. Receiver function analyses (Figure 6) will allow us to analyze velocity discontinuities beneath Hudson Bay. In addition to bulk crustal properties (layer thickness and P/S wavespeed ratio) we can investigate the existence of an eclogite root beneath the Bay that may be partly responsible for the formation of the basin.

P-to-S conversions generated deeper in the mantle at ~410 and ~660km depth will be deflected up or down in response to variations in temperature (Figure 7). Thus we will be able to understand better the mantle flow patterns beneath Hudson Bay.

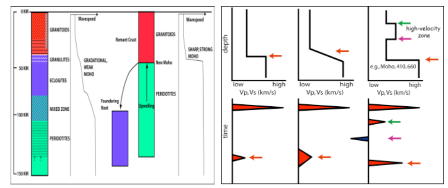


Figure 6: Moho structure from receiver function analyses. An eclogite root at the base of the Hudson Bay crust will result in a more gradational velocity profile than when normal mantle peridotite directly underlies a granitoid crust. Receiver function analyses are sensitive to these velocity structures - more impulsive P-to-S conversions are predicted in the no-eclogite case.

After Zandt and Gilbert (2007).

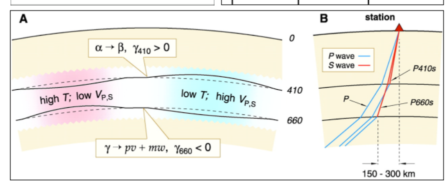
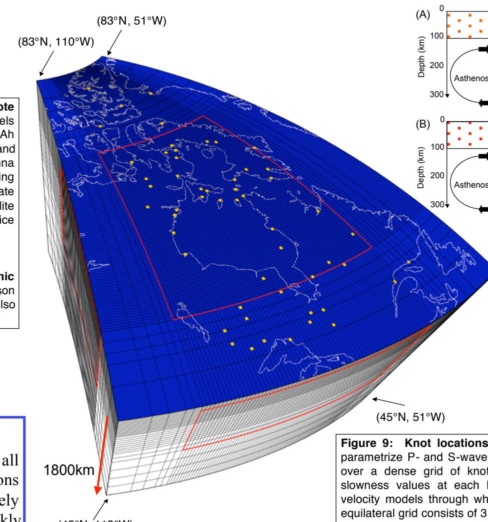


Figure 7: Investigating the mantle transition zone using receiver function analyses. (A) In the high temperature environment, the 410km discontinuity is depressed and the 660 uplifted, resulting in a thinner transition zone. The opposite effect can be seen in the low temperature region. (B) P-to-S conversions at the transition zone. Modified from Lebedev et al., (2002).

SEISMIC TOMOGRAPHY

With a network aperture of ~2000km we will be able to image mantle seismic structures to depths below the transition zone using seismic travel-time tomography. P- and S-wave images will offer lateral resolution of variations in the nature of the lithospheric root and the flow of mantle material around it. V_P/V_S ratios will provide a means of distinguishing between compositional and thermal effects.



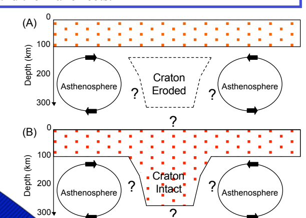


Figure 8 (above): Vertical cross-sections through end-member models for a craton. A: Lithosphere of the Archean craton has been eroded and replaced by low density asthenosphere. B: Craton is intact and has a lithospheric thickness of more than 200km. Modified after Ritsema et al., (1998).

Figure 9: Knot locations for taut spline parametrization. We parametrize P- and S-wave slowness using B-splines under tension over a dense grid of knots (Cline 1981). Interpolation between slowness values at each knot allows the generation of smooth velocity models through which ray tracing can be performed. The equilateral grid consists of 31 knots in depth between 0-1800km, 90 knots in latitude between 45-83°N and 82 knots in longitude between 51-110°W for a total of 22870 knots parametrizing velocity structure.