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Report of activities for Teleseismic study of Banks Island on the western Arctic margin of the Northwest Territories

GEM 2 Western Arctic Margin Project

D.B. Snyder

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Canada

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Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2014, GEM's new research program has been launched with 14 field activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Introduction

Goals & objective

The teleseismic study of Banks Island forms one part of Natural Resource Canada's GEM (Geo-Mapping for Energy and Minerals) program and its Stratigraphy of Banks, Brock, Borden, and Mackenzie King islands: Sverdrup Basin Petroleum Systems and Mineral Potential activity. The teleseismic activity objective is to provide information on crustal structures beneath Banks Island to improve understanding of the geological history of the region, especially that relevant to its petroleum potential. Mapping deeper structures within the mantle would be important information to planning diamond exploration in this region.

Scientific question addressed

Seismic observations can provide information about deep structure of the crust and mantle to depths of several hundred kilometres. These structures, and especially the crust-mantle boundary called the Moho by seismologists, provide clues to the geologic history of the area. In this case, rifting of the western Arctic margin during the opening of the Arctic Ocean, caused the region that is today Bank’s Island to subside and accumulate sediments rich in petroleum source material. The cooling and further subsidence of these sediments is important for understanding the thermal maturation of petroleum products. Did higher heat flow in this margin during Arctic Ocean rifting develop temperatures that placed petroleum source material within the so-called oil maturation window?

Recently published surface wavespeed models of North America (Schaeffer & Lebedev, 2014) indicate wavespeeds at 100-150 km depths that are similar or equal to those beneath Canada’s diamond mines in the central Slave craton north of Yellowknife. These relatively high wavespeeds continue as far north as Prince Patrick Island and as far west as the Mackenzie River and perhaps the Brooks Range of Alaska. On one hand, this suggests that Banks Island is part of the Canadian Shield and any kimberlites found on Banks Island would be promising candidates to contain some diamonds. On the other hand, the higher velocities are inconsistent with this being a tectonically disrupted and thinned lithosphere along the margin of the Canada Basin of the Arctic margin (Helwig et al., 2011; Chin & Snyder, 2014).

Location

One seismic station located about 25 km east of Ulukhatok on Victoria Island (latitude 70.7533° N, longitude 117. 1851° W) was removed on 12 August, transported to Johnson Point on Banks Island (latitude 72.7643° N, longitude 118.50617° W) and reconstructed on 13 August, 2014.

Methodology

Teleseismic observatories are sited in remote locations in either linear or rectangular arrays where they record distant earthquakes for several years. Each station consists of a sensor buried <1 m in gravel, a data recorder or satellite dish, solar panels and battery/electronics boxes. Seismic waves travel from distant earthquakes occurring around the globe to be recorded by the sensor and eventually taken to Ottawa where they can be processed, analyzed, archived and made publically accessible via the internet.

We cannot control or predict when suitable source earthquakes will provide useful seismic waves at a particular location. It has been shown that each station in northern Canada must typically record for 3-8 years depending on several factors. One is the spacing between stations in the array; the greater the spacing the more the number of earthquakes that must be recorded at a single station to have robust results. The greater the signal-to-noise noise ratio at a given site, the less recording time is required. Station function can also be disrupted by lack of sunlight in winter or by wildlife vandalism.

The new station on Banks Island re-establishes a similar one that operated there from August, 2011 to August, 2013 while an exploration camp run by Rio Tinto was active at Johnson Point. The station removed from Victoria Island effectively forms a very broadly spaced area with the one on Banks Island. It recorded earthquakes from July, 2009 until June, 2012. The Earthscope program in the USA currently operates equivalent stations in the communities of Sachs Harbour and Paulatuk, installed in summer, 2013.

Each of these stations contributes data to several different lines of research. The stations help to locate regional (within 1000 km) earthquakes more accurately and to smaller magnitudes and thus aid hazard studies. Taken together or in pairs, these stations provide critical data for continental-scale seismic wave-speed modelling or anisotropy studies (e.g., Schaeffer & Lebedev, 2014; Snyder & Bruneton, 2007). For the crustal-scale objectives of this activity, one-dimensional soundings for seismic discontinuities beneath single stations, sometimes called receiver functions, are the prime methodology used (e.g., Snyder & Kjarsgaard, 2013).

Results (achieved or forecasted)

The former station at Johnson Point recorded 18 earthquakes suitable for receiver function analysis between 2011 and 2013. A single depth sounding using all 18 earthquakes, regardless of source direction, is shown in Figure 2. Major structures (seismic discontinuities) appear as large excursions from the zero axis. These discontinuities can be compared with seismic reflectors observed on seismic marine profiles acquired off the west coast of Banks Island in 2009 (Helwig et al., 2011). A strong positive-negative pair of discontinuities occurs at 5 km depth and correlates well with the interpreted contact between Proterozoic strata and crystalline basement on the seismic reflection section. A second, lesser discontinuity pair occurs on both radial and transverse components at 24 km depth and again correlates with reflectors observed on the seismic reflection section west of Banks Island. No deeper discontinuities are observed, so the structure at 24 km is here interpreted as the Moho, at odds with the interpretation of Helwig et al. (2011).

The Moho is by definition the first-order seismic discontinuity observed everywhere on Earth. Its ambiguity of interpretation on the current data from the east and west sides of Banks Island is bothersome. More data from Johnson Point and new data from Sachs Harbour will help. It must be noted that the 112 earthquakes recorded by the station on Victoria Island can also not detect a Moho deeper than about 24 km. Moho discontinuities at 15-25 km are typical of highly thinned or oceanic crust, but not of continental shield regions. The thinning history of Banks and western Victoria Island remains cryptic.

Conclusions & future work required

The current understanding of crustal structure and hence the rifting history of the western Arctic margin remains inconsistent and hence confused. New data acquired at a few isolated stations over the next few years will help, but more extensive seismic data acquisition will be required to fully characterize the rifting, subsistence and thermal history of this margin.

Acknowledgments

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Figures

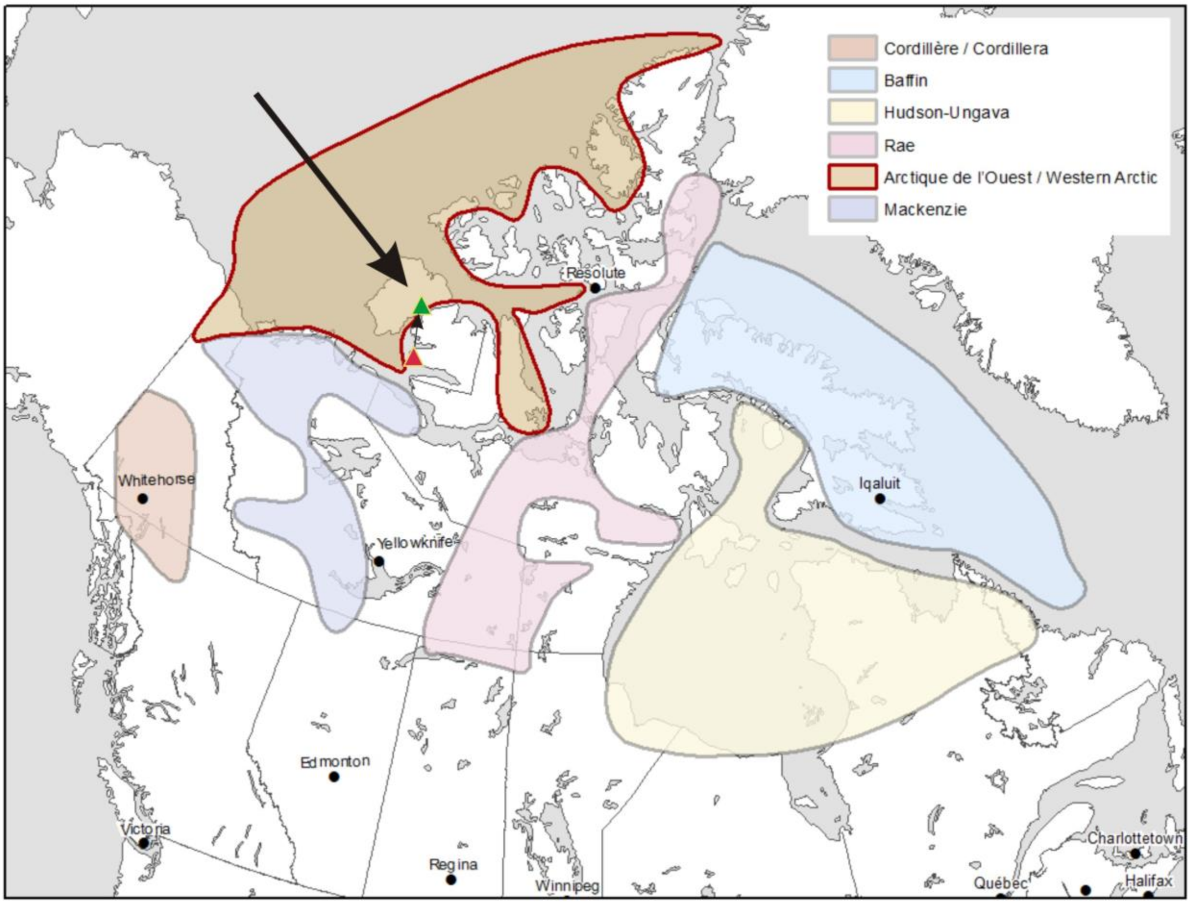

Figure 1: Regional map locating seismic station locations on Banks (green triangle) and Victoria islands (red triangle) and focus areas of the GEM program.

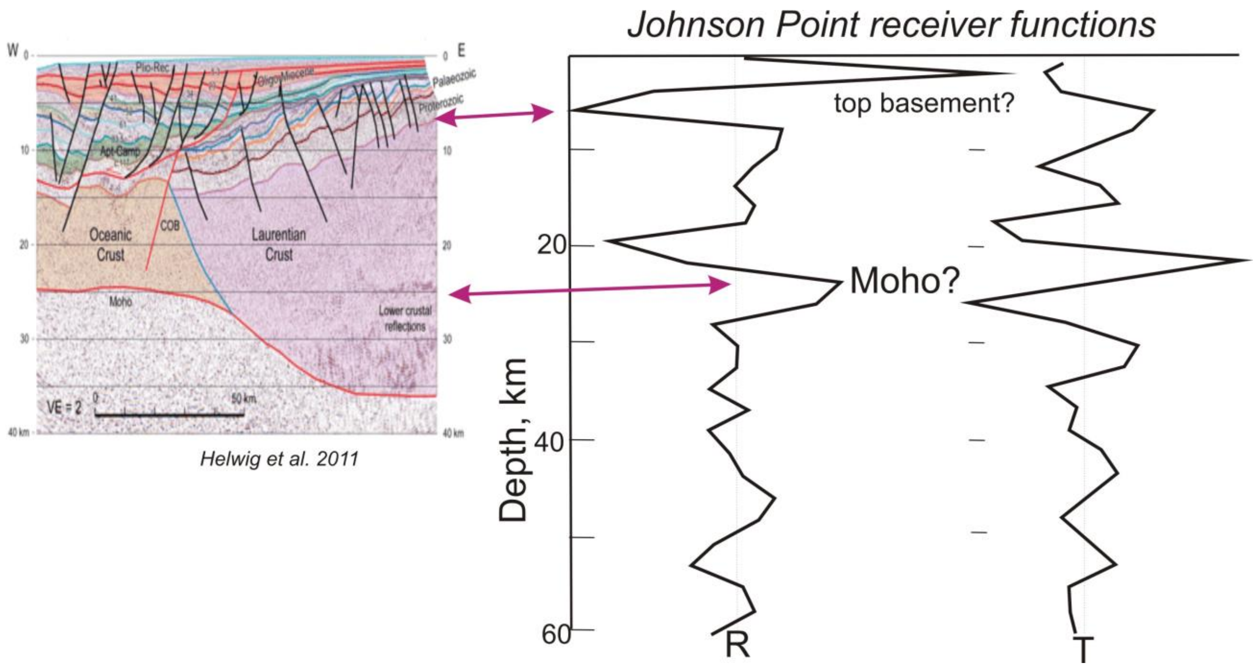

Figure 2: Receiver function for the teleseismic station at Johnson Point, Banks Island. R and T are the radial and transverse components, respectively. Seismic reflection section at left is taken from Helwig et al., (2011).

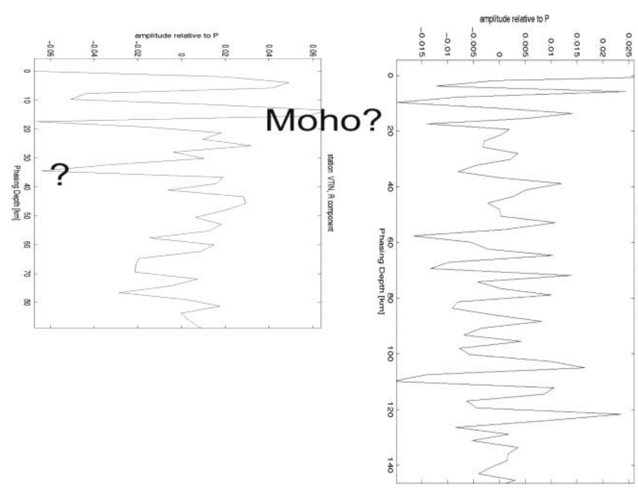

Figure 3: Receiver function for the teleseismic station near Ulukhatok, Victoria Island. R and T are the radial and transverse components, respectively.