Preliminary Results from a Microseismic Noise Test Utilizing Passive Seismic Transmission Tomography, Nechako Basin (NTS 092O/11, 14), South-Central British Columbia[1]

by M.E. Best[2] and J. Lakings[3]

KEYWORDS: microseismic, Nechako Basin, earthquakes, petroleum, seismic noise test

SUMMARY

Results of a reconnaissance microearthquake survey in the southern portion of the Nechako Basin are presented here. The data were acquired over a time period of approximately 24 hours in June 2006 and analyzed at the office of MicroSeismic, Inc. The analysis provided measurements of the background noise level and its diurnal variation. The very low background noise levels between 50 and 100 nm/s show that a surface seismic array is capable of detecting microearthquakes of local magnitude (M_l) approximately 0.0 and possibly down to approximately –0.5 as much as 30 km away. Earthquakes of this size are similar to small blasts at construction sites or mining quarries, and require a network of closely spaced, highly sensitive seismograph stations to detect and locate them. The high station density and the frequent occurrence of microearthquakes make these data ideally suited for mapping crustal structure in seismogenic belts. The initial results from the reconnaissance survey also located a magnitude 0.0 earthquake using a computer-aided search routine for microearthquake activity. This event was observed on all five of the geophone stations in the array and was approximately 30 km away from the centre of the array. Three-component geophones now occupy these same five sites and will remain there for approximately 8 weeks, in order to determine the amount of microseismic activity within this region.

INTRODUCTION

The Nechako Basin is one of several interior sedimentary basins in British Columbia. This basin is partially covered with basalt flows, which make it difficult to map the subsurface geology using traditional seismic methods. A few wells were drilled within the basin prior to 1980. The most significant exploration program, however, was carried out in the early 1980s by Canadian Hunter Exploration Ltd. They conducted 2-D seismic (Fig 1) and gravity surveys, and drilled several wells. The quality of the seismic data was relatively poor due to surface and near-surface basalt flows. Nevertheless, several wells were drilled based on the seismic data. Sedimentary rocks were encountered in the wells, often with crystalline rocks. Economic accumulations of hydrocarbons were not encountered at that time; consequently, Canadian Hunter abandoned the play. No exploration activity has been carried out in the basin since that time.

In 2004, the BC Ministry of Energy, Mines and Petroleum Resources began a geological mapping program within the Nechako Basin (Hayes *et al.*, 2005), the objective of which is to provide new data that will encourage industry to re-examine the basin. They reprocessed several of Canadian Hunter's 2-D seismic lines using modern processing methods and investigated source-rock maturation levels in partnership with the Geological Survey of Canada (GSC). A detailed ground gravity and magnetic survey was carried out by Bemex Consulting International for the ministry along a 32 km line that crossed a large gravity low observed on the Canadian Hunter regional Bouguer gravity data (Best, 2004). During the 2005 and 2006 field seasons, the ministry conducted geological mapping and collected samples for density and magnetic susceptibility measurements (Ferri and Riddell, 2006).

Acquiring good-quality data from conventional 2-D seismic surveys in areas covered with basalt flows (e.g., the Columbia Plateau and parts of the Libyan desert) has always presented a challenge for the petroleum industry. The Nechako Basin is no exception, and this is one possible reason why there has been little exploration activity within the basin. Modern acquisition and processing methods may overcome some of the difficulties associated with acquiring traditional seismic data in basalt-covered regions of the world.

Alternative methods of acquiring 2-D and 3-D seismic information need to be investigated as well. This project proposes to use passive seismic transmission tomography (PSTT) as an alternative method for obtaining structural and lithological information within the Nechako Basin (e.g., Kapotis *et al.*, 2003; Mahony, 2003). The PSTT method utilizes the naturally occurring acoustic energy generated by microearthquakes in the upper few kilometres of the Earth as a seismic source. It employs conventional seismological methods to determine the hypocentres of these small-magnitude events, and then applies seismic tomographic techniques (Zhao *et al.*, 1992; Eberhart-Phillips, 1993; Thurber, 1993) to the data to produce 3-D, multicomponent velocity volumes through the area of interest. The PSTT energy source is located below the basalt and has to traverse the high-reflectivity zones only once,

[1] *Geoscience BC contribution GBC028*

[2] *Bemex Consulting International, 3701 Wild Berry Bend, Victoria, BC*

[3] *MicroSeismic, Inc., 175–800 Tully Road, Houston, TX*

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Energy, Mines and Petroleum Resources website at http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/cat_fldwk.htm

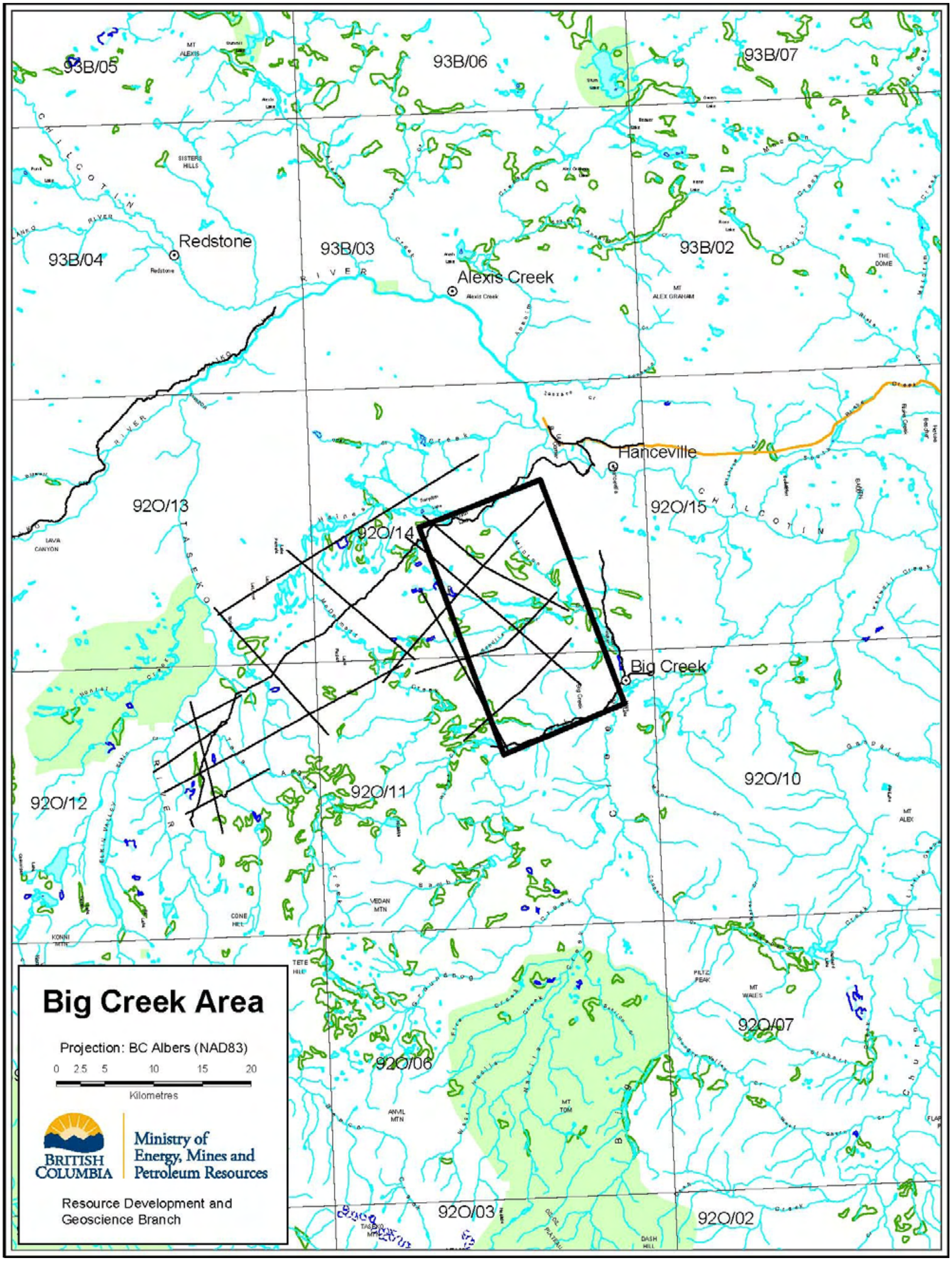

Figure 1: Approximate location of proposed passive seismic transmission tomography survey area (indicated by black rectangle); lighter black lines show locations of several 2-D seismic lines run by Canadian Hunter Exploration Ltd. in the early 1980s; map courtesy of BC Ministry of Energy, Mines and Petroleum Resources.

thus providing a less attenuated and more coherent signal than conventional sources placed directly on or above the basalt. The method provides a regional 3-D image of the Earth for the region of interest at a fraction of the cost of conventional 3-D surveys.

The focus of the fieldwork presently being carried out is to measure background noise levels and to estimate the amount of seismic activity in the rectangular area shown in Figure 1. This region was selected for the study because it contains several 2-D seismic lines shot by Canadian Hunter and a well that intersected sedimentary rocks. The recent detailed gravity and magnetic survey line described above (Best, 2004) and a regional gravity low are also located in this area (Fig 2). The large gravity low is intriguing, as it may be related to a sedimentary sub-basin within the Nechako Basin. The 2-D seismic quality, however, is too poor to determine if this is a sub-basin and, without more control, the gravity data alone cannot determine if the low is caused by sedimentary rocks or different volcanic rock units.

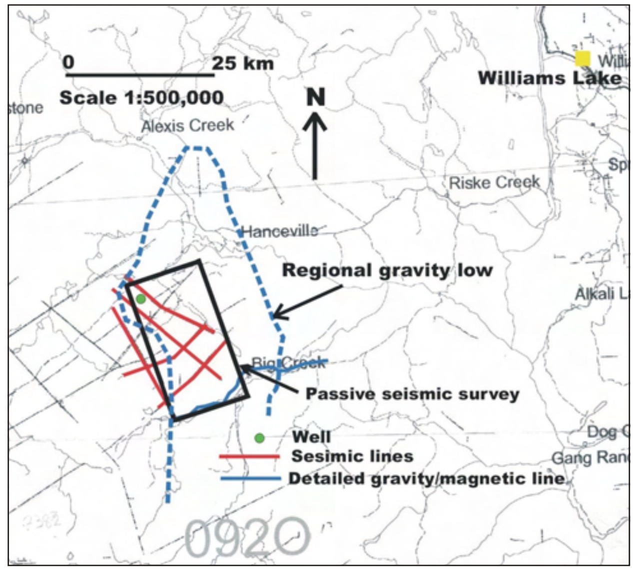

Figure 2: Locations of gravity low, exploration well drilled by Canadian Hunter Exploration Ltd. and recent gravity and magnetic survey carried out by Bemex Consulting International (Best, 2004).

ACQUISITION

The surface noise in the Nechako Basin was sampled at five separate locations, four of which form the corners of the rectangular area in Figure 1, with the remaining station near the centre. The station locations were surveyed using hand-held Global Positioning System receivers. At each station, a Refraction Technology Inc. (REF TEK) RT-130 seismograph was used to record ground motion on three vertical 4.5 Hz geophones laid out over a 7.6 m interval. The stations were set up during the day and left to record for a period of approximately 24 hours (June 24–25, 2006). The data were sampled at a rate of 2000 µs (2 ms) with a +32 dB gain. The units recorded the data using flash memory, which was later downloaded to a laptop computer. The data were converted to standard SEG-Y format for further processing and analysis.

ANALYSIS

The raw data were scanned using a trigger detection algorithm to find events that occurred on at least three stations. During the overnight recording period, one small microearthquake was detected on all five stations. The seismograms were converted to ground motion by deconvolving the instrument response. The amplitude spectra of the deconvolved traces were used to measure the frequency content of the signal and noise (Fig 3). The microearthquake had an M_l value of approximately 0.0 and the signal-to-noise ratio was 3:1 during the evening.

RESULTS

The Nechako Basin is seismically active and characterized by very low levels of background noise. The noise level hovers around ±100 nm/s during the day, with occasional spikes to 1 µm/s. During the evening, the noise drops off and is approximately half that during the daytime. These very low levels of background surface noise suggest that it will be possible to detect and time many of the numerous small microearthquakes in the area that are necessary for a successful PSTT project. This result is further supported by the small events (down to local magnitude of zero) reported for this area in the Geological Survey of Canada (GSC) earthquake catalogue. During the overnight recording period, an event with an M_l value of 0.0, approximately 30 km away, was recorded across the array, although it was too small to be reported by the GSC.

FUTURE WORK

The reconnaissance survey (phase I) of the project is now in progress. Five three-component seismometers, one being considered a spare, have been deployed for a period of approximately eight weeks at the sites that were tested for the noise analysis. The data will be used to constrain the strength, frequency and location of the background seismicity. With the generally very quiet recording conditions at the site, it was not necessary to deeply bury the geophones. The three-component seismometers were oriented and grouted in hand-augured holes that had been augured to a depth of approximately 1 m to ensure adequate coupling. This recording configuration will help to further refine the microearthquake detection threshold for this survey area and its economic implications.

The results of the phase I survey will determine if there is sufficient microseismic activity in the area to warrant a full-scale 3-D survey of the rectangular area shown in Figures 1 and 2.

ACKNOWLEDGMENTS

The authors would like to thank Geoscience BC and the BC Ministry of Energy, Mines and Petroleum Resources for joint funding of this project.

REFERENCES

Best, M.E. (2004): Qualitative interpretation of potential field profiles: southern Nechako Basin; *in* Summary of Activities 2004, *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/subwebs/oil

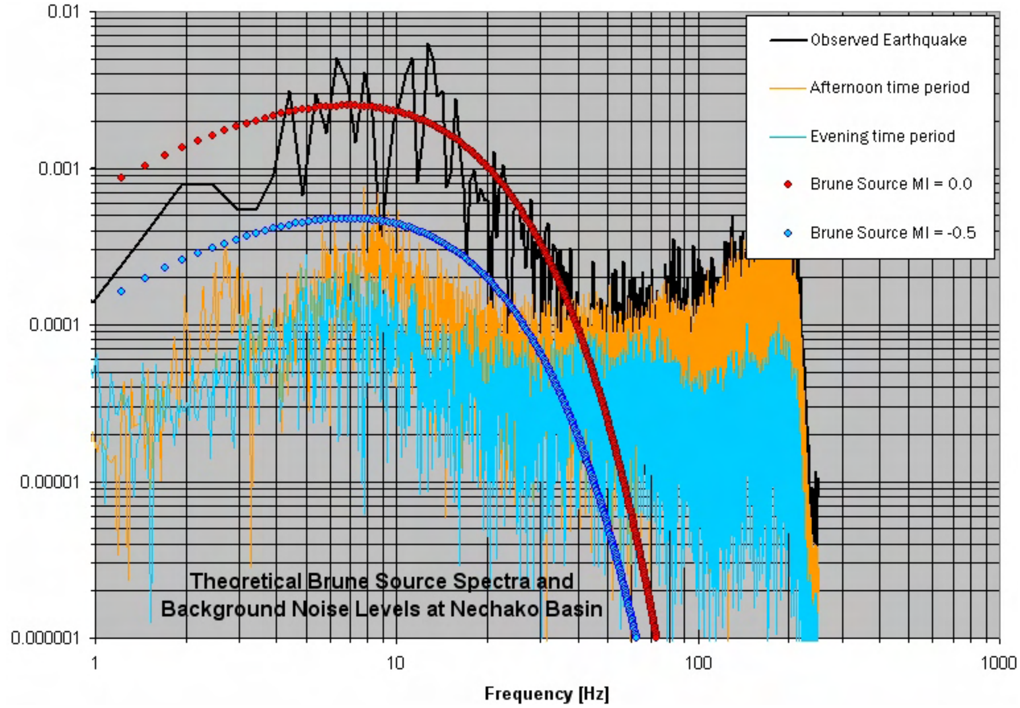

Figure 3: Amplitude spectra showing daytime and night-time noise levels and the amplitude spectrum of the observed earthquake; theoretical Brune source spectra for events with M_l values of 0.0 and 1.0 are also shown when the distance to the events is 30 km.

andgas/pub/reports/summary2004.htm> [November 2006], pages 73–77.

Eberhart-Phillips, D. (1993): Local earthquake tomography: earthquake source regions; *in* Seismic Tomography Theory and Practice, Iyer, H.M. and Hirahara, K., Editors, *Chapman & Hall*, London, United Kingdom, pages 613–643.

Ferri, F., and Riddell, J. (2006): The Nechako Basin project: new insights from the southern Nechako basin; *in* Summary of Activities 2006, *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/subwebs/oilandgas/pub/reports/summary2006.htm> [November 2006], pages 89–124.

Hayes, M., Ferri, F., and Moril, S. (2005): Interior basins strategy; *in* Summary of Activities 2004, *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/subwebs/oilandgas/pub/reports/summary2005.htm> [November 2006], pages 69–71.

Kapotis, S., Tselentis, G-Akis and Martakis, N. (2003): Case study in NW Greece of passive seismic tomography: a new tool for hydrocarbon exploration; *First Break*, volume 21, December, pages 37–42.

Mahony, J. (2003): No footprint seismic; *New Technology Magazine*, December, pages 10–12.

Thurber, C.H. (1993): Local earthquake tomography: velocities and Vp/Vs theory; *in* Seismic Tomography Theory and Practice, Iyer, H.M. and Hirahara, K., Editors, *Chapman & Hall*, London, United Kingdom, pages 563–583.

Zhao, D., Hasegawa, A. and Horiuchi, S. (1992): Tomographic inversion of P and S wave velocity structure in NE Japan; *Journal of Geophysical Research*, volume 97, pages 19909–19928.