Seismic Imaging of Quaternary Channels, Rainbow Lake, Northern Alberta, Canada

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Introduction

The University of Alberta in conjunction with the Geological Survey of Canada (GSC) and the Alberta Geological Survey (AGS) instituted a project to acquire high resolution seismic data close to existing shallow Quaternary gas wells near Rainbow Lake, Northern Alberta (Fig. 1). The objective of this seismic survey are: 1) to image the surface of the Sub-Cretaceous unconformity upon which a maximum of about 300 meters of Tertiary and Quaternary sediments are deposited; 2) to image shallow Quaternary or Tertiary channels resting on and above the unconformity. Preliminary interpretation reveals the Pre-Cretaceous unconformity, shows the presence of two stacked Quaternary channel margins. Quaternary fluvial channels are also been studied by the U of A geophysics field school students near Milk River, Southern Alberta.

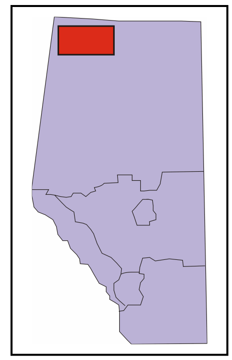

Fig. 1: Location of area

Seismic Acquisition

A ten kilometer east-west survey was acquired during March 2004 using the University of Alberta IVI minivibrator as the energy source that consists of a high-frequency vibrator of 6000 pounds peak force mounted on a weighted 3-ton truck. The source operated with linear sweeps of 7 seconds duration from 20 Hz to 250 Hz at 6000 pounds 'hold on' weight, 24 meter shot spacing and 5-7 sweeps per shot point. The force level of the vibrator plate remained uniform over the entire sweep, indicating good coupling with the ground. Seismic traces were acquired using the University of Alberta 240-channel semidistributed system that consists of ten 24-channel Geometrix Geode field boxes linked via a field intranet to the control and recording computer. Standard 40 Hz geophones were placed at 4 meter intervals with one geophone per station. The dominant frequency of the data was >100 Hz. Seismic data has enough temporal and spatial resolution in order to image small and thin geological features.

Seismic Processing and Interpretation

Seismic data was processed using PC based processing system (VISTA). After field geometry application data was edited and bad traces were killed, ground roll was surgically muted. Seismic data was processed using a standard processing flow. First breaks were picked for refraction and tomo statics. Velocity analysis was carried out every 100 m. Seismic data was processed with refraction statics (plus minus method) and tomo statics. Tomo statics were calculated using GLI3D (Hampson-Russel), standard industry software for tomo statics. Because of short station spacing (4 m) tomostatics solution was not appropriate to use. Final processed section was made with refraction statics.

In addition to the shallow refraction analysis (Tomography for tomo statics) far offset refractions were modeled and interpreted using the intercept-time method. Analysis of refraction patterns show two layers of different velocity in the eastern part of the section, and three layers in the west end. The sharp velocity contrast in the east (Fig. 2) between the unconformity and the overlying sediment creates problems in ray tracing (forward modeling) for refraction tomography, which usually requires a smooth velocity gradient. However, at the western end there is gradual increase of velocity (Fig. 3) and seismic data shows three layers of refractions. Instantaneous amplitude (Fig. 4) aids identification of the unconformity and high amplitude dipping events in the Quaternary.

Discussion and Conclusions

The refraction interpretation and velocity analysis (Figs. 5, 6) clearly reveal the presence of Cretaceous sediment (~2600 m/s) in the western part of line above the unconformity (~5000 m/s) and Quaternary or Tertiary sediment (~1800 m/s) in the eastern part of the line. The velocity of each of these sediment packages is quite distinct. In the eastern part of line, the Quaternary section directly lies on the Mississippian unconformity. However, geological data indicates that the deepest part of the Quaternary channel overlies the Devonian Wabamun Formation. Furthermore, the thick, low velocity Quaternary stratum in the east effectively 'pulls down' the unconformity on a time section (Fig. 7), and combined with refraction analysis may be a good method to determine the presence of Quaternary channels on time sections. Above the unconformity on the west end of the section, flat lying reflectors of the lower Mannville Group above the unconformity appear to terminate at steeply dipping, possible Quaternary/Tertiary channel margins.

Acknowledgments

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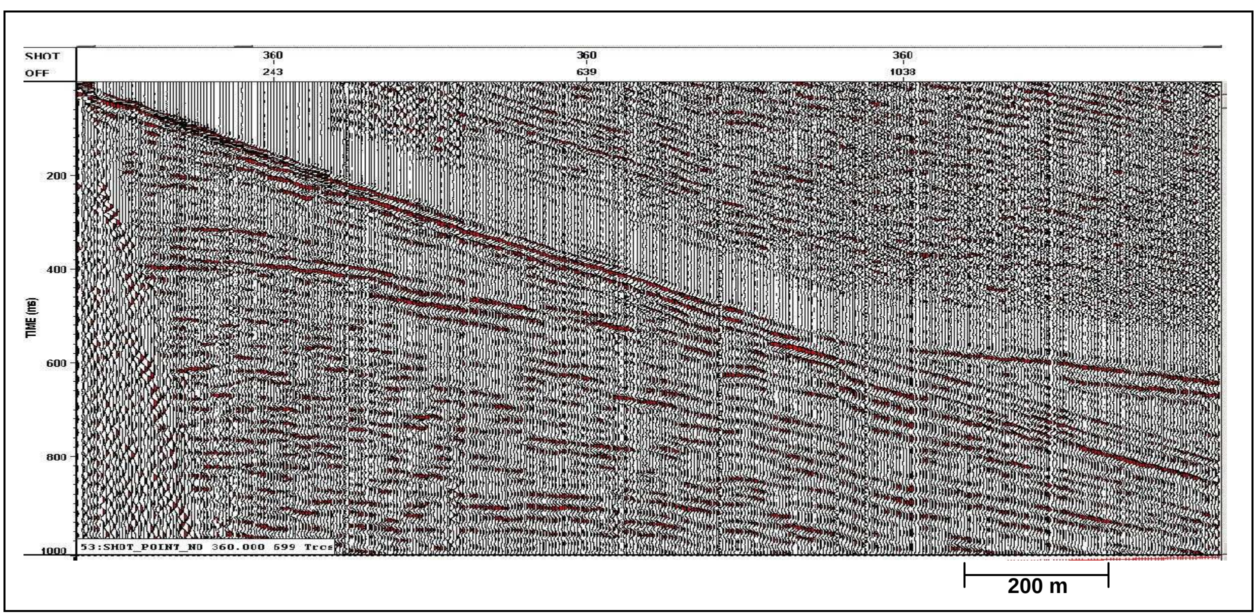
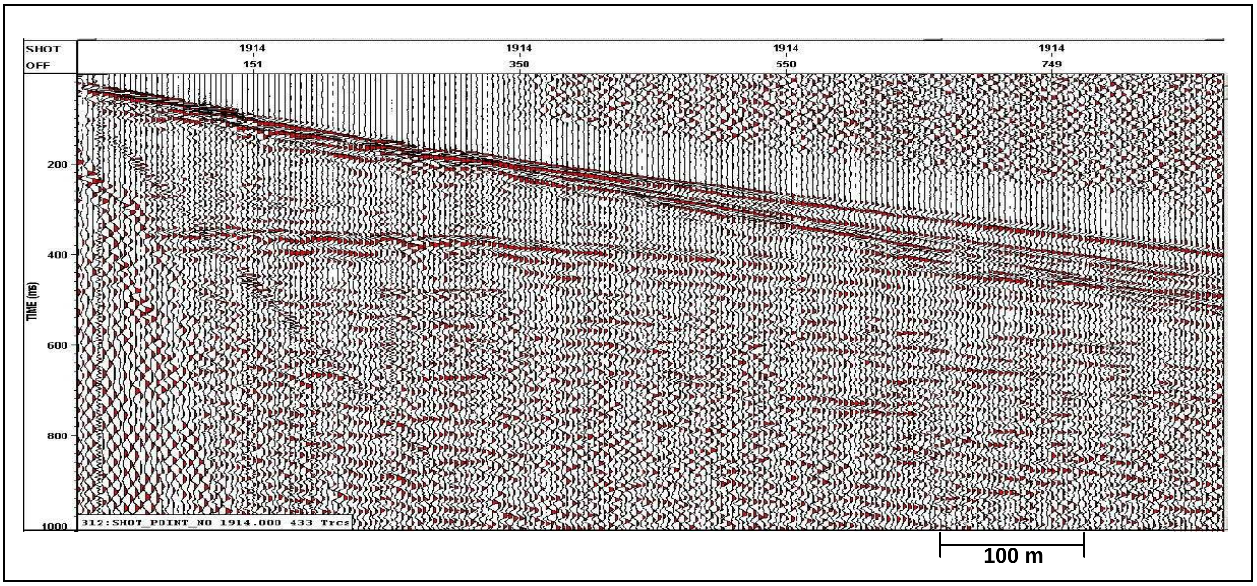
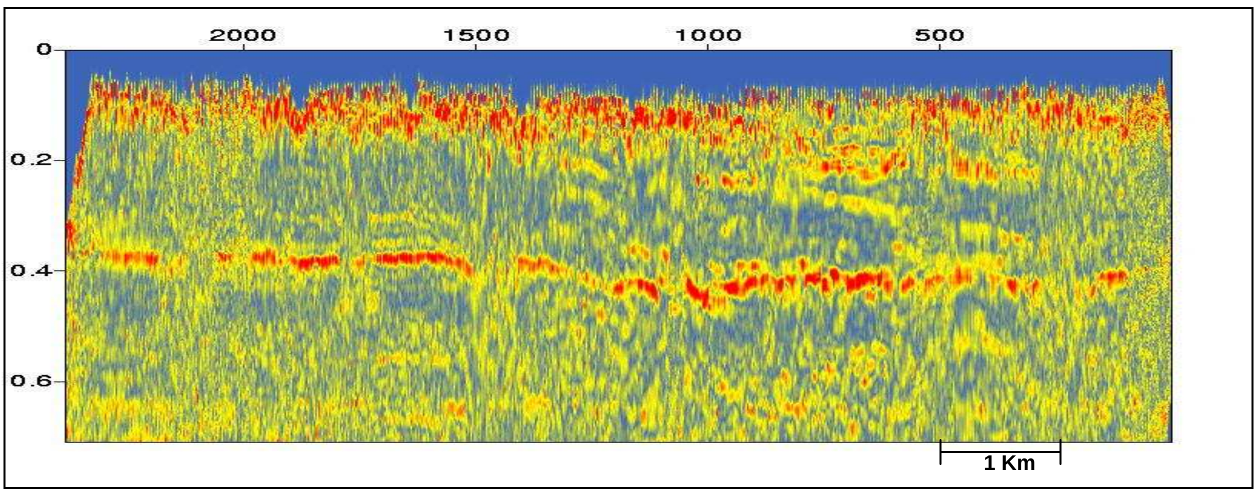


Fig. 2: Shot gather on eastern side (shot point 360), showing two layers on refractions; Quaternary Strata is overlying Mississippian Lime Stone.





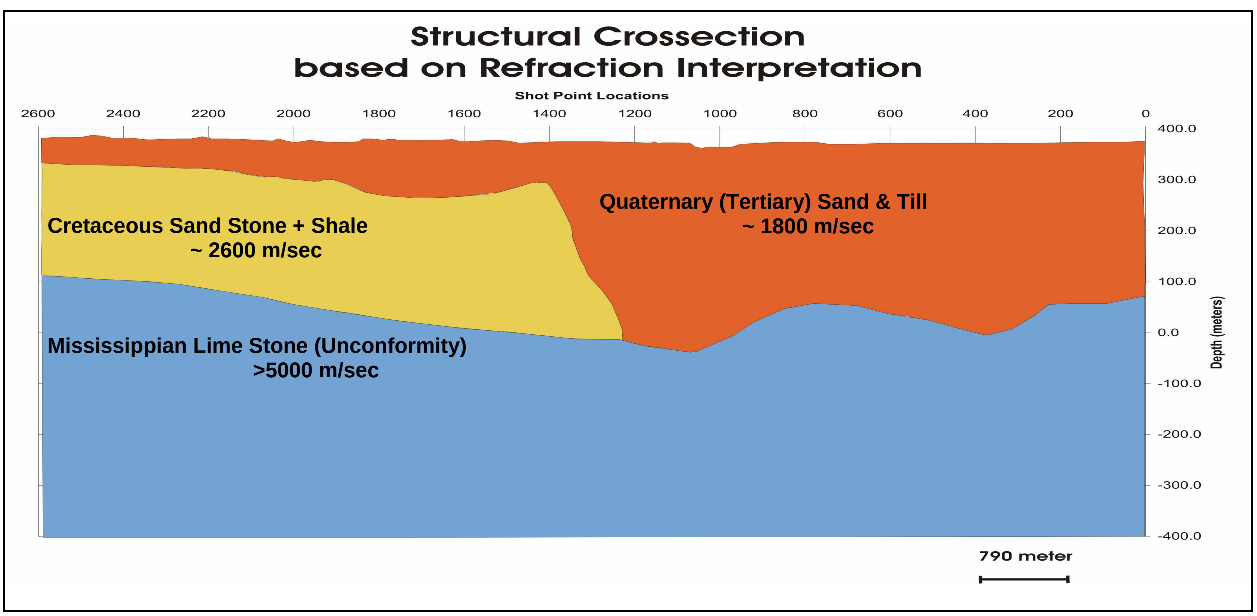
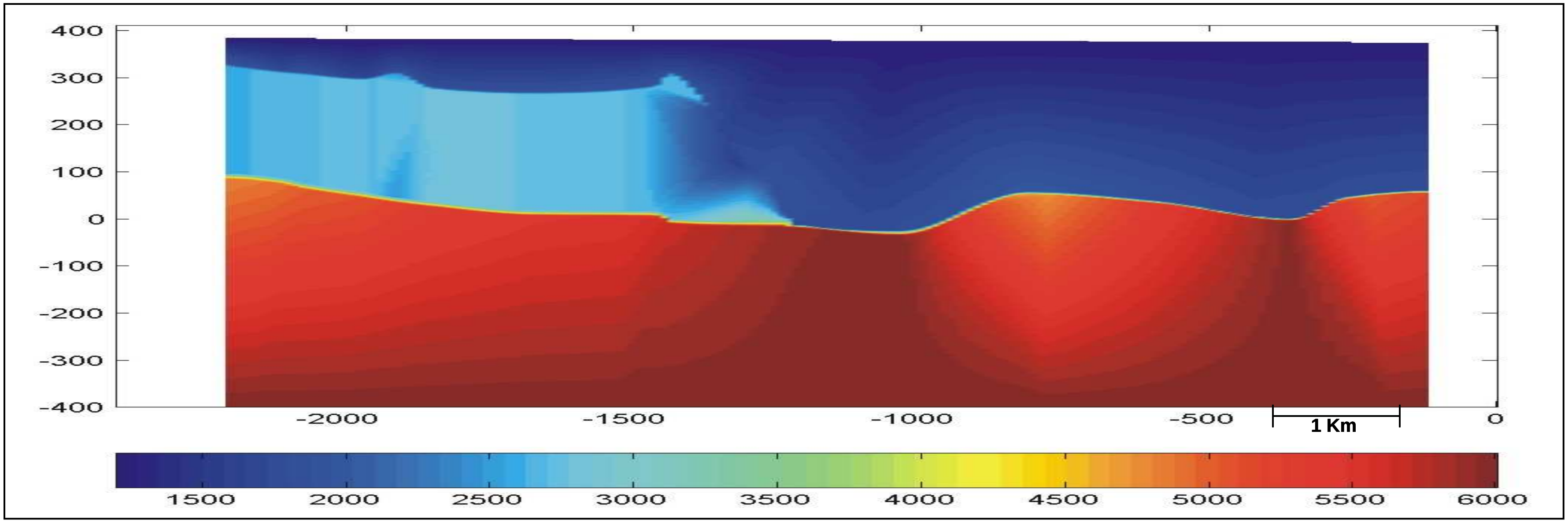


Fig. 3 (top): Shot gather in western side (shot point 1914) showing two refraction layers, Quaternary and Cretaceous. Fig. 4 (middle): Instantaneous amplitude section. Fig. 5 (bottom): Geological Model based on refraction interpretation



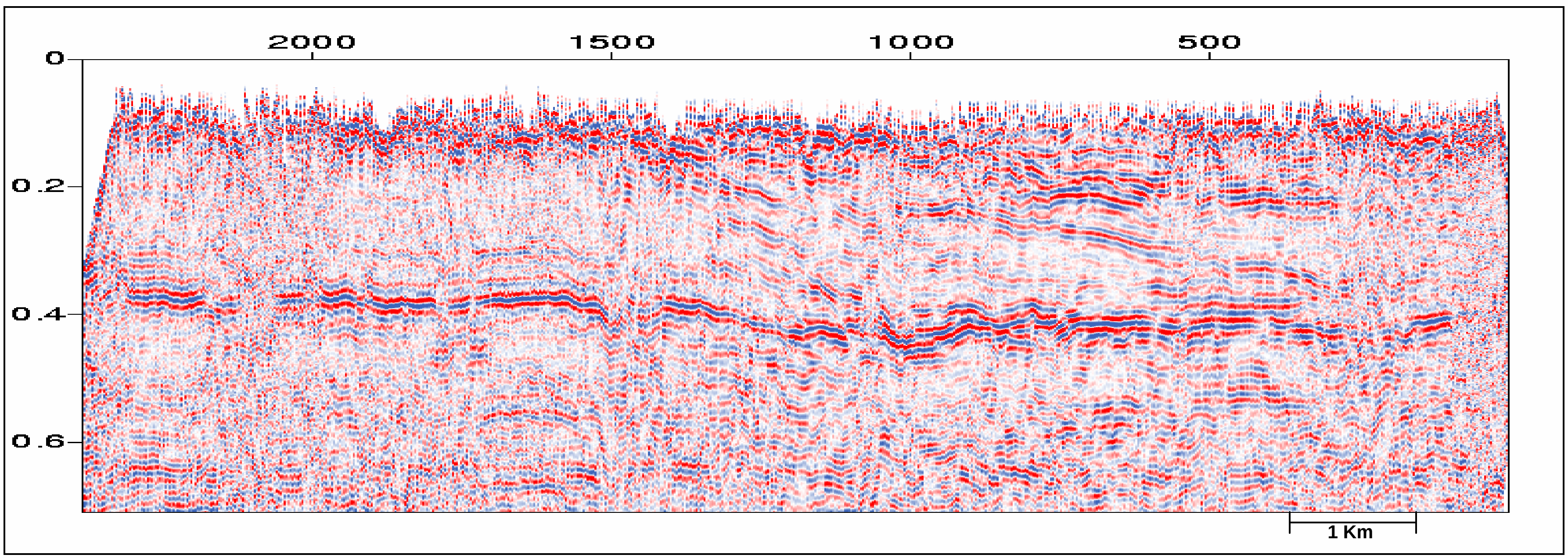


Fig. 6 (top): velocity model after refraction interpretation. Fig. 7 (bottom): Seismic section final stack (unmigrated)