Ross Lake 3C-3D Seismic Survey and VSP, Saskatchewan: A preliminary interpretation

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INTRODUCTION

The Ross Lake oil field, operated by Husky Energy Inc, is located in southwestern Saskatchewan, Township 13 Range 17 West of 3rd Meridian. The producing reservoir is interpreted to be a Cretaceous age channel sand in the Dimmock Creek member of the Cantuar formation of the Mannville Group.

There are 4 vertical wells in our area of interest, 10-25, 11-25, 14-25 and 15-25. There is also one horizontal well drilled in the channel sandbody. The sand is over 30 m thick in the 11-25 well and there is about 12-13 m of oil pay. There is no gas cap.

Currently, only well 15-25 and the horizontal well are producing, the others being shut-in. The produced oil is heavy, about 13° API.

The pool is on primary production and there is no waterflood. The reservoir strategy is not complete yet. Husky is observing the horizontal well to see if the pool will be economic. If so, there could be additional horizontal wells.

A 3C-3D seismic survey was conducted in May, 2002 by Veritas Geophysical. In addition, the CREWES Project acquired a multi-offset VSP survey in June, 2003. Our goal is to combine the VSP, well-logs, and 3C-3D surface seismic survey to achieve a full reservoir description.

BACKGROUND GEOLOGY

Fig. 1 and Fig. 2 give the regional overview of Upper Jurassic and Lower Cretaceous in southwestern Saskatchewan.

In the Jurassic, above the Shaunavon limestone, is the Vanguard Group, including Rush Lake shale, and Roseray sandstone and sandy mudstone. The sandstone and shale overlying the unconformity on the Jurassic, and underlying the Joli Fou Formation of the Colorado Group, are defined as the Mannville Group. Three sub-divisions from oldest to youngest are the Success Formation, Cantuar Formation and Pense Formation. The Cantuar Formation also has three subdivisions (oldest to youngest): McClaud Member, Dimmock Creek Member and Atlas Member.

A high-relief erosion surface is carved through Jurassic and Mississipian Strata and is in turn filled in with Cantuar sediments. The McCloud Member occupies the base of the erosional relief, the Dimmock Creek Member (DCM) infills much of the remainder, and the Atlas Member forms the regional blanket.

The DCM comprises "olive-green and dark grey, argillaceous sandstones, sandy mudstones and shales, locally mottled with red, interbedded, and interrupted by massive quartzose sandstones expanded to nearly the full thickness of the member." (Christopher, 1974)

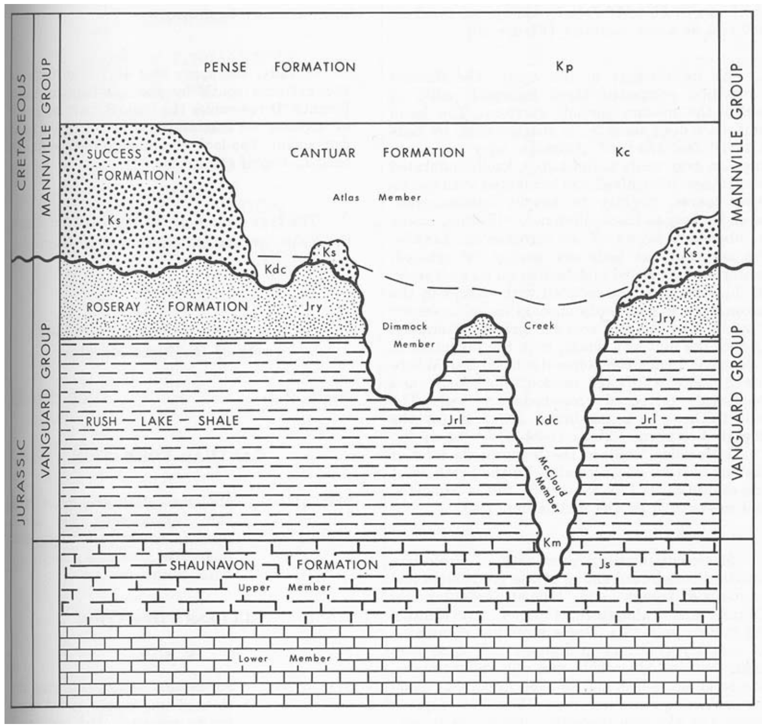

FIG. 1. Diagram illustrating the stratigraphic relationship of the upper Jurassic and Lower Cretaceous, southwestern Saskatchewan. (from Christopher, 1974)

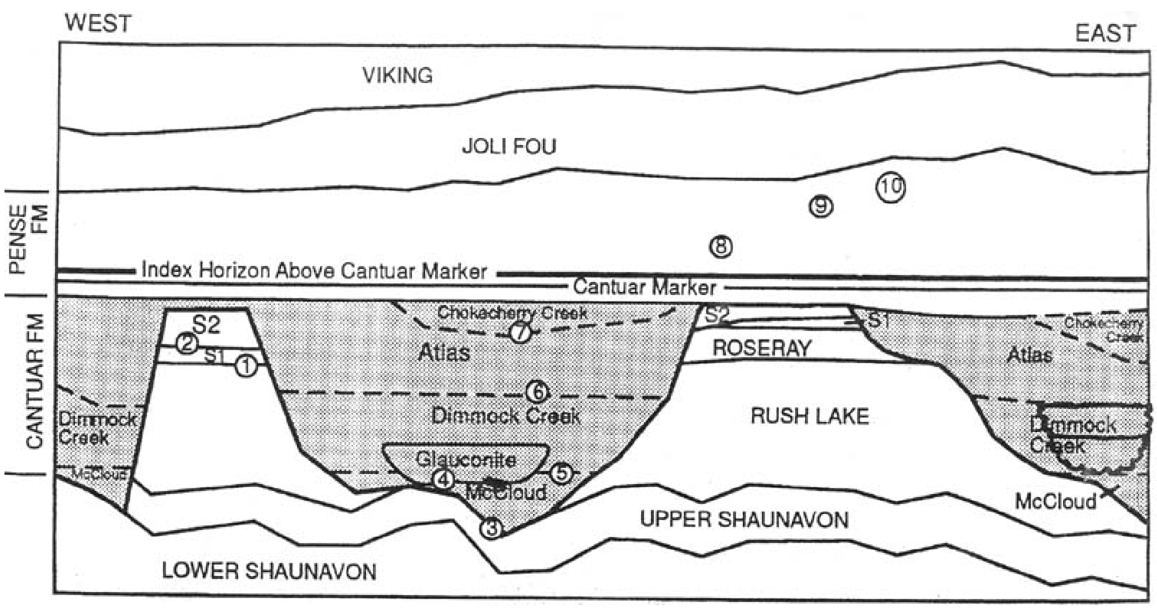

FIG. 2. Diagram showing the stratigraphic relationship of the formations within the Mannville Group. (from Vanbeselaere, 1995)

Sand bars in the silty mudstone of Dimmock Creek Member are developed, and become the targets of drilling.

The sand bars in Dimmock Creek member have porosities of about 30% and very high permeability in the 3 Darcy range. In the middle, pyrite cement exists somewhere showing very tight porosity resulting in high velocity and high density.

ACQUISITION OF SEISMIC AND VSP

3C-3D surface seismic

A 3D multi-component VectorSeis seismic survey was shot by Veritas Geophysical in this area in May, 2002. This orthogonal acquisition's parameters are:

Receiver: group interval = 50 m

E-W receiver line spacing = 180 m

Source: dynamite 0.5 kg @ 15m depth

Shot interval = 50 m

N-S shot line spacing = 325 m

Seismic natural bin size = 25 m × 25 m with fold of 45.

Veritas processed this 3C-3D data, and delivered stack and post-stack Kirchhoff migration datasets of vertical, radial and transverse component to the CREWES Project on October, 2003.

VSP survey

In June 2003, a multi-offset VSP survey was conducted in well 11-25-013-17W3 as well as a DSI Dipole Shear Sonic Imaging log by Schlumberger Canada. The source locations are shown in Fig. 3. The survey parameters were:

I. Survey type: zero-offset VSP:

Offset = 53.67 m

Azimuth = 16.34 degrees true north

Source type: 1. Litton 315 P-vibe: sweep = 8 - 180 Hz, 12sec, linear

2. IVI S-mini-vibe: sweep = 5 - 100 Hz, 12sec, linear

II. Survey type: offset VSP: offset #4

Offset = 399.12 m

Azimuth = 337.23 degrees true north

Source type: Litton 315 P-vibe: sweep = 8 - 180 Hz, 12sec, linear

III. Survey type: offset VSP: offset #6

Offset = 698.72 m

Azimuth = 301.54 degrees true north

Source type: Litton 315 P-vibe: sweep = 8 - 180 Hz, 12sec, linear

IV. Survey type: walkaway VSP:

Four offsets = 149.99 m, 250.66 m, 558.08 m, 996.8 m

Azimuth = 336.15, 337.63, 310.5, 319.52 degrees true north

Source type: Litton 315 P-vibe: sweep = 8 - 180 Hz, 12sec, linear

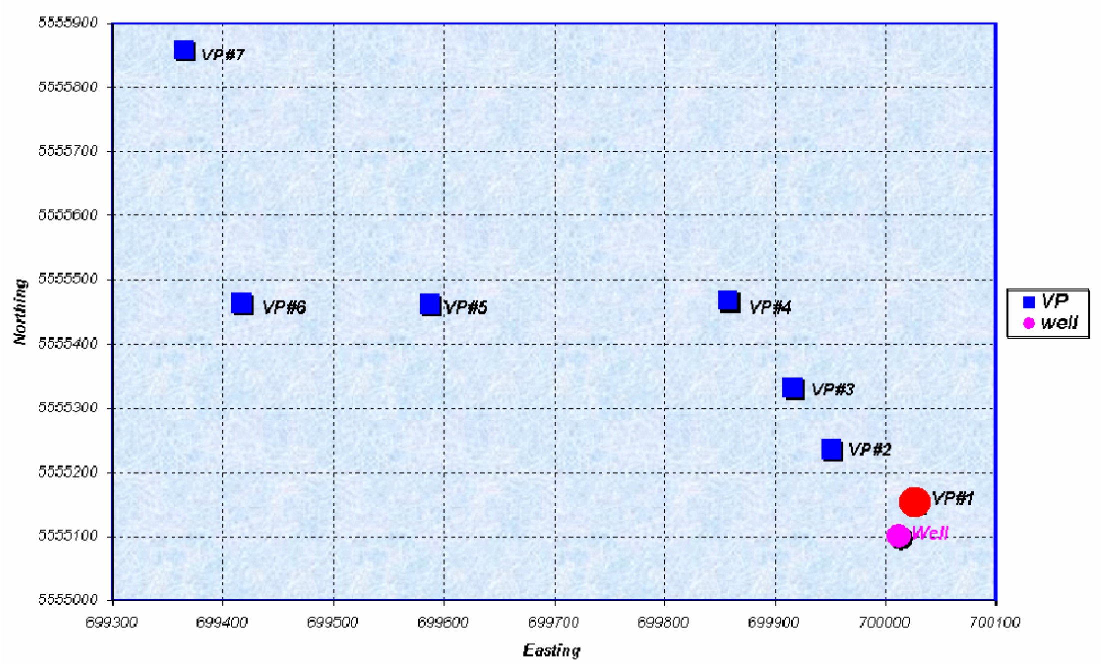

FIG. 3. Source locations of the VSP survey (Schlumberger).

DSI

A Dipole Sonic Log (DSI) was run in the cased well 11-25 in attempt to acquire shear information through casing. However, the logging results were quite poor and largely unusable.

INTERPRETATION

Veritas DGC processed the 3C-3D seismic data that are shown here. The CREWES Project will reprocess the multicomponent data in the months ahead.

The total survey covers 7.5 km^2 with a 25 m by 25 m bin size. The N-S inline range is 1-132 and the E-W Crossline is 1-91.

Migrated vertical, radial and transverse datasets were loaded into Hampson-Russell's latest version CE6R3 (released in October, 2003) of ProMC. This is a new software package developed as an integrated framework for the interpretation and modelling of multicomponent seismic data.

Frequency content

Fig. 4 displays the average amplitude spectra of these 3 data volumes. When calculating the spectra, 10 traces from each side of the 3D volume are excluded to avoid edge effects. In the time window of 800-1300 ms, the PP data shows a signal band of about 8-100 Hz. The PS1 data, in its corresponding PS time window of 1000-2000 ms, has narrower frequency bandwidth of about 10-60 Hz. Notice that 1) there is a platform of 60-100 Hz possibly boosted by spectral balancing routine and most of which may be noise; 2) the lack of low frequencies, i.e. below 8 Hz. The PS2 data in the same window as PS1 shows a narrower bandwidth of 10-40 Hz.

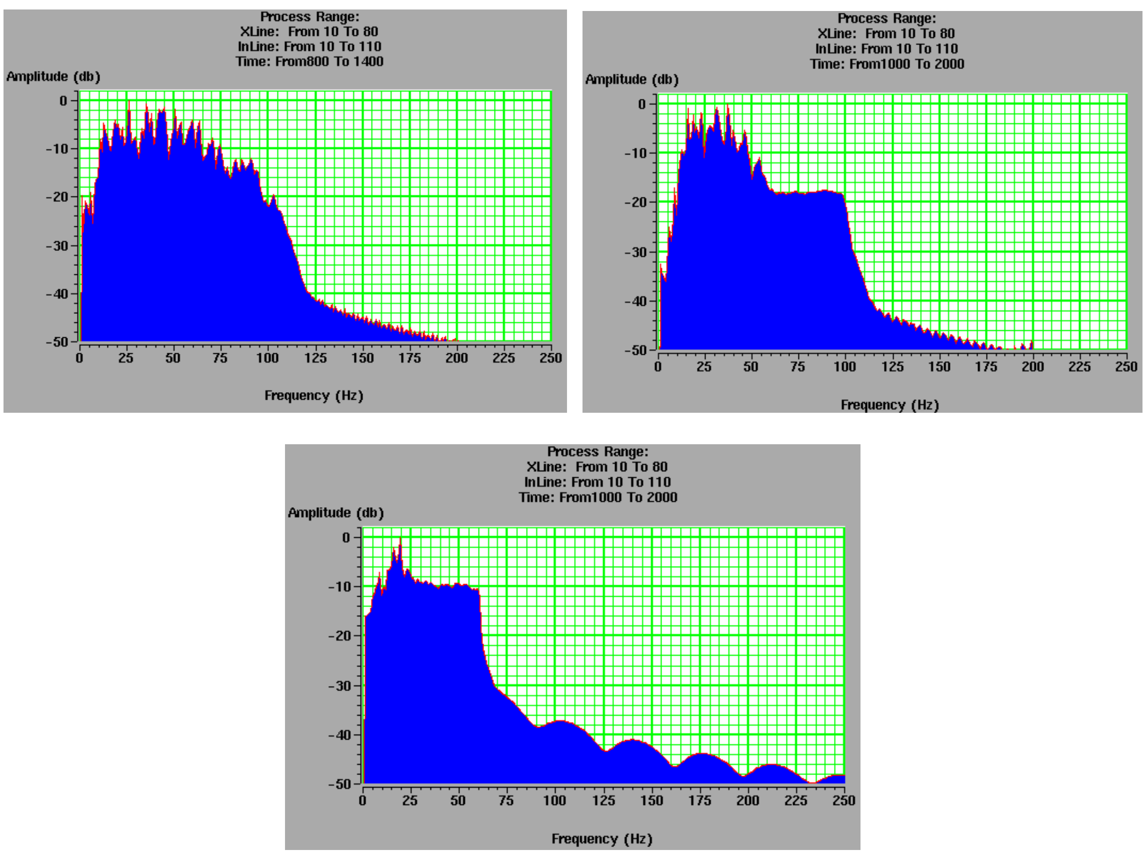

FIG. 4. Amplitude spectrum of PP (upper left), PS1 (upper right) and PS2 (lower).

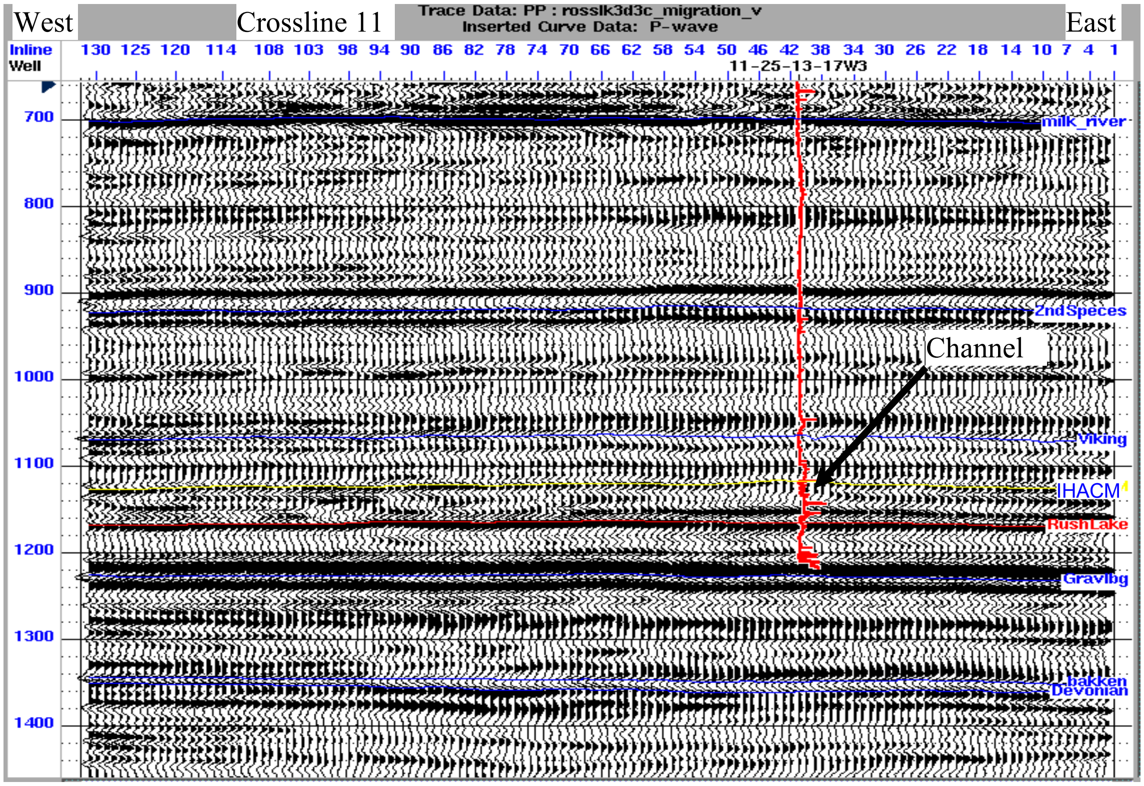

FIG. 5. East-West Xline 11 crossing well 11-25 with P-velocity curve annotated. Some PP data horizons are interpreted.

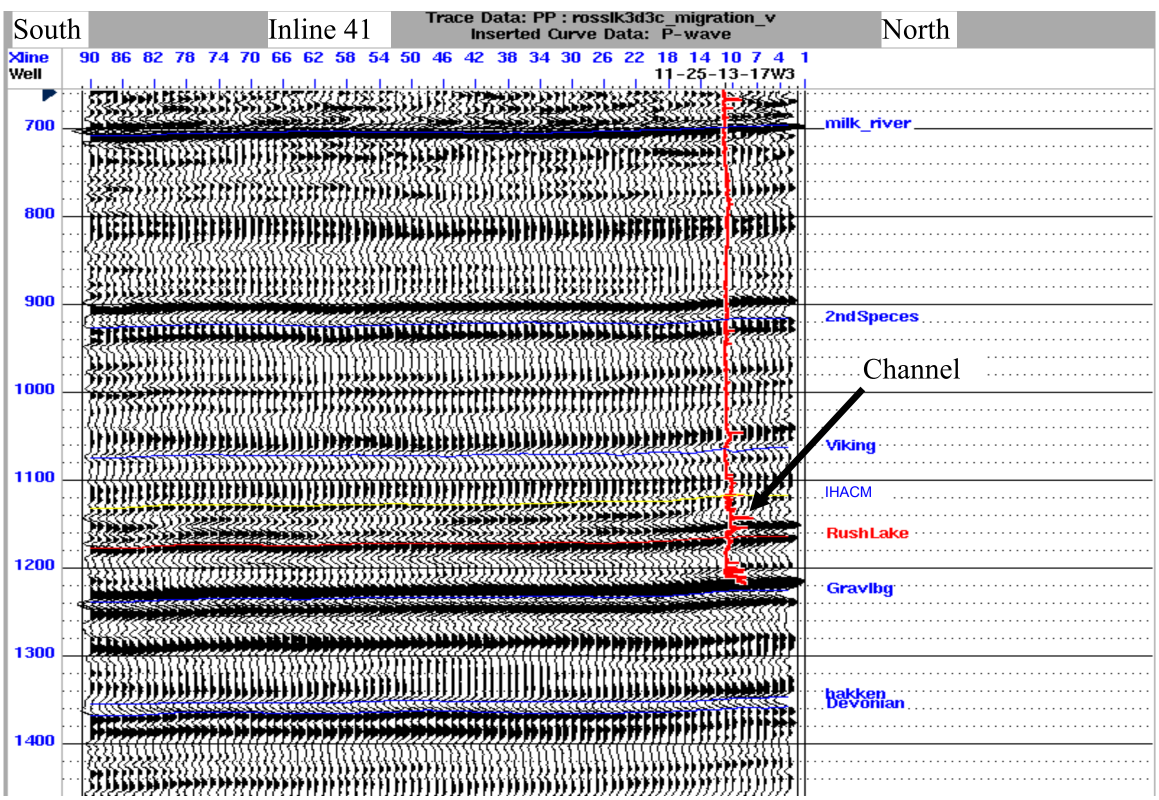

FIG. 6. East-West Xline 11 crossing well 11-25, PP data, with interpreted horizons.

Fig. 5 and Fig. 6 show the east-west xline and north-south inline section of the PP migrated data crossing the well 11-25. The sand channel is characterized by a bump on IHACM (abbreviation of Index Horizon Above Cantuar Marker) horizon.

Given a constant Vp/Vs value and P-velocity, we plotted the PS data in PP time. Fig. 7 shows Xline 11 of the PP and PS1 sections, crossing well 11-25, plotted in PP time. Time conversion uses constant Vp/Vs = 2.35 and Vp = 3000 m/s. The P-wave log in well 11-25 is superimposed as a red curve at the well location.

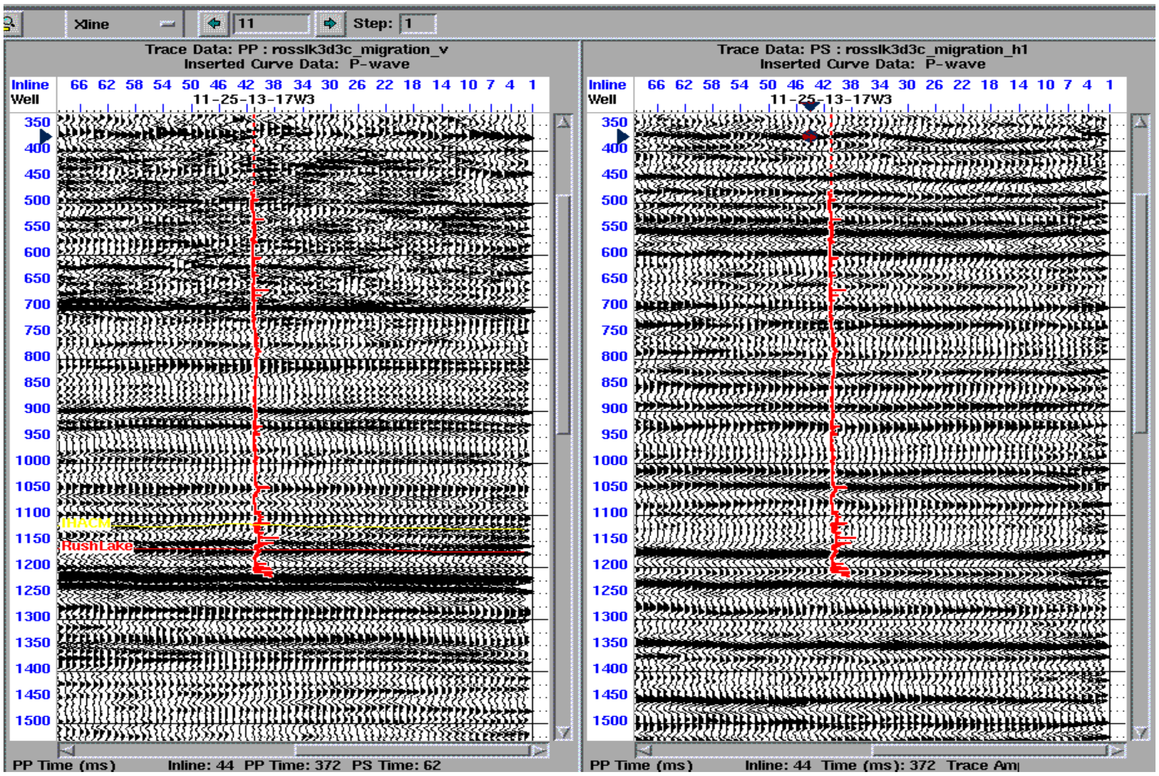

FIG. 7. Xline 11 crossing well 11-25 of PP section (left) and PS1 section, in PP time. The time conversion for PS1 is constant Vp/Vs=2.35 and Vp=3000 m/s..

Compared with the radial component, the transverse data demonstrate some clear, continuous seismic events below a certain time, for example, 1900 ms PS time on Xline 11 (Fig. 8). This may indicate that the instance formation above 1900 ms has fractures or azimuthal anisotropy. We intend to address this possibility in our later reprocessing.

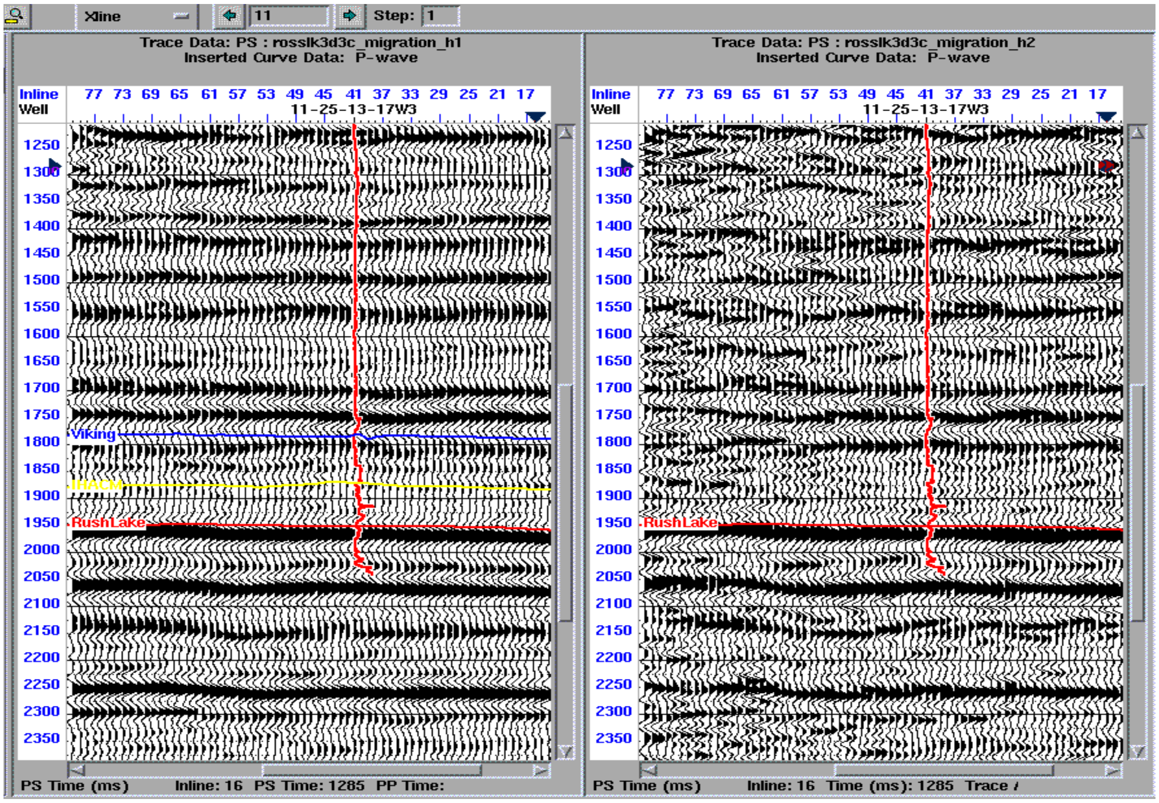

FIG. 8. Xline 11 of Radial (left) and Transverse (right) sections plotted in PS time. The conversion from PP to PS time for the inserted well P-wave curve and horizons is constant Vp/Vs=2.35.

Well 11-25 is used here to generate a P-wave synthetic to correlate with the P-wave surface seismic data.

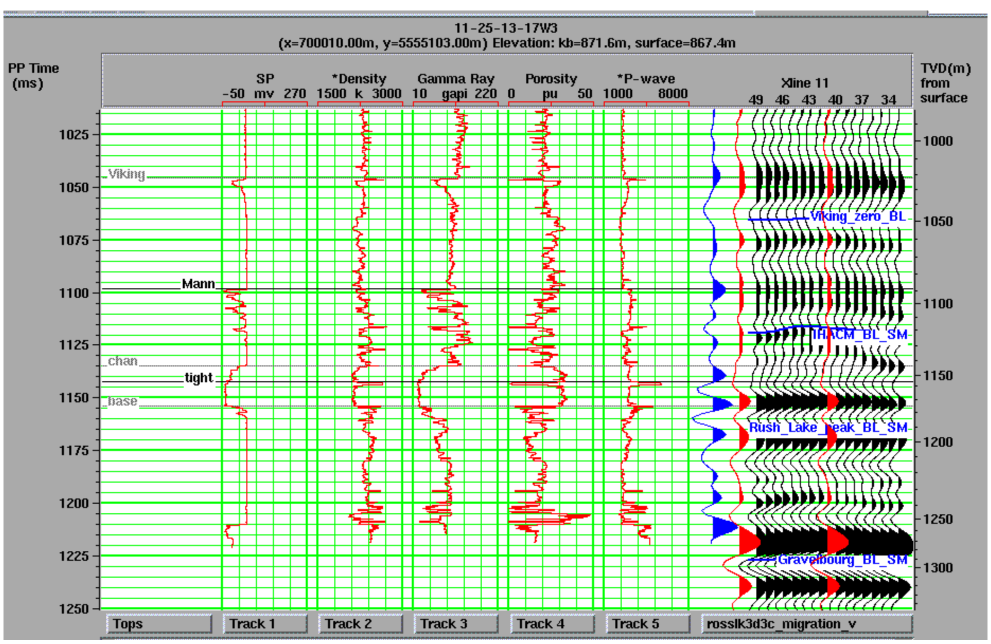

FIG. 9. Correlation of the PP synthetic with PP seismic at well 11-25.

The vertical component corridor stack of P-source zero-offset VSP is put beside the PP seismic at well 11-25, showing an excellent correlation.

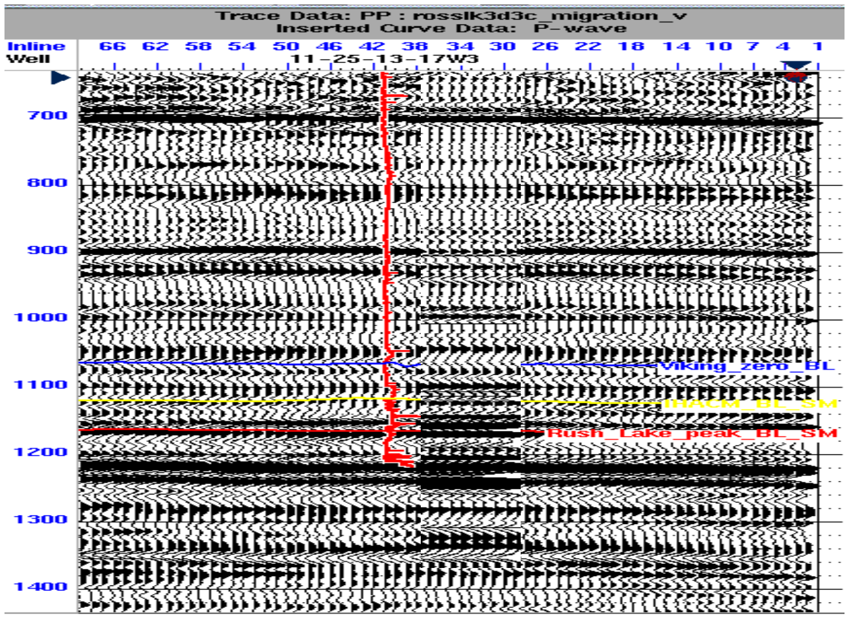

FIG. 10. The zero-offset VSP's PP corridor stack is inserted in the surface seismic PP section at the well location for correlation.

The far-offset (700m) VSP maps for both PP and PS components are also inserted into surface seismic PP and PS sections. Similar to the zero-offset VSP, the PP data shows very nice correlation. About the PS data, although surface seismic is plotted in PP time using a constant Vp/Vs value, we can find a reasonable rough correlation with the PP section.

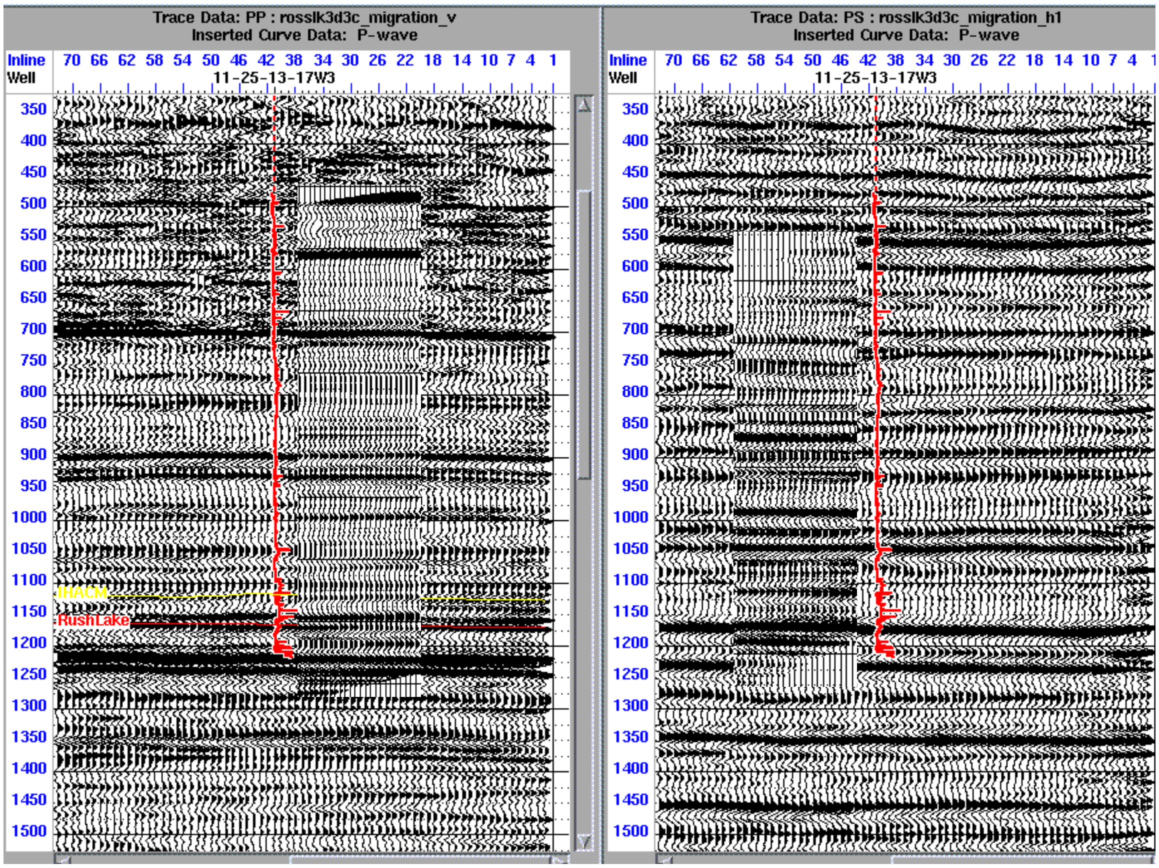

FIG. 11. The far-offset (700m) VSP's PP map and PS map are inserted in the surface seismic PP and PS sections at the well location, respectively (left-hand side is PP, right-hand side is PS). All are in PP time. A constant Vp/Vs=2.35 is used to convert seismic PS into PP time.

Horizon slices

On the conventional PP seismic section, the channel feature is the bump on the IHACM horizon with a relatively flat Rush-Lake. In general, there is a north-east to south-west dip on both horizons' time structure maps (Fig. 12). When subtracting, the time thickness map between IHACM and Rush-Lake clearly shows the sandbody with thicker value (shown in Fig. 13). This may be due to the differential compaction of the sand and surrounding sediments. The horizontal well was drilled along this high value trend.

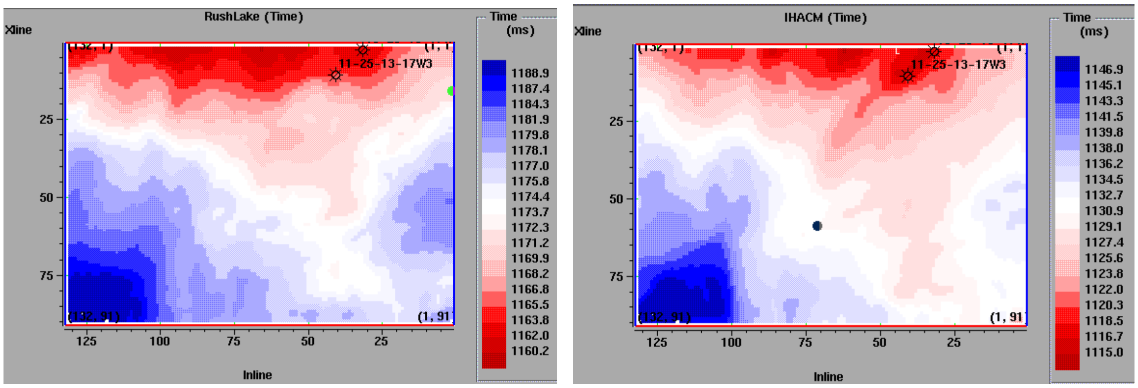

FIG. 12. Time structure of Rush-Lake picking (left) and IHACM (right).

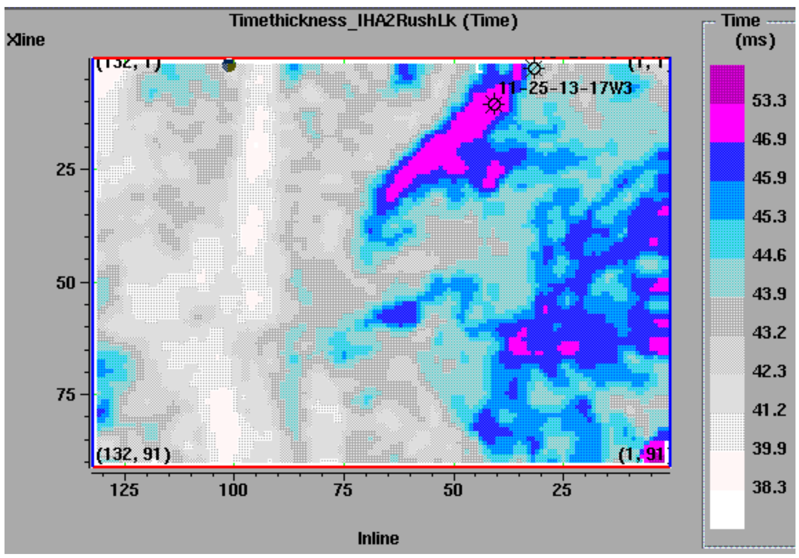

FIG. 13. Time thickness map between horizon Rush-Lake and IHACM.

FUTURE WORK

1. To identify geological events on PS data with a high confidence level.

2. To build a shear-velocity model at the well using zero-offset shear source VSP and a regional shear log, then to cross-check by partial-good DSI data, and offset VSPs.

3. Investigate fractures using Radial and Transverse data.

4. Inversion on PP and PS or joint inversion to extract petrophysical properties.

SUMMARY

A variety of multicomponent seismic data have been acquired in the Ross Lake, Saskatchewan oil field. We present some of the log, synthetic, VSP, and 3C-3D data here. The seismic data are excellent and show the target reservoir. A detailed reprocessing of the elastic-wave data and further interpretation is planned in the next months.

ACKNOWLEDGEMENT

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