Quantitative Interpretation of 4D Seismic data for Thermal EOR Applications

The earliest 4D seismic field studies were designed to monitor thermal recovery operations in heavy oil reservoirs in the USA, Canada and Indonesia. Thermal recovery operations were chosen to demonstrate the viability of 4D seismic because of the large contrasts in the seismic velocity of the heavy crude as it is heated (Nur, 1982), combined with the weak framework of the unconsolidated sand reservoirs and the relatively shallow reservoir depths. All of these factors contribute to the large seismic changes that occur during thermal production.

Early pilot projects successfully demonstrated the viability of the 4D seismic method as documented by Greaves and Fulp (1983), Stang et al (1984), and Pullin et al (1987). The application of thermal recovery processes to heavy oil reservoirs clearly caused differences in amplitude and travel time in the seismic data. However, as the thermal operations continued in mature fields it was often difficult to understand the magnitude and types of seismic changes that were observed in the data. This led to a more rigorous study of the temperature, pressure and saturation changes that occur during thermal recovery and the effect of these properties on the velocity and density of the reservoir rocks (Wang et al, 1996).

Improved rock physics and synthetic seismic modeling methods, which include phase transitions for bitumen and water, are essential to the correct understanding of the complex seismic changes that occur in mature thermal recovery operations. Seismic inversion offers the additional potential of simplifying time-lapse seismic monitoring by converting the observed amplitude changes to acoustic impedance changes, which are more directly related to rock properties. Unfortunately, this benefit frequently isn't realized due to differences in event times between surveys that are caused by velocity changes within the reservoir interval. These time differences cause a misalignment of geologic events below the reservoir that result in artifacts when the acoustic impedance results for each survey are subtracted. This problem is compounded when the velocity changes in the reservoir contain frequency components that are below the effective seismic bandwidth, and this often occurs in thermal recovery processes. Fortunately, the low frequency

Continued on Page 8

Keith Hirsche has greatly enjoyed working as a Research Geoscientist for Hampson-Russell Software since December 1998. During this time, he has acted as project leader for the time lapse seismic monitoring (Pro4D) and multi-component interpretation (ProMC) software development.

Keith started his career working in seismic data collection and processing from 1977 to 1980. From 1980 to 1998, he was employed by Geophysical Services Incorporated and Western Geophysical. During this time, he was primarily involved in reservoir characterization Research and Development with assignments in Calgary, Dallas, London, Singapore and Perth.

Inspired by his father's career in oil and gas production, Keith's research interests have focused on using seismic information to improve the recovery from existing fields – primarily through integration with geology, petrophysics, reservoir engineering and production data. Most of his research activities have related to Time-Lapse (4D) seismic monitoring, multi-component seismic analysis and geostatistical reservoir characterization.

Keith, together with Jan Porter-Hirsche – his partner and long-time co-worker – will be leaving the oil and gas industry at the end of June to pursue their interests in organic farming, alternative energy and sustainable development. Their daughters, Kailee and Krista will go along with them on the journey, while their son Trevor will continue his post-grad education in environment sciences – specializing in water management issues.

★ ★ ★ ★ ★ ★

JUNE LUNCHEON

DATE:	June 16, 2008
TIME:	11:30 A.M. Lunch
LOCATION:	Telus Convention Centre, Calgary
TICKETS:	Contact CSEG office
TELEPHONE:	262-0015 or Fax: 262-7383

SEPTEMBER LUNCHEON

September 15, 2008

Peter M. Duncan

Fall 2008 SEG/AAPG Distinguished Lecturer

Aggressively Passive:
Microseismic opportunities over an oilfield's life

MicroSeismic, Inc.

Quantitative Interpretation of 4D Seismic data...

Continued from Page 7

velocity change information can be inferred through a careful analysis of the changes in event timing between base and monitor surveys. When this low frequency information is included in the seismic inversion, the results improve significantly over conventional inversions (Hirsche et al, 2006).

As the interpretation of 4D seismic surveys has improved there has been a growing desire to understand the seismic response in terms of underlying changes in reservoir properties such as temperature, pressure and fluid saturations. This is especially true in thermal operations where accurate information about these properties can have significant economic impact. Unfortunately, the seismic response to changes in these properties can be highly non-unique. For example, a small drop in pressure can liberate methane from cold bitumen and this can cause the same magnitude of velocity decrease that occurs at very high reservoir temperature. Detailed modeling and analysis can help to distinguish the reservoir changes that underlie a specific seismic response. The integration of production and injection data together with volumetric information from the seismic monitoring results can further reduce uncertainty and derive a more quantitative interpretation (Hirsche and Ma, 2006). R

References

Nur, Amos M., 1982, *Seismic imaging in enhanced recovery:* SPE 10680.

Greaves R.J, Fulp, T.J, and Head, P.L., 1983, *Three-dimensional seismic monitoring of an enhanced oil recovery project,* SEG Technical Program Expanded Abstracts 2, 476

Stang, HR, Kuniansky, J. and Soni, Y., 1984, *The Saner Ranch pilot test of Fracture-Assisted Steamflood Technology,* Soc. Pet. Eng. AIME, Pap. ; Vol/Issue: SPE13036; 59.

Nur, A., Tosaya, C. and Thanh, D. V., 1984, *Seismic monitoring of thermal enhanced oil recovery processes,* 54th Ann. Internat. Mtg: Soc. of Expl. Geophys., Session:RS.6.

Pullin, N., Matthews, L. and Hirsche, K., 1987, *Techniques applied to obtain very high resolution three-dimensional seismic imaging at an Athabasca tar sands thermal pilot:* The Leading Edge, 06, no. 12, 10-15.

Pullin, N. E., Jackson, R. K., Matthews, L. W., Thorburn, R. F., Hirsche, W. K. and den Boer, L. D., 1987, *3-D seismic imaging of heat zones at an Athabasca tar sands thermal pilot,* 57th Ann. Internat. Mtg: Soc. of Expl. Geophys., Session:SEG1.7.

Eastwood, J., Anderson, D. and Boone, T., 1996, *3-D seismic monitoring for enhancing thermal recovery,* 66th Ann. Internat. Mtg: Soc. of Expl. Geophys., 2103-2106.

Batzle, M. and Wang, Z., 1992, *Seismic properties of pore fluids:* Geophysics, Soc. of Expl. Geophys., 57, 1396-1408.

Wang, Z., 1997, *Feasibility of time-lapse seismic reservoir monitoring:* The physical basis: The Leading Edge, 16, no. 09, 1327-1329.

Wang, Z., Langan, R., Jenkins, S., Bee, M. and Waite, M., 1996, *Aspects of rock physics in 4-D seismology,* AAPG Bulletin; Vol/Issue: 5

Hirsche, K, and Ma, F., 2006, *Reducing uncertainty in time-lapse seismic interpretation for thermal applications,* CSEG convention abstracts.

Hirsche, K., Hampson, D., and Russell, B, 2006, *Integrated time lapse seismic inversion for heavy oil applications,* CSEG convention abstracts.

★ ★ ★ ★ ★ ★

Presidential Column

Continued from Page 4

Peer-Reviewed Articles

As announced earlier in the April issue of the RECORDER, Satinder Chopra, RECORDER Editor, and Michael Enachescu, CSEG Director of Communications, have proposed guidelines for publishing peer-reviewed articles in the RECORDER. With the demise of the CSEG Journal some years ago, we are excited to be able to offer again a venue for this kind of articles. We all look forward to the first of these articles. Watch your RECORDER in the fall!

Summer Break

With the coming summer months, we are all looking forward to taking a break. The executive does not meet in July and August. I look forward to giving you an update in the September RECORDER.

François Aubin
President