ÉCOLE DOCTORALE SCIENCES DE LA TERRE

Subject offered for a contract starting in September 2012

SUBJECT TITTLE: Study of the elastic effects in waveform inversion of active low-frequency seismic data for velocity model building and imaging

Advisor: **PLESSIX René Edouard, PR, plessix@ipgp.fr**
Second Advisor/ Supervisor: **SINGH Satish, PR, singh@ipgp.fr**

Host lab/ Team: **IPGP- Team Geosciences Marines – UMR7154**

Financing: **Doctoral contract with industrial funding**

For more information go to http://ed109.ipgp.fr, section: Offres de these (PhD offer), You must apply on the Doctoral School website

Presentation of the subject: (1 or 2 pages)

Imaging the first ten kilometers of the subsurface is important for studying subduction zones and geological basins containing oil and gas deposits. Over the last decades, active seismic acquisition has moved towards denser acquisition with wider azimuths, long offsets, and low frequencies. In this way, the wavefield that travels in the first ten kilometers is more completely recorded and we can often detect both pre- and post-critical reflections. Interpreting the full wavefield allows us to obtain a more precise characterization of the subsurface (Shipp and Singh, 2002, Ravaut et al., 2004, Plessix et al., 2011). Seismic full waveform inversion technique, which consists of minimizing the misfit between observed data traces and computed ones (Tarantola, 1987), greatly benefits from these acquisition improvements (Virieux and Operto, 2010). Over the last years, full waveform inversion techniques have then regained attraction. One application of full waveform inversion consists of determining more precisely the long and intermediate wavenumbers of the, generally acoustic, velocity field that is subsequently used in an imaging (migration) algorithm to map in depth the discontinuities recorded in time in the seismic data.

At large scales, due to the computational cost of solving the wave equation, most of the applications make the acoustic assumption. In sedimentary basins, with mild velocity changes, this acoustic assumption may be sufficient to interpret the long-offset transmitted waves, which can be treated as P-waves only. Several 3D real data set inversions have been described in the recent literature using acoustic approximation (Plessix and Perkins, 2010, Sirgue et al., 2010). However, in the presence of large velocity contrasts, for instance due to basalt or salt inclusions or carbonate layers, the elastic effects (Sears et al, 2010) will modify the dynamics of the P-wave and generate converted (S) waves, which can limit the applicability of acoustic full waveform inversion. When the thickness of the large-contrast layers is small compared to the seismic wavelength, acoustic effective medium theory, which accounts for anisotropy, may be sufficient. However, in the 1-5 Hz frequency range, which is the current low frequency end of the active source seismic data spectrum, layer thicknesses of large salt, basalt or carbonate structures are of the order of the seismic wavelength.

In this project, we propose to investigate the impacts of the elastic effects in the determination of the P-wave velocity by full waveform inversion of the low-frequency active source seismic data. During this study, we will investigate what physical representation of the Earth should be adapted (elastic, anisotropic, or based on effect medium theory) to invert the low-frequency active source seismic data sets in the context of velocity model building. This work shall involve the development of prototype full waveform inversion codes in order to test the methodological approaches. During this study, we will also address the frequency continuation waveform inversion approach, where we first invert the low frequencies and long offsets, and the effects of the wave interferences at low frequencies. Applications to long real streamer or ocean bottom seismometer data sets should be considered to evaluate the approaches.

Students with strong background in mathematics, physics and interest in numerical methods are invited to apply. The project is funded through the newly established IPG Paris Industry Chair program (GPX) in partnership with Ecole des Mines de Paris and several industry partners. The students will work closely with our academic and industry partners, and will have opportunity to work in industry during the Ph.D. He/she will receive training in seismic wave propagation, modeling, inversion and analysis of seismic data.

References:

Plessix, R.-E., & Perkins, C., 2010. Full waveform inversion of a deep-water Ocean Bottom Seismometer data set, *First Break*, **28,** 71–78.

Plessix, R.-E., Baeten, G., de Maag, J.W., Klaassen, M., Zhang, R. & Tao, Z., 2010. Application of acoustic full waveform inversion to a low-frequency large-offset land data set, in *Proceedings of the 80th SEG Annual Meeting, Expanded Abstracts*, Denver, pp. 930–934.

Ravaut, C., Operto, S, Improta, L., Virieux, J., Herrero, A. & Dell'Aversana, P., 2004. Multiscale imaging of complex structures from multifold wide-aperture seismic data by frequency-domain full-waveform tomography: application to a thrust belt, *Geophys. J. Int.,* **159,** 1032–1056.

Sears, T., Singh, S.C., Barton, B.J., (2008). Full elastic waveform inversion for multi-component OBC data, *Geophysical Prospecting* **56**, 842-863.

Sears, T., Barton, B.J., Singh, S.C. (2010). Elastic full waveform inversion of multi-component ocean bottom cable seismic data: Application to Alba Field, UK North Sea, *Geophysics,* **75**, R109-R119.

Shipp, R.M. & Singh, S.C, 2002. Two-dimensional full wavefield inversion of wide-aperture marine seismic streamer data, *Geophys. J. Int.,* **151,** 325–344.

Sirgue, L., Barkved, O.I., Dellinger, J., Etgen, J., Albertin, U. & Kommedal, J.H., 2010. Full waveform inversion: the next leap forward in imaging at Valhall, *First Break,* **28,** 65–70.

Virieux, J. and Operto, S., 2009, An overview of full-waveform inversion in exploration geophysics, *Geophyscis*, **74**, WCC127-WCC152.

Tarantola A. 1987. *Inverse Problem Theory*. Elsevier.