ÉCOLE DOCTORALE
SCIENCES DE LA TERRE

Subject offered for a contract starting in September 2012

SUBJECT TITTLE: Visco-elastic full waveform inversion for velocity model building and imaging

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Financing: Doctoral contract with or without assignment

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Presentation of the subject: (1 or 2 pages)

Seismic data sets are one of the main sources of information on the Earth's interior. They are used in seismology to understand the plate structure and in mining and exploration industries to study the geological basins that contain natural resources. Most of the conventional seismic imaging methods assume that the earth is elastic, or even acoustic. However, the waves are attenuated in the Earth due to scattering and visco-elastic effect. This means that the Earth parameters are frequency dependent. We can observe significant absorption and dispersion in the near surface on land or in presence of gas pockets that create shadow zones on our impedance map. Including attenuation in imaging and velocity analysis should increase the resolution of the results. Moreover, the analysis of the attenuation could help to better characterize the Earth interior, for instance in fracture zones.

Generally, attenuation is characterized by a quality factor, where the inverse the quality factor represents the amount of energy lost over one wavelength. Several techniques have been proposed to retrieve this quality factor (for instance Quan and Harris, 1997); Full waveform inversion (Tarantola, 1987) is one of them. This approach is attractive because it does not rely on some picked information, but retrieves the information by minimizing the misfit between observed and computed data (Hicks and Pratt, 2001, Malinowski, 2011). The attenuation is taken into account in the forward modelling by solving the visco-acoustic wave equation. The determination of the quality factor is challenging, because it is generally a second order effect and both absorption and dispersion effects should be considered (Hak and Mulder, 2011). However, since the Earth is elastic and the amplitude loss due to partitioning of energy between P and S-wave is much stronger than simple attenuation, visco-acoustic full waveform inversion is of limited application.

In this project, we propose to formulate the visco-elastic full waveform inversion in the time domain and consequently solve the wave equation in the time domain. At IPG Paris, we have developed a prototype of visco-elastic waveform inversion (Royle, 201), and here we explore different aspect of inversion. One question that would need to be answered during this project is how the frequency continuation that is currently used in waveform inversion to mitigate the presence of the local minima in the misfit functional should be adapted with viscous waveform inversion? Another question is related to the parameterization of the inverse problem that may dependent on the type of applications of the waveform inversion (for velocity model building or for reservoir characterization). What happens when model is assumed to be visco-acoustic instead of visco-elastic?

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:

Hicks, G.J. and Pratt, R.G., 2001, Reflection waveform inversion using local descent methods : estimating attenuation and velocity over a gas-sand deposit, *Geophysics*, 66, 598-612.

Hak, B. and Mulder, W. A., 2011. Seismic attenuation imaging with causality, *Geophysical Journal International* 184(1),439-451.

Malinowski, M, Operto, S., and Ribodetti, A., 2011, On the footprint of attenuation on full waveform inversion of land data – a case study from the Polish basin, EAGE annual conference, E043.

Quan, Y., and J. M. Harris, 1997, Seismic attenuation tomography using the frequency shift method: *Geophysics*, 62, 895–905.

Royle, G.T., 2010, Viscoelatic full waveform inversion for ocean-bottom cable seismic data, Ph-D, IPGP.

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