INTEGRATED PSDM AND SIMULATED ANNEALING OPTIMIZATION FOR DECOLLEMENT 2D QUANTITATIVE IMAGING

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Summary

To analyse the physical properties of seismic reflectors as possible indicators of the presence of fluids, we develop an improvement of our previous work based on conventional preserved amplitude prestack depth migration/inversion (PSDM) coupled with a specific post-processing of the tomographic model. The specific post-processing sequence allows us to: (1) eliminate effects of limited source bandwidth and source-receiver aperture range; (2) obtain the absolute values of the seismic attributes; (3) obtain the correct geometry of seismic reflectors reaching the theoretical seismic resolution of the source wavelet. Unlike our previous work, during the post-processing sequence the model space exploration is made automatically via a random search, and optimal models are determined using the very fast simulated annealing algorithm. We present an application to multichannel seismic reflection data to obtain 2-dimensional quantitative imaging of the decollement on a profile located on the Ecuadorian margin. Preliminary results suggest that the decollement corresponds to a layer of a thickness of 80 meters and with a negative velocity perturbation around -50 m/s that can reach locally values down to -150 m/s. Along the decollement we can observe regions with a relative velocity decrease due to the variations of the physical properties between the subducted sediments and the overriding plate materials above the decollement. The relative velocity decrease can be probably associated with the change in fluid pressure.

Introduction

In subduction zones, the decollement is a gentle slope fault zone that acts as a mechanical division between the sediments being carried by the subducting plate and the materials of the overriding plate. Multichannel seismic surveys have shown that the decollement is a clear reflector between 3 and 15 km in depth, that generally exhibits an inversion of polarity. Much of the available information has come from seismic reflection data (e.g. Bangs et al. (1999)) calibrated by limited in situ (drilling, borehole) data. One important issue is the role of fluids in the formation and mechanical behaviour of the decollement. Numerous studies involving forward modeling and inversion of multichannel seismic reflection data have been carried out to constrain seismic velocity enhancement due to fluids inside and below the decollement and the presence of a low velocity zone associated with fluids in the sediment beneath it (e.g. Bangs et al. (1999)). However, the small scale velocities inside and below the decollement reservoir are still poorly known. In this work, we design an integrated approach to obtain the small scale velocities around the decollement area. The integrated approach is based on 2 steps: (1) asymptotic waveform inversion (Thierry et al. (1999)) to obtain a 2-D quantitative depth model for velocity; (2) an automated post-processing procedure to eliminate the source signature from the tomographic images and to estimate the absolute values of the velocity along the decollement. The processing sequence is an improvement of our previous work (Ribodetti et al. (2003)).
Methodology

Step (1): Preserved amplitude prestack depth migration/inversion is performed in angle domain (Thierry et al. (1999)) and accuracy of the tomographic model is obtained by iterative correction of the background velocity model (Al-Yahya (1989)). Step (2): Due to the limited source bandwidth and source-receiver aperture range, geological interpretation of the inversion results may be difficult. In order to remove the source signature from the tomographic images and to estimate the absolute values of the seismic attributes, we implemented a specific post-processing sequence of the tomographic model. The post-processing is formulated as an automatic non-linear inverse problem where the data space is composed of several one-dimensional logs extracted for different offset from the depth migrated image. The models space is composed of a family of realistic impulse layered models in depth, parameterized by a limited number of parameters (random velocity amplitude and a random thickness for each layer). These models mimick the logs of the physical model searched. To build the predicted dataset, the tested logs are converted from space to time using the velocity of the background medium and are convolved with the source wavelet. To estimate the source wavelet we use an average of the direct wave. The predicted dataset are computed by convolution of the depth-to-time converted impulse models with the source wavelet and compared with the tomographic models. The inverse problem is solved by a random exploration of the model space for each offset, using the very fast simulating annealing algorithm (VFSA) (Sen and Stoffa (1995)).

Application to 2D multichannel seismic reflection data

The real data used for this application has been acquired in the Colombia-Ecuador convergent margin during the SISTEUR cruise. We processed the line 72 located in Gulf of Guayaquil. This data set consists of 1900 shots per line with shot distance of 50 meters and 348 receivers spaced by 12.5 meter. The central frequency of the source is 23 Hz. The pre-processing was applied to preserve as much as possible the amplitude information in the data. The velocity macro-model was estimated by velocity analysis, transformed with Dix law and then interpolated and smoothed to obtain 2D smooth velocity macro-model. PSDM is applied to obtain two-dimensional quantitative imaging of the decollement. Result is presented in Figure1. We applied the automatic post-processing sequence, described above, to the tomographic model in the area of the decollement (Figure 2). We tested approximately 1500000 models per each log. Results are shown in Figure 2. We can note that different reflectors signatures results in different impulsional model anomalies (e.g. see Figure 2 (a) and (b) at X=72Km and X=70 km at reflector T). However, negative velocity perturbation at the decollement (D) is a constant feature for all the resulting best fitting impulsional perturbations. This result is not evident by simple inspection of the tomographic trace. Locally, some spikes are obtained in some of the best fitting logs (Figure 2 (b)); we consider that they are not realistic, and correspond to artifacts of the inversion, associated with the minimum thickness allowed. Negatives perturbations at decollement are due to the variations of the physical properties between the subducted sediments and the overriding plate materials. These perturbations are probably linked to the hydraulic conditions of fluids (and notably the pressure) inside and below the decollement. Present results also suggest that the decollement corresponds to a layer of a thickness of 80 meters and with a negative velocity perturbation around -50 m/s that can reach locally values down to -150m/s. Uncertainties for theses values are being currently investigated by statistical tests.

Conclusions

Velocity model derived by asymptotic waveform inversion conducted on multichannel seismic reflection profile located across the Ecuadorian margin, allowed us to identify variations in the physical properties of the decollement. Integrated approach based on PSDM and on automatic global optimization (VFSA) method to remove the source signature from the tomographic image and to
estimate the absolute value of the velocity along the decollement and the top of the oceanic crust was presented. In some area the decollement exhibits relative velocity decrease possibly due to presence of fluids inside and below the decollement. We can conclude that this method could be an useful tool to detect small scales variations of physical properties in seismic reflectors.

References


Figure 2: On the top: zoom of the tomographic model and source wavelet (in the boxcar). (a) Tomographic log (blue) is superimposed with the best fitting convolved model (red) at X=70,72,74,76,78,80 km and shows a good fit at the decollement (D) and at the top of the oceanic crust (T). (b) Best fitting impulsional model for the velocity perturbation in depth (red). Note the negative perturbation associated with the decollement (D). (c) Total velocity model results of the sum between the velocity macro-model log and the best fitting impulsional model. Note a clear velocity inversion at X=70 km and X=72 km between D and T corresponding to the sediments in the subduction channel.