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Extracting structural parameters from chaotic seismic reflection images of mass-transport deposits

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Mass-transport deposits (MTDs) are often characterised in reflection images by a so-called chaotic seismic texture, lacking coherent internal seismic reflectors. Such chaotic zones are often interpreted as having incoherent structural fabric, caused by strong stratal disruption and/or disaggregation during mass-transport. Subsequent coring and borehole geophysics, however, often reveal surprisingly little apparent stratal disruption and similar log characteristics to unfailed sediments above and below the MTD.

Here we propose a methodology to invert for possible internal structure of such deposits from seismic reflection images, by generating random media models for the internal velocity heterogeneity of the MTD. Random media models are parametrised by statistical-structural parameters such as lateral and vertical characteristic scale lengths, dominant dip and the standard deviation of the velocity distribution. The random medium zone is integrated with a representative overburden model built from prior geological information. Numerical seismic forward modelling is used to partially account for overburden effects, multiple scattering and sub-resolution heterogeneity. The forward modelling uses a plane wave source with a pseudo-spectral, visco-acoustic, time-domain scheme (Carcione, 2014). A realistic processing flow, including a migration, is used to generate a seismic image comparable with the observed image. The likelihood of the proposed model is estimated by taking the residual of the 2-D autocorrelation functions of the modelled and observed chaotic zones.

The inversion uses a standard Bayesian Monte Carlo Markov Chain (MCMC) to explore the chosen parameter space (constrained by priors). The results are posterior probability density functions for each parameter. Sampling these joint distributions can give a most likely random media model and estimates of relative uncertainties of each parameter.

The technique is demonstrated here on a well-studied MTD from the Nankai Trough, offshore Japan (Strasser et al., 2011). The MTD is imaged by a 3-D seismic reflection survey and fully penetrated by two IODP sites, C0018 and C0021 (with core and LWD petrophysical logs available). The MTD is up to 182 m thick and shows a chaotic internal texture in the seismic image.

This method is a novel way to validate proposed models of the internal structure of MTDs for arbitrary seismic reflection experiments, by comparing modelled and observed seismic images in autocorrelation domain. By assuming that the MTD can be approximated by certain types of random media it is possible to estimate probability density functions for statistical-structural parameters such as characteristic scale lengths. This method can be easily extended to the 3-D case and to joint inversion with, for example, borehole logs.

Carcione, J.M., 2014; Wave Fields in Real Media: Wave Propagation in Anisotropic, Anelastic, Porous and Electromagnetic Media (Vol. 38). Elsevier.
Strasser, M., Moore, G., Kimura, G., Kopf, A., Underwood, M., Guo, J., Screaton, E.; 2011; Slumping and mass transport deposition in the Nankai fore arc: Evidence from IODP drilling and 3-D reflection seismic data. Geochemistry, Geophysics, Geosystems, 12(5), Q0AD13, doi:10.1029/2010GC003431.