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Subsalt Elastic Velocity Prediction With a Look-Ahead AVA Walkaway

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Abstract

Drilling through salt in deep water is expensive and risky. Abnormally high pore pressure just underneath salt is a common problem, and one of the essential inputs to pore pressure prediction is seismic velocity. Velocity estimates from surface seismic beneath salt often have large uncertainties, what is needed is a method to predict sub-salt seismic velocities with reduced uncertainty. In this paper we discuss the new approach of using a walkaway VSP survey to predict seismic velocities just below the base salt interface.

The idea is to acquire a walkaway survey with an array of three component receivers clamped in the salt just above the base salt interface. These data are then processed with a true amplitude sequence, the base-of-salt P-p and P-s reflections are picked, amplitudes are extracted and these are then indexed by angle of incidence derived from measured polarizations before inverting for sub-salt elastic parameters. The AVA inversion is Bayesian and Monte Carlo, providing posterior uncertainty estimates in parameters: compressional and shear wave impedance (Ip, Is) (or their ratio: Vp/Vs) and dip. Given a prior estimate of sub-salt density (with uncertainty) inverted impedances are transformed to velocities.

The technique was discussed in the context of synthetic data previously (Leaney et. al. (2004)), here we show results of the technique on real data from the deep water Gulf of Mexico. We find that the uncertainty in Vp is reduced significantly from pre-drill bounds and an estimate of shear velocity (Vs) is also provided, opening up new opportunities for sub-salt pore pressure predictions. The velocities or the Vp/Vs ratio are then fed into a pore pressure transform to predict mud weight.

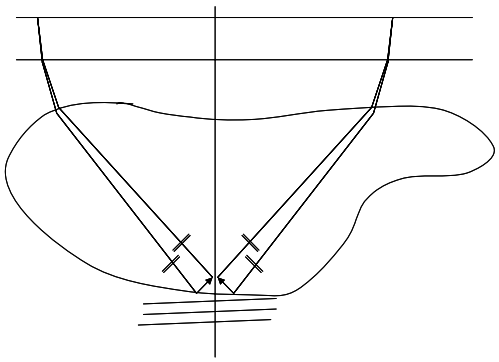

Figure 1. Schematic of a walkaway acquired for AVA. An array of 3C receivers is clamped just above the base of salt while shots are acquired along a line on the surface.

Survey

Marine multi-offset VSPs or "walkaways" designed for measuring reflection amplitude variation with offset (AVO) have the receiver array clamped just above the target reflector(s) (Leaney (1994)). In such a survey the reflection points remain close to the receivers so the downgoing path for direct and reflected arrivals is virtually the same and processing can remove the effect of the overburden.

The same idea is used for the sub-salt problem depicted in Figure 1. An array of three component (3C) receivers is clamped just above the base of salt while a seismic source vessel traverses a line over the receivers. Typical receiver arrays used contain 20 3C receivers spaced at 50ft with a typical number of shots being 400-800, depending on the line length. The direction and length of the line are determined from pre-survey 3D modeling, usually resulting in a line shot in the direction of base salt dip and extending at least 25,000ft either side of the well. The downhole array of receivers should be clamped as close to the base salt (<500ft.) as the well plan and drilling logistics permit. Stopping close to the base of salt is important to assure that the fundamental requisite of the technique is satisfied – that the downgoing path for direct and reflected events is the same (or nearly so) – and this can be aided greatly by intermediate and/or real time VSPs acquired in the salt. Since the results of the survey are needed for salt exit drilling decisions turn-around time from last shot to final prediction must happen expeditiously, usually in 1-2 days. To accomplish this the data set is transmitted from the rig to the computing center and since the data set is relatively large (for VSP data) compression prior to