Please fill in the name of the event you are preparing this manuscript for.	International Petroleum Technology Conference 2023 (15th IPTC)
Please fill in your 5-digit IPTC manuscript number.	IPTC-22955
Please fill in your manuscript title.	From Raw Seismic Data to AVA via Acoustic FWI

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Abstract

The objective of this work is to demonstrate that accurate elastic amplitude-versus-angle (AVA) parameters can be estimated from raw seismic data using purely acoustic full-waveform inversion (FWI). The problem is approached first via a simple synthetic experiment that provides a graphical explanation of the proposed workflow, followed by an application of the workflow to a synthetic dataset generated using a realistic representation of a gas field from offshore Australia.

Full-bandwidth acoustic FWI can be used to generate three-dimensional models of acoustic reflectivity that are closely analogous to those produced by conventional non-linear least-squares acoustic reverse-time migration. Whilst desirable in terms of its speed, reliability, and high signal-to-noise ratio, this approach to imaging does not by default generate pre-stack attributes, which are important for subsequent quantitative interpretation. The proposed workflow for alleviating this shortcoming begins by using all available offsets to recover an acoustic velocity model that predicts the travel times of all the important phases present in the data. This full-offset model is then used as the starting point for true-amplitude offset-restricted acoustic FWI, which seeks to capture the AVA properties of the data. The data are divided into discrete offset bins that represent approximately uniform increments in reflection angle, as per Figure 1. The acoustic models recovered are then analysed so as to transform the amplitudes of reflectors in the model domain into the amplitudes of reflections in the image domain.

Conventional AVA estimation and analysis requires the removal of the effects of various otherwise confounding phenomena that can influence reflection amplitudes – anelasticity, geometric spreading, anisotropy, acquisition directivity, surface ghosts, and wavelet stretch, to name but a few. The FWI-based workflow for AVA estimation proposed here is in principle much simpler because most of these phenomena are accounted for automatically by the FWI algorithm. FWI does not attempt to map true-amplitude seismic data into the image domain, rather it attempts to find an acoustic model of the subsurface that best predicts those data, in a least-squares sense. Thus, if true-amplitude FWI recovers different models when using seismic data from different offset ranges, then that provides a direct measure of the AVA anomaly of that data with respect to the AVA behaviour of an equivalent pure-acoustic model. As such, acoustic FWI can provide a direct quantitative measure of true AVA.

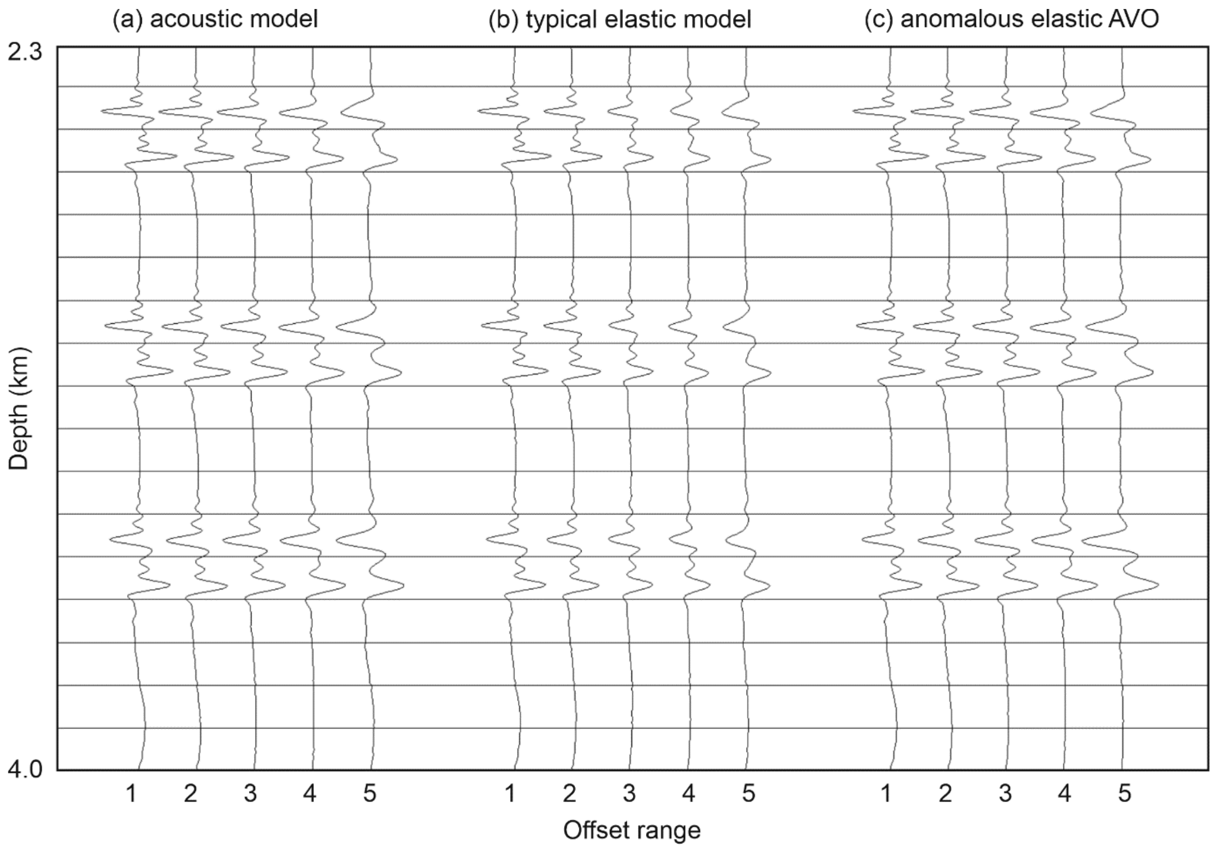

Figure 1: *Vertically differentiated acoustic FWI results, generated by inverting offset-restricted data, for three simple synthetic models; (a) $v_s = 0$, (b) $v_s = 0.5v_p$, and (c) v_s independent of v_p. Each model contains three layers with low acoustic velocity. Offset ranges 1 and 5 span the narrowest and widest incident angles, respectively. Each of these FWI results contain the band-limited reflectivity required to best explain the true amplitudes of the input reflection data over their limited offset range, when assuming a purely acoustic model. This figure contains all of the information required for the direct extraction of accurate AVA parameters from raw seismic data.*

Combining full-bandwidth FWI for depth imaging with offset-restricted FWI for AVA extraction can provide a complete workflow for highly accelerated, accurate, and repeatable handling of raw seismic data without any requirement for conventional data processing, model building, migration, or Kirchhoff-based AVA extraction. Furthermore, the proposed workflow holds the promise of being able to extract AVA parameters from beyond the linear angle range.