High-resolution impedance estimation using multi-parameter visco-elastic FWI in a Gulf of Mexico setting

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ABSTRACT

As oil production moves into increasingly complex geological settings, obtaining high-resolution amplitude-compliant information about the reservoir is crucial for reducing development and exploration risks. In this context, Full Waveform Inversion (FWI) (Tarantola, 1984) emerges as an essential tool for velocity model building and elastic properties estimation, due to its ability to simulate complex wave phenomena such as transmission loss, interbed multiples, converted waves and attenuation.

We present a multi-parameter visco-elastic TTI FWI workflow that delivers acoustic and shear impedances for reservoir characterization. This workflow was applied to a Gulf of Mexico dataset characterized by a complex salt geometry with variable thickness. The thinner part of the salt creates imaging challenges underneath, since small velocity errors create defocusing of key reflectors. Moreover, scattering and transmission loss in the salt-sediment interface reduce the subsalt amplitudes in the recorded data.

To obtain the initial model for our multi-parameter FWI, we first update the velocity model using 9 Hz visco-elastic FWI with phase-only objective function (Liu et al., 2022). The main goal of this step is to reduce first-order velocity errors and sharpen the salt-sediment interface in the velocity model. For this step, a constant Q value was used for the sediment layers.

In the second part of the workflow, we focus on updating the Q model. This is an important step when trying to explain the amplitudes of the recorded data. For this update, we employ a visco-elastic FWI up to 7 Hz, using both phase and amplitude information, followed by Q-tomography. This step is succeeded by an additional round of FWI velocity updates to minimize any residual inconsistencies between the velocity and Q model.

Finally, once the kinematics and attenuation of the model have been satisfactorily explained, we focus on explaining the reflection data amplitude. This last step consists of 30 Hz multi-parameter visco-elastic FWI, inverting for P-impedance and Vp/Vs (Plessix et al., 2013). Figure 1 shows the inverted acoustic, shear impedance and the derived normal reflectivity. The final elastic properties of the multi-parameter FWI covers not only the reservoir target area but also its overburden and surroundings, incorporating interbed scattering from mudline to reservoir base.

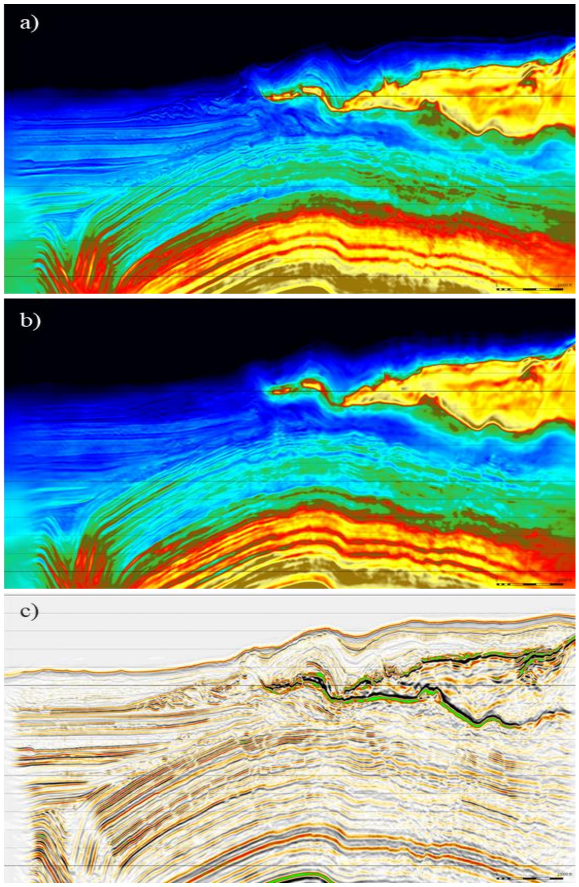

Figure 1: Retrieved 30 Hz impedance volumes: a) Acoustic impedance b) Shear impedance; and c) Normal reflectivity derived from acousit impedance model.

To benchmark our results we performed iterative, angle-dependent, least-squares reverse-time migration (LSRTM) (Duveneck, 2021) using the same velocity followed by post-migration Q compensation using the FWI-derived attenuation model. In general, consistent amplitude behavior was observed between the two methodologies.

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