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Please fill in your manuscript title.	Imaging Thrust Belt Using Multi-azimuth Full Waveform Inversion and Least Squares Q Migration

Please fill in your author name(s) and company affiliation.

Given Name	Surname	Company
Choong Chee	Lam	CGG
Hoang Lam	Do	CGG
Shivaji	Maitra	CGG
Hafiez	Mohamed	CGG
Liyana	Rosely	CGG
Andy	Bisset	PTTEP
Vaughan	Till	PTTEP

Abstract

Objective

The study area is located offshore Sabah, one of the most actively explored area in Malaysia, which is characterized by fold-thrust belt system located within a compressional tectonic regime. The imaging of the main structure of the study area, a toe-thrust anticline, has been challenging due to velocity heterogeneities, gas cloud, complex structural geology with steep dips and potential multi-pathing. Latest imaging techniques in Full Waveform Inversion (FWI) and Least-Squares Migration (LSM) were used to address these challenges and improve the image quality.

Method

In order to model the velocity heterogeneities, FWI (<12Hz peak frequency) was run using multi-azimuth (MAZ) seismic data acquired on three azimuths. This MAZ FWI model was then used to estimate the Q model with ray-based tomography and QFWI. A second pass of FWI was run to update the velocity to higher frequencies (30Hz peak frequency) using visco-acoustic FWI incorporating the estimated Q model. With the derived velocity and Q model, Least Squares Q-Kirchhoff Depth Migration (LS-Q-KDM) was run to compensate for amplitude loss and phase distortion caused by the absorption in the presence of gas bodies while suppressing the noise over-boosted by the Q-migration, and mitigating the acquisition-related effects such as uneven azimuthal illumination effects, and migration artefacts.

Results

FWI was able to produce a high-resolution velocity model that i) captures the velocity variation of complex overburden (Fig 1), ii) shows good agreement with well checkshots (Fig 2), iii) improves the seismic image and iv) resolves azimuthal velocity variations to a certain extent. Comparing with conventional Q-Kirchhoff Depth Migration (Q-KDM), we see uplift in improved S/N ratio, event continuity (Fig 3), and balanced illumination (Fig 4) on LS-Q-KDM.

Conclusion

FWI helps to reduce the velocity uncertainty in complex geological setting where the ray-based reflection tomography suffers from its limitation. This high-resolution velocity can be used as an interpretation tools to provide additional information other than seismic data. With LS-Q-KDM, it is able to compensate for amplitude loss and phase distortion while suppressing the noise to produce cleaner image. The LSM flow naturally mitigates the uneven illumination and migration artefacts.

Presence of azimuthal anisotropy was observed during velocity model building. For future work, orthorhombic-FWI and orthorhombic-VMB needs to be considered to take into account of the azimuthal anisotropy effect. Wave equation migration such as Reverse Time Migration (RTM) is also preferred to handle the potential multi-pathing in such complex geological setting.

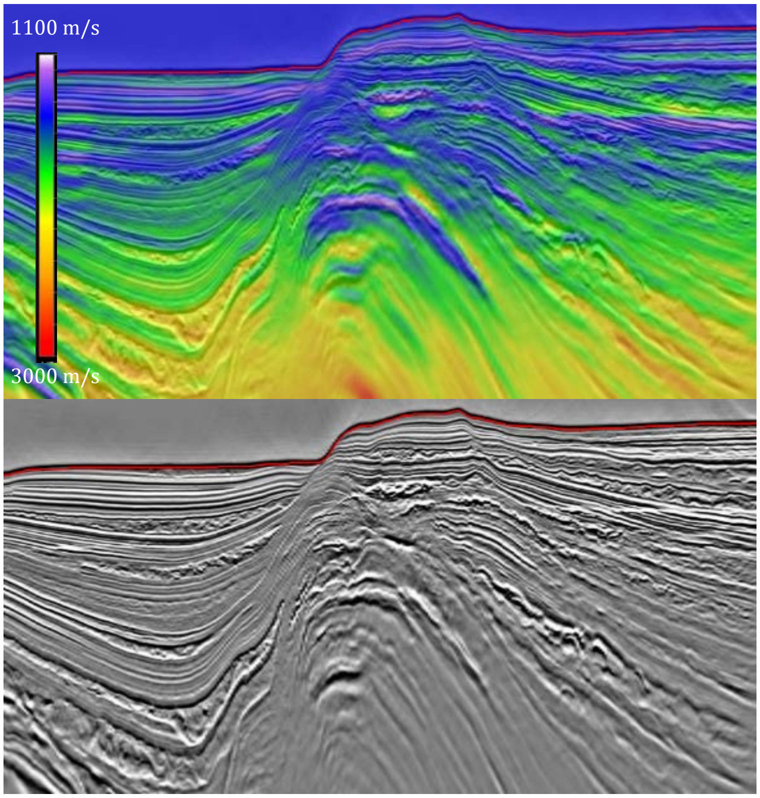

Fig 1. FWI manages to capture the velocity variation of complex overburden.

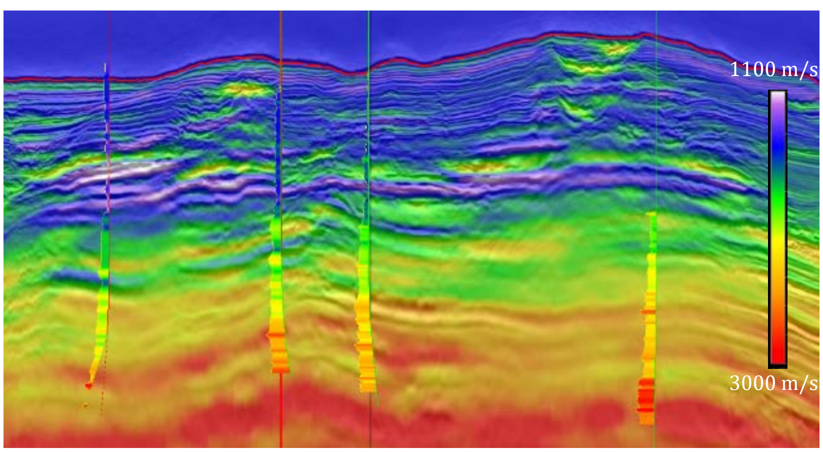

Fig 2. FWI velocity shows good agreement with well checkshots.

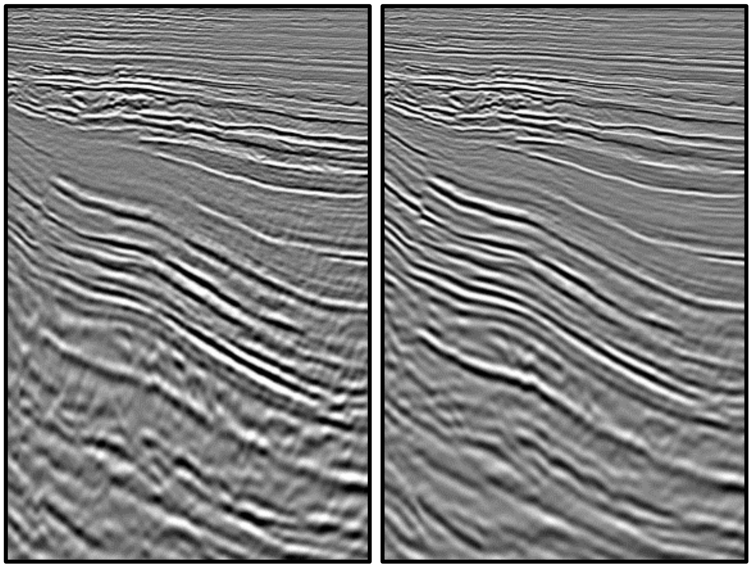

Fig 3. Less migration swings and better event continuity in LS-Q-KDM (right) compared to Q-KDM (left)

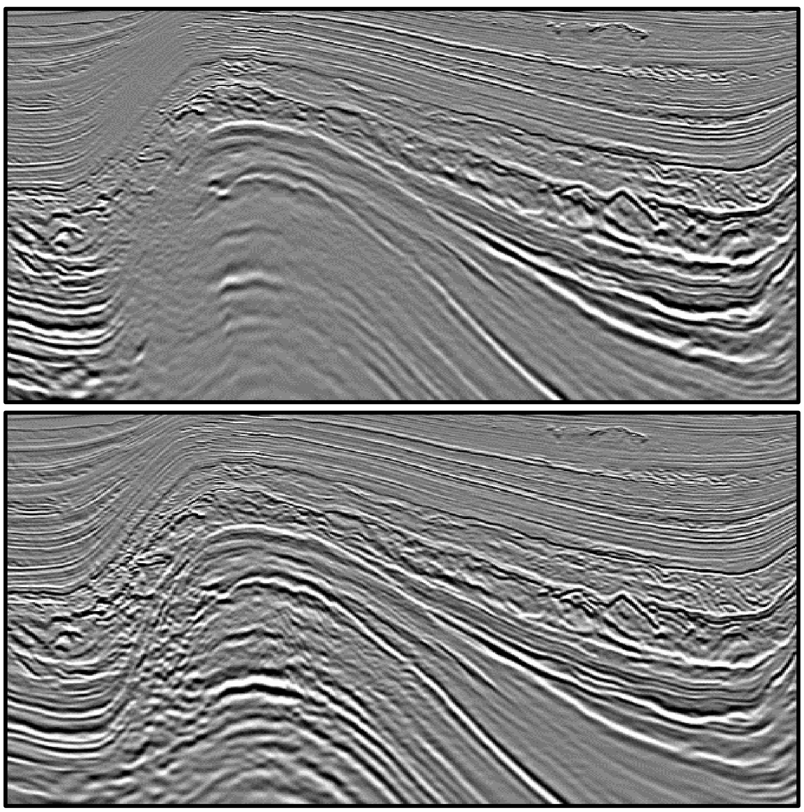

Fig 4. More balanced illumination in LS-Q-KDM (below) compared to Q-KDM (above)