Reducing charge risk using velocities from elastic FWI & sparse node OBN

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SUMMARY

Recent advances in seismic acquisition (sparse node OBN) and processing (Elastic FWI) have enabled detailed velocities that fit geology to be obtained deeper in the seismic section even under complex overburden. The images and velocity models produced from sparse node OBN data allow explorers to reduce charge risk by highlighting potential source rocks and charge migration pathways in areas where these features were unimaged on legacy data.

INTRODUCTION

The long offset sparse node Engagement and Amendment programs have revealed strikingly improved images of the Mesozoic section. As the source rocks for the Gulf of Mexico (GOM) plays are often Mesozoic in age, these improved images allow much more confidence in assessing whether source rocks are present and in identifying potential pathways from the source rocks to the reservoirs. Both assessments were much more difficult to do on the legacy streamer data which lacked the long offsets required to properly image the Mesozoic section. In addition, elastic FWI in combination with sparse node OBN produces detailed velocity models which are valuable interpretation tools, providing a potential means to identify source rocks.

THEORY

A key aspect of the hydrocarbon exploration process is assigning risk to a prospect or a play. The risk of a prospect is usually calculated by first assessing the risk of the following being present:

- Trap
- Reservoir
- Charge
- Seal

These individual risks are then convolved into one overall risk. Because source rocks are typically located beneath reservoirs and trapping elements, they are more poorly imaged than the traps, reservoirs, and seals. This makes charge risk (sometimes further broken into source rock presence risk and the risk that charge will migrate from source rocks into the trap) the most difficult to assess.

Analysis of hydrocarbons in GOM fields shows that they typically originated in Mesozoic aged source rocks. Because the Mesozoic section is poorly imaged and is very seldom penetrated with the drill bit, the usual exploration tools of seismic interpretation and offset well analysis are not very effective for assessing charge risk.

However, the detailed velocity models produced from elastic FWI and sparse node OBN data provide Mesozoic velocity and seismic signatures that match the characteristics of source rock sections that have been penetrated in wells in the eastern GOM. Elastic FWI is particularly good at defining the sharp velocity changes that occur in the Mesozoic with changes in lithology between sections that are predominately carbonates, shale (which includes source rocks), and salt. This allows more confident assessments of source rock presence and a clearer picture of potential pathways from these source rock sections into traps significantly lowering the charge risk for prospects identified on this more advanced data.

EXAMPLES

In the Eastern GOM, Mesozoic source rocks have been penetrated by wells targeting the Jurassic Norphlet section. These wells have revealed that the Tithonian source rock interval has slower velocity and lower impedance than the intervals surrounding it. The lower impedance source rock section is characterized by a soft reflection at the top and hard at its base and lower interval velocities (Figure 1).

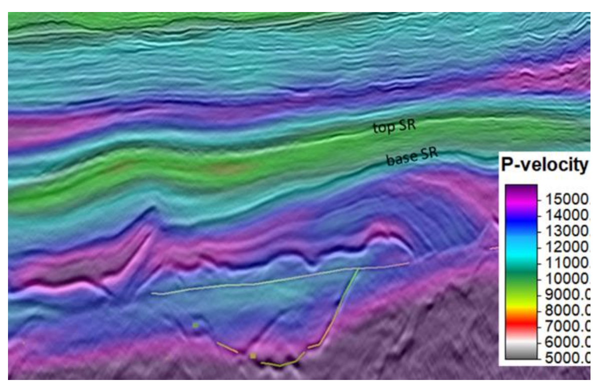

Figure 1: Eastern GOM streamer section showing seismic and velocity characteristics of a source rock interval.

These same characteristics are revealed in source rocks from the Norwegian Sea (Figure 2).

Reducing charge risk with FWI velocities

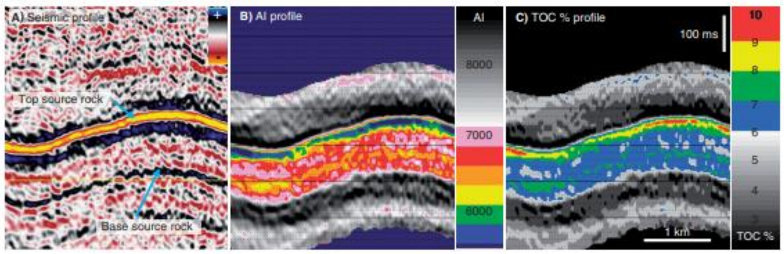

Figure 2: Source rock interval shown on A) seismic section B) acoustic impedance profile C) % TOC profile.

The Mesozoic section in Figure 1 is well imaged on streamer data as it is away from the complex overburden caused mainly by shallow salt and this data has longer offsets than typical for streamer data (12000m). However, the images of the Mesozoic section resulting from sparse node OBN and elastic FWI is superior to this. Despite a complex overburden and a more deeply buried Mesozoic section, sparse node OBN data produces striking images of the Mesozoic section with the detailed velocities produced by elastic FWI conforming beautifully with the geology (Figure 3).

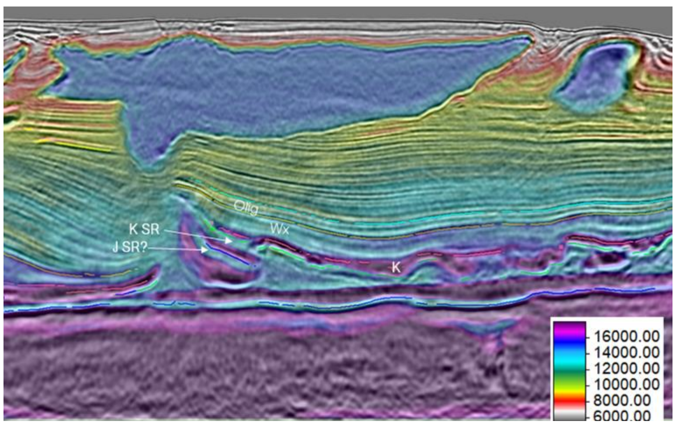

Figure 3: Sparse node data overlain with eFWI velocity model showing potential source rocks under an existing field.

Both Figures 1 & 3 show alternating fast and slow zones in the Mesozoic section. From well control close to Figure 1, we know that the fast zones are Mesozoic carbonates and the slow zone is the Tithonian source rock section. From the similar seismic and velocity characteristics in the same aged rocks, we can infer that the slow zones below top Cretaceous have a strong probability of being source rocks. They have soft reflectors at the top and hard reflectors at the base and exhibit significantly slower interval velocities than the surrounding rocks.

In addition, by comparison with penetrated sections in the Eastern GOM and the known age of the Louann salt, it appears that there is both a Cretaceous and Jurassic source rock package that can be mapped around. They are at about the right position to be the Cenomanian/Turonian and Tithonian source rock packages that are known to source oil fields and seeps in the Northern GOM.

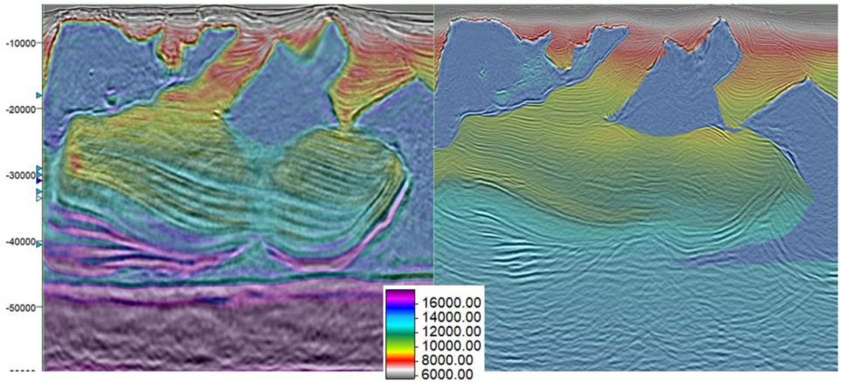

Figure 4: Comparison of A) sparse node OBN with eFWI velocities B) legacy coil plus streamer image with legacy velocities

CONCLUSIONS

A comparison with legacy streamer data in the area shows that it was impossible to map potential source rocks on the streamer data, but now it is possible to not only identify potential source rock zones, but also to assess charge migration pathways and timing (Figure 4). In addition, the superior image from base salt to basement coupled with detailed velocities that fit geology make it easier to evaluate all aspects of the petroleum system such as reservoir deposition and thickness, trap formation and timing, and seal effectiveness in addition to aspects of charge risking.

Discovered prospects and fields can benefit from these improved images as well. Geochemistry information from wells would help to identify the source rock sections and migration pathways that fed into the reservoirs and would provide constraints on the size of discovered accumulations.

ACKNOWLEDGEMENTS

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