Combining Velocity Model Building and Interpretation Techniques to Reduce Uncertainty in Pre-salt Imaging

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SUMMARY

There is ever increasing interest in exploring pre-salt provinces across the South Atlantic Conjugate Margin The 2006 discovery of the Lula (Tupi) field in the Brazil Santos Basin and more recent discoveries such as the 2012 Azul Field in the Angolan Kwanza Basin in the Lower Cretaceous, have proven that there is a working hydrocarbon system across the South Atlantic Conjugate Margin. The key to evaluating the prospectivity of these pre-salt provinces is generation of an accurate seismic image using pre-stack depth imaging methods. However, it is not possible to obtain a useable image below allochthonous salt using an approach entirely dependent upon algorithms to construct the PSDM velocity model. The introduction of geological understanding through seismic interpretation, basin modelling and the (limited) available well data can aid PSDM velocity model accuracy and reduce uncertainty of the pre-salt image obtained (Merry, 2012). This paper reviews an approach taken to resolve the pre-salt image using data examples from Angola Blocks 24 and 25.

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Introduction
When constructing velocity models over allochthonous salt terrains it is common industry practise, after establishing the post-salt sediment velocity structure, to construct the geometry of the salt through a variation of a two pass layer stripping approach. An initial sediment flood migration is performed, from which a top salt interpretation is picked. A salt velocity flood is inserted in the sediment model and a further migration performed. Interpreters then attempt to utilise both volumes to construct flank and base salt interpretations of the allochthonous bodies. Where an overhang exists the construction of a reliable salt flank geometry requires the interpreter to pick the return under the top salt, illuminated through the salt from the salt flood migration, and then marry this to the base of the flank picked within the sediment flood migration.
The majority of the flank is generally either poorly illuminated by either flood migration or improperly positioned due to the imposition of inappropriate local velocities within both scenarios. This can lead to a high degree of ambiguity in establishing a reliable local salt geometry, which then further impacts the ability to establish deeper structural control of the autochthonous salt and pre-salt sediments.

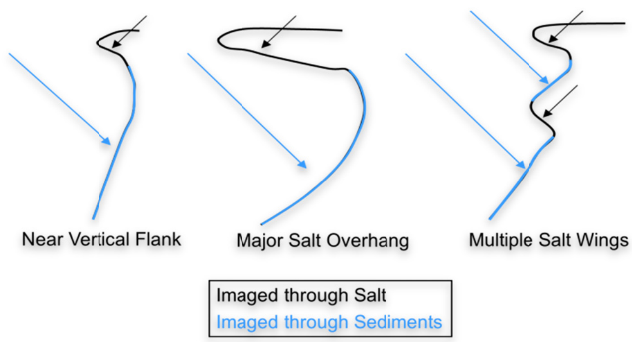

Figure 1 *Schematic illustration of illumination pathways for complex (recumbent) salt geometries.*

To overcome this problem, PGS have developed a dual model migration technique that allows data passing through sediment to be imaged with sediment velocity but any data migrating through a canopy salt interface is imaged with a salt velocity. This approach delivers a volume to the interpretation groups that combine the properties of a sediment and salt flood giving the ability to pick the base and flank salt geometries from a single migration volume. This results in a single migrated volume where the transmitted wave fields through both salt and sediment are imaged with the appropriate velocity, reducing the previous ambiguity of the flank and base salt interpretations.

Seismic imaging to aid interpretation

The successes to resolving pre-salt structures rely upon accurate salt placement within the velocity model. Currently, this process is interpretation-led, where changes to the interpretation vastly affect the velocity model as a whole and will produce erroneous results if positioned incorrectly. Since the salt position can be ambiguous in seismic sections, this can pose a problem to the interpreter deciding upon accurate salt geometries. The key to achieving the best possible understanding of salt construction within blocks 24 and 25 in Angola has been to use more than one relevant stack type while interpreting. The images below highlight the stack types that were made available to the interpretation team. Associated pre-stack data gathers were also provided.

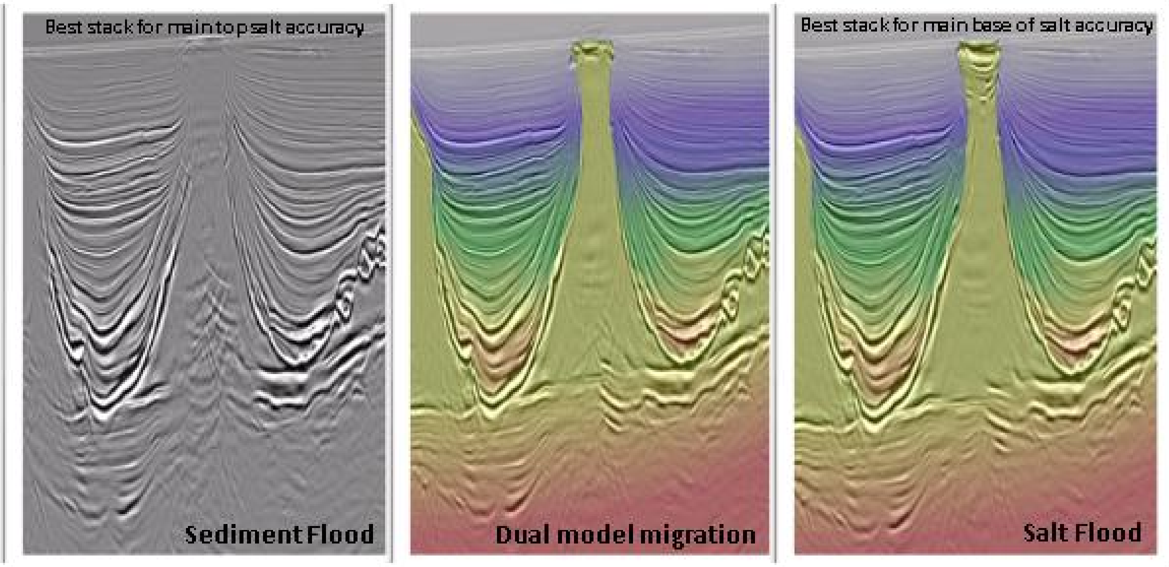

Figure 2 *Sediment flood stack (above left), used to interpret the main top salt and canopy salt tops. Standard salt flood stack (above right), used to interpret the main base of salt. This stack is not suitable to interpret the main top salt and canopy salt tops because the accurate salt position is distorted. Using a dual model migration approach, it is then possible to better image the salt flanks when only the canopy structure is known (above middle).*

The main drawback of both sediment and salt flood migration is that neither provide optimal positioning of the salt flanks since the velocity model is inaccurate below the canopy. Using a dual velocity model migration, it is possible to combine the best elements of single velocity flood migrations into a single image. This approach has an added benefit that arrivals through sediment are imaged with sediment velocity entirely and are not mispositioned due to a curtain of salt velocity hung from the top canopy.

The imperfect image

Even using the most accurate of stacks, it is still not always obvious where the top of the salt should be positioned, or indeed understanding the geometries within it. Effects of sediment packages apparent around the top of the salt bodies can create uncertainty over its actual position, particularly if they appear to be within the salt (see figure 3). In this instance, these reflections have been attributed to the incorporation of clastic sediments during salt movement. Since these clastics have a similar velocity to the surrounding salt, adding them as part of the salt body has little impact on the velocity model. It is however, not to be assumed that this occurs for all salt bodies over a given area; each should be investigated separately.

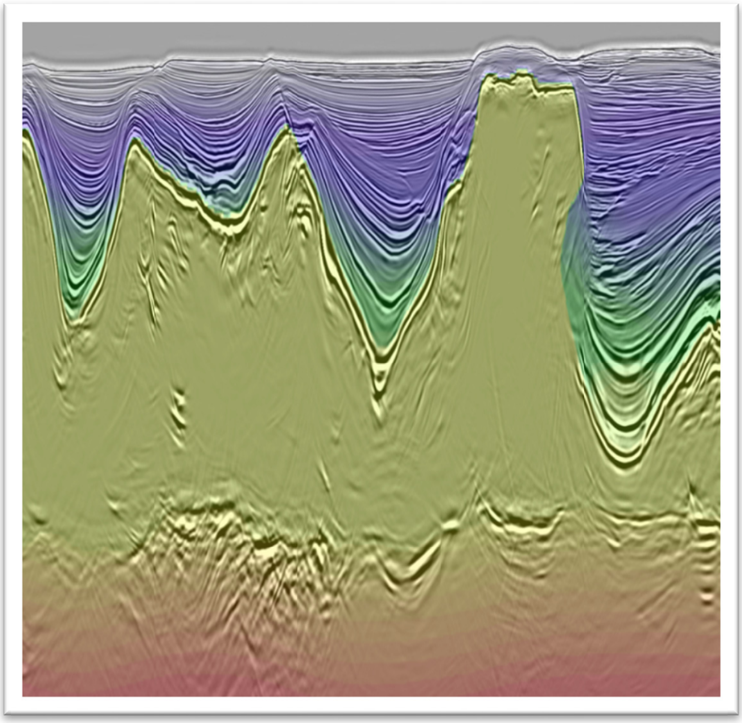

Figure 3 *Intra-salt reflectivity when migrated with salt velocity does not appear to change the base salt image.*

Other reflections within the salt can also indicate either more complex geometries, with packages of sediments trapped within the salt, or could alternatively demonstrate a body which is entirely made up of salt, albeit muddled in structure with internal high-amplitude anomalies. Conclusive evidence of the exact nature of these bodies is only available with detailed well data, and so in many projects remains uncertain. For some salt bodies, it is possible to generate multiple salt geometry scenarios and then selecting the most geologically appropriate result based upon a structural concept for base salt geometry.

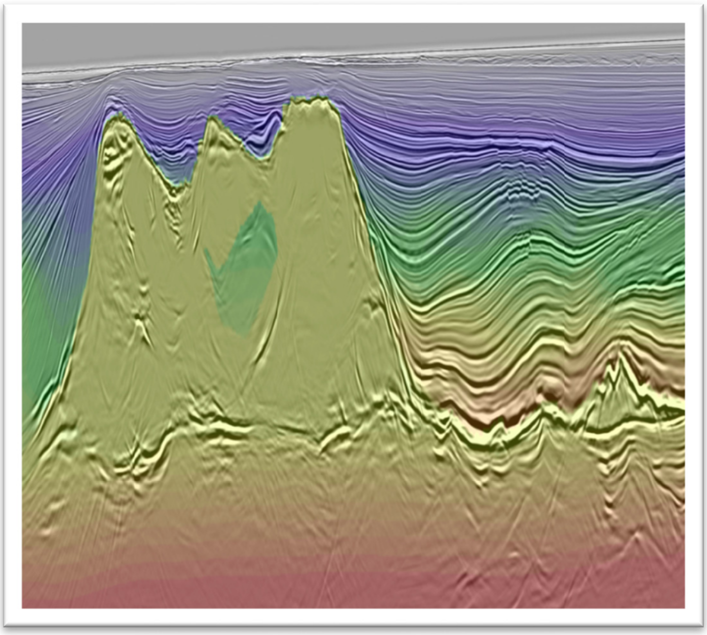

Figure 4 *Salt flood depth image illustrating an area where various geometries of salt could be interpreted.*

Comparison with Brazil

Well data from the Santos Basin, Brazil has indicated that the equivalent evaporate sequence comprises salt layers varying greatly in velocity and density. Mobile halite is present within the Ariri Formation appearing as diapiritic salt, encased with evaporates with different mineral compositions. Overall the non-mobile salts give a typical seismic response identical to a sediment package, however as the individual evaporate velocities can be as low as around 3000m/s for tachydrite and as high as 6500m/s for anhydrite, it can massively affect building a velocity model. While PGS has not identified this phenomenon in their Angolan datasets, it has been suggested that similar sequences exist in deep-water Angola. Well-control penetrating evaporates in Angola is on a limited scale, whereas the Brazilian evaporate sequence has been confirmed by wells across the Santos Basin.

Conclusions

Modern PSDM techniques are critical for generation of accurate seismic images to aid pre-salt exploration. Within velocity model building, there are now tools that can be deployed which greatly reduce uncertainty on salt flank positioning. For some salt bodies located in block 24 & 25, there remains significant uncertainty regarding salt geometry. This can be attributed to a variety of factors including limited illumination or lack of impedance contrast between clastic and evaporate sequences. The problem is compounded in some deep basins where fast carbonates cause a velocity inversion into the salt.

More importantly, there are reflections within the salt whose origin are very poorly understood at present. These reflections could be evidence of multiple salt movements, anhydrite rafting or clastic contamination within salt. For the block 24 and 25 case study, intra salt anomalies do not appear to have a velocity signature that is significantly different from the mobile halite velocity at least to within the resolution limits of surface seismic acquisition.

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References

Merry, A., Madsen, A., Crawley, M. and Trayfoot, M. [2012] Pre-salt imaging offshore Angola. *82nd Annual International Meeting, SEG*, Expanded Abstracts.