

# **The impact of Reverse Time Migration on the evaluation of mature Southern North Sea assets.**

Stuart Fletcher, Centrica Energy Upstream, Maidenhead Road, Windsor, SL4 5GD, Berkshire

## Summary

A case study is presented on the impact of Reverse Time Migration (RTM) in the derivation of a geologically realistic velocity model in a depth imaging sequence applied to a field development in the Southern North Sea. Exceptionally complex salt overhangs in the area make imaging of the Rotliegend objectives particularly challenging and despite repeated applications of the depth imaging technique since the mid 90's, with the most recent one carried out in 2008, it has remained challenging to define the reservoir compartmentalisation and reconcile mapped GIIP volumes with well production profiles. The present interpretive processing workflow, with the application of state-of-the-art RTM in the velocity model building stage and a close cooperation of interpreters and depth imagers, has improved the imaging particularly below salt overhangs, yielded a geologically plausible model of the reservoir structure and offered new options for optimum development well placement.

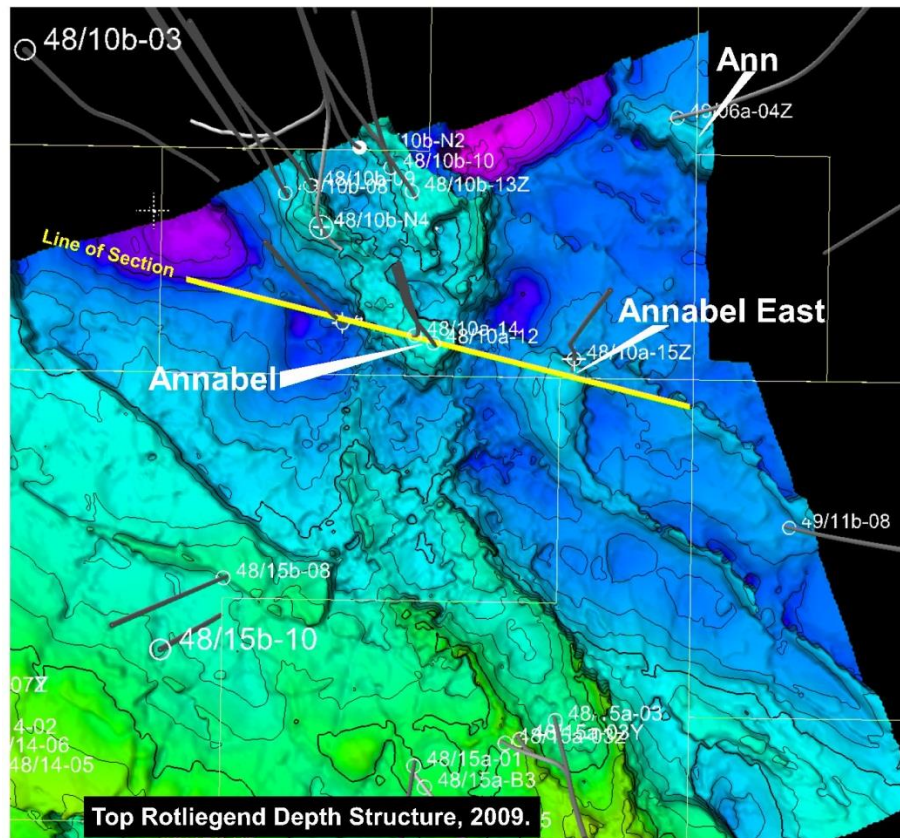
## Introduction

The application of depth imaging to improve the seismic imaging of Permian and Carboniferous reservoirs in the Southern North Sea is well established. Appropriately designed and executed interpretive workflows coupled with the application of advanced depth imaging algorithms result in significant improvements in reservoir definition despite the limitations of the acquisition configurations of legacy 3D data.

In 2008 Centrica (then Venture Production Ltd) carried out a Prestack depth imaging project to help in the evaluation of certain prospects in the 48/10 and 15 blocks. Annabel East, a Rotliegend prospect, was mapped as an independent fault block, on trend with the Annabel field, one of Centrica's producing gas fields

The prospect was drilled in 2009 by well 48/10a-15 which proved the presence of gas, but in a reservoir too tight to be developed. The 2008 PrSDM seismic image shows Annabel East as a separate structure from Annabel, leading to the conclusion that the fault block was tested and proven un-commercial, Figure 2.

However, the story is not as simple. There is a long standing problem of being able to reconcile the dynamic production data from Annabel with the static GIIP volumes.



**Figure 1. Top Rotliegend reservoir (in depth) mapped on the 2008 PrSDM. The Annabel field and the Annabel East prospect appear as two separate fault blocks, separated by a depression.**

The inconsistency suggests that Annabel may be in communication with another gas accumulation, and the neighbouring Annabel East fault block looked to be a prime contender.

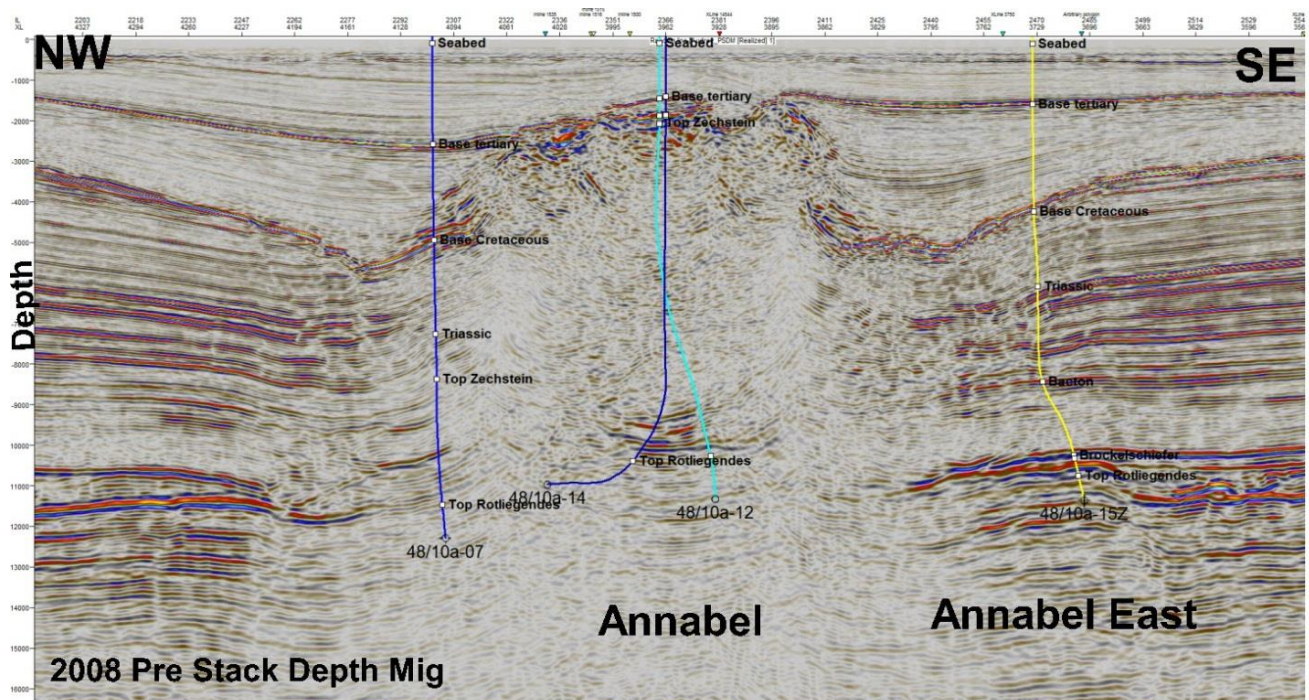
Re-evaluating the structural picture led to the suspicion that the depression separating Annabel and Annabel East may be an imaging artefact due an overestimate of the salt geometry, and the application of too fast velocities on the flanks of the dome.

In an attempt to answer these questions, a new state-of-the-art depth migration project was commissioned, this time deploying Reverse Time Migration.

#### New Depth Imaging, Methods and Results

The failing of the 2008 PrSDM image is that there are no reliable sub-salt reflectors underneath the salt dome flanks. This may be due to poor illumination or the limitation of the ray-tracing-based Kirchhoff algorithm to correctly position reflected energy. In the Kirchhoff method only one travel path/time pair can be migrated and so, in the case where a reflection time can have several travel path options, multi path energy is incorrectly migrated, leading to incoherent noise on the seismic section. The 2008 PrSDM also suggests that there is a syncline between Annabel and Annabel East, (Figure 1) which appears to go against the prevalent NW-SE structural grain of the Permian and underlying structure in the Southern North Sea. In map form and in cross-section, this syncline

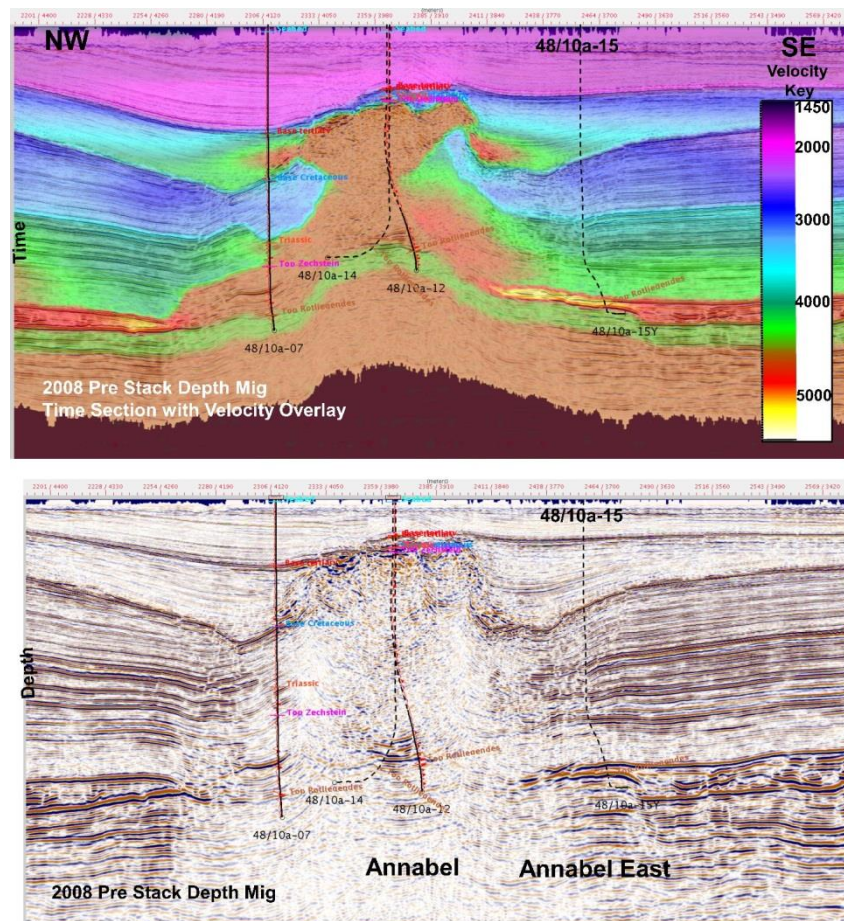
seemed to be salt related pointing to the suspicion that it was an artefact of an erroneous velocity model, (Figure 2).



**Figure 2 NW-SE section through the 2008 PrSDM. The producing Annabel field is separated from the Annabel East prospect by a prominent depression directly below the salt flanks.**

The velocity model derived for the 2008 Kirchhoff migration, (Figure 3) has fast velocities on the flanks which push down the pre-salt horizons. The problem in deriving accurate velocities in this area again lies with the poor continuity of reflections which is thought to be due to the limitations of the Kirchhoff algorithm to account for multipath reflections. This limitation results in the derivation of a sub-optimal velocity model which further hampers correct energy focusing.

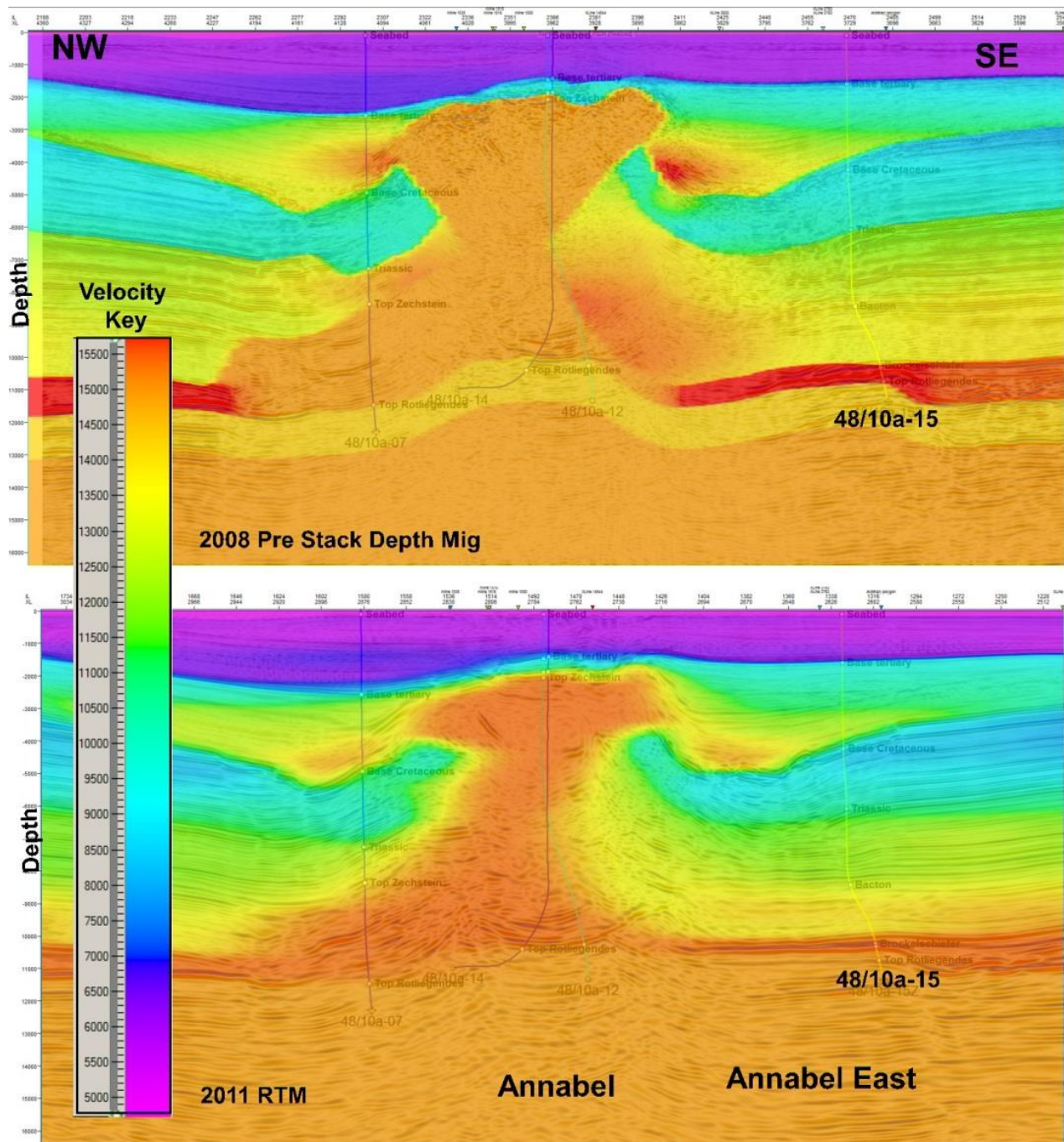




**Figure 3** The 2008 PreSDM interval velocity model (top) and its corresponding depth structure (bottom). High velocities on the RHS of the salt diapir defocus and depress the structure.

Thus, we looked combinations of Reverse Time Migration and Beam Migrations as tools to help us get a more accurate velocity under the salt flanks. Reverse Time Migration is a two-way wavefield extrapolation technique which can account not only for energy travelling along a single direction downwards from the source and upwards from the receiver but also for changing direction double bounce arrivals (e.g prism wave, Jones 2010) as it would certainly be the case in a complex velocity and salt overhang structural model.

In the current flow, the velocity model was built using Kirchhoff summation for the shallow layers and a combination of Beam migration and Reverse Time Migration for the salt edge and steeply dipping layers under the salt flanks. This velocity model was then used for the final Reverse Time Migration. A comparison of the two models is given in Figure 4.



**Figure 4. Depth migrated data of the 2008 (top) and the 2011 (bottom) PrSDM with the corresponding velocity models as colour backdrops. Note the high velocity area to the SE of the salt stem has been eliminated from the 2011 model and the Annabel and Annabel East structures are now at a similar depth.**

Despite being severely limited by the relatively short offsets (less than 3km) of the legacy seismic data, we have achieved a real improvement in the imaging of the steep post salt reflections under the tear drop overhang of the salt, (Figure 5). This figure also shows that the much improved and better focused imaging of the overburden closer to the salt has led, finally, to a more geologically realistic looking Top Rotliegend reflector.



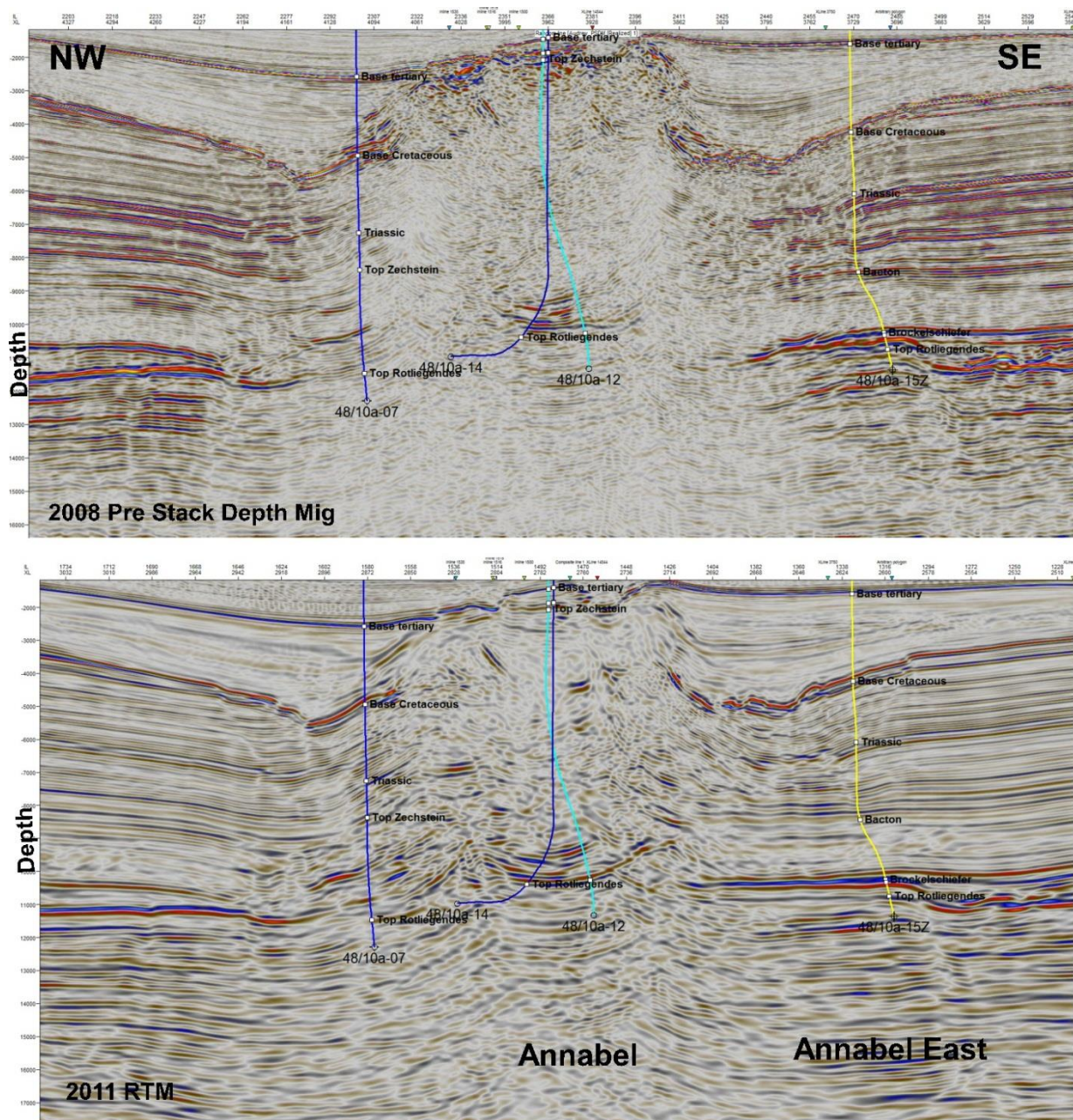
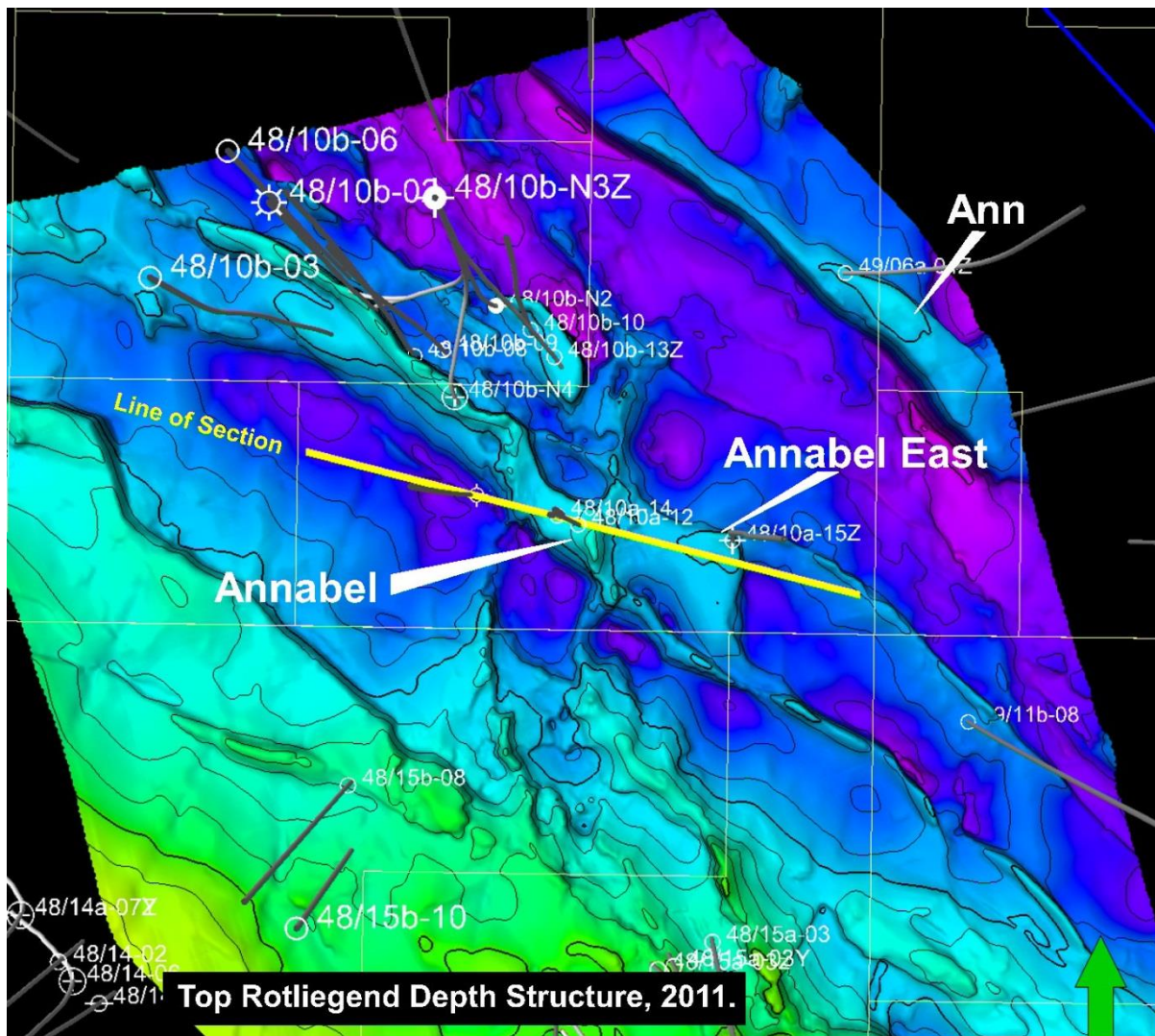


Figure 5 Comparison of the 2008 PreSDM migration (top) and the 2011 RTM (bottom).

In this instance the removal of the structural low between Annabel and Annabel East shows that the two blocks can be structurally linked and that Annabel East is a strong candidate for holding the reserves seen in the production figures of the Annabel wells, Figure 6. Based on this new structural picture Centrica are now looking to drill, once again, into the Annabel East fault block, which, if successful, could be turned into an accelerator production well.





**Figure 6** The revised Top Rotliegend map based on the RTM migration. The Annabel and Annabel East are more convincingly seen as one structure leading to the possibility that the Annabel East block could provide an opportunity for an accelerator well.

There are still a lot of improvements to be made. A small salt imprint on the data remains and the reservoir horizon under the salt flanks still has a lot of artefact interference. This is possibly down to inaccuracies in defining the true salt edge. Ray tracing models suggest reflections bouncing from the overhanging salt flanks may only be captured at offsets of 6-10km. With the 2.5-3.0km cable lengths of our 1990's data it is hardly surprising that we do not see good salt overhang reflections.

## Conclusions

Historically, the image distorting effect of the massive Audrey salt wall has made it very difficult to produce a reliable structural model for well placement and to calculate accurate GIIP volumes. With the gas from Annabel and Audrey being transported to shore via a gas gathering network with an uncertain long term future, there is an economic imperative to get an accurate picture of the existing and future potential for these already mature fields. Reverse Time Migration looks like it will be a useful tool for the geoscientists who have to achieve that goal.

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### References

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