PS Subsalt Imaging: An Integrated Approach to Image Improvement of Vintage Data*

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Abstract

Reservoir objectives trapped under allochthonous salt bodies remain some of the most interesting plays for oil and gas exploration. Accurate imaging of the geological structures is a key factor to reduce uncertainty of the potential prospects. Pre-stack depth migration has been known to help improve the seismic image around complex targets with sharp lateral velocity variations. In a salt environment, the generic workflow to tackle this problem involves several iterations of depth migration, model updating and manual picking of the top and base of the salt bodies.

Velocity model building and seismic imaging of subsalt sedimentary system remains a challenge in the petroleum industry. Thus, in this study, we have taken a step forward to improve subsalt imaging by combining: 1) state-of-the-art pre-processing techniques of long-offset vintage data, such as de-noising, efficient attenuation of surface related multiples and its diffractions, and deghosting1; 2) iterative seismic interpretation of allochthonous salt bodies; and 3) cutting edge velocity model building technique such as multi-parameter acoustic full waveform inversion2 (FWI) and ray-based tomography. The result of this approach largely improves the salt geometry and the resolution of the velocity model, thus leading to an improved final migrated subsalt image. The final image using reverse time migration3 (RTM) with surface offset gathers, benefitting from a low frequency boost from the deghosting applied during the pre-processing, gives rise to better imaging of deeper sediments.

In conclusion, with the inherent difficulties in subsalt imaging, we are able to show the value of a multi-faceted approach to providing uplift in the subsalt image. For vintage acquired seismic datasets, modern pre-processing techniques such as deghosting, can add immense value. Combining this enhanced pre-processing with iterative seismic interpretation of allochthonous salt bodies, and multi-parameter acoustic FWI, helps achieve a global improvement of the image of sediments subsalt leading to better de-risking of exploration prospects.

Selected References

Giboli, M., R. Baina, L. Nicoletis, and B. Duquet, 2012, Reverse time migration surface offset gathers part 1: a new method to produce 'classical' common image gathers: 82nd Annual International Meeting, SEG, Expanded Abstracts, http://dx.doi.org/10.1190/segam2012-1007.1.

Landolsi, F., B. Duquet, C. Rivera, and E. Bergounioux, 2016, Multiparameter acoustic FWI: Marine carbonates case study: SEG Technical Program Expanded Abstracts, 2016, p. 1263-1267, http://dx.doi.org/10.1190/segam2016-13779014.1.

Poole, G., S. King, and J. Cooper, 2016, Simultaneous Source Designature and Receiver Deghosting in the Joint Shot-Receiver Domain: 78th EAGE Conference and Exhibition, 2016.

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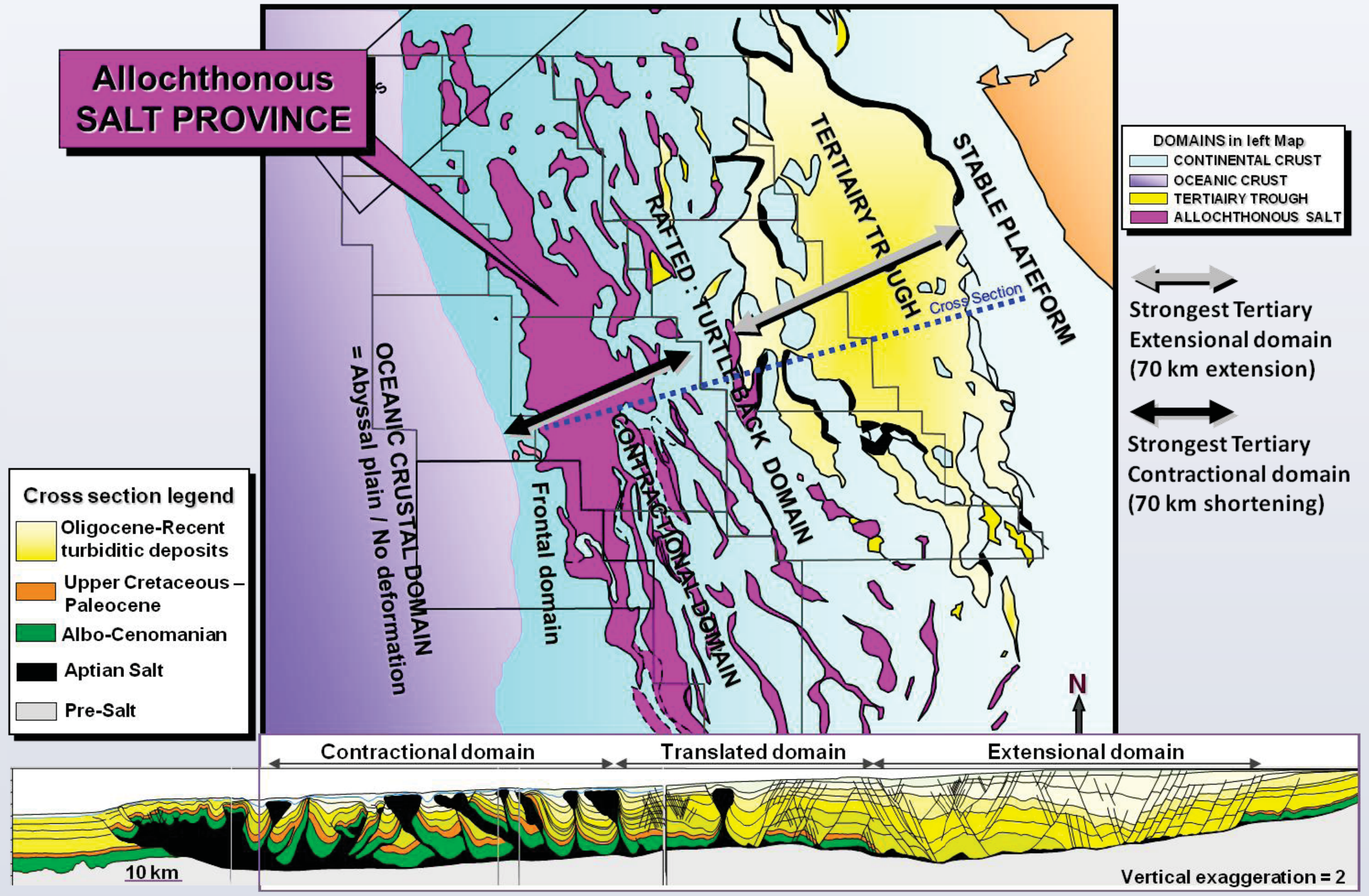
ABSTRACT

Reservoir objectives trapped under allochthonous salt bodies remain some of the most interesting plays for oil and gas exploration. Accurate imaging of the geological structures is a key factor to reduce uncertainty of the potential prospects. Pre-stack depth migration has been known to help improve the seismic image around complex targets with sharp lateral velocity variations. In a salt environment, the generic workflow to tackle this problem involves several iterations of depth migration, model updating and manual picking of the top and base of the salt bodies.

Velocity model building and seismic imaging of subsalt sedimentary system remains a challenge in the petroleum industry. Thus, in this study, we have taken a step forward to improve subsalt imaging by combining: 1) state-of-the-art pre-processing techniques of long-offset vintage data, such as de-noising, efficient attenuation of surface related multiples and its diffractions, and deghosting[1]; 2) iterative seismic interpretation of allochthonous salt bodies; and 3) cutting edge velocity model building technique such as multi-parameter acoustic full waveform inversion[2] (FWI) and ray-based tomography. The result of this approach largely improves the salt geometry and the resolution of the velocity model, thus leading to an improved final migrated subsalt image. The final image using reverse time migration[3] (RTM), with surface offset gathers, benefitting from a low frequency boost from the deghosting applied during the pre-processing, gives rise to better imaging of deeper sediments.

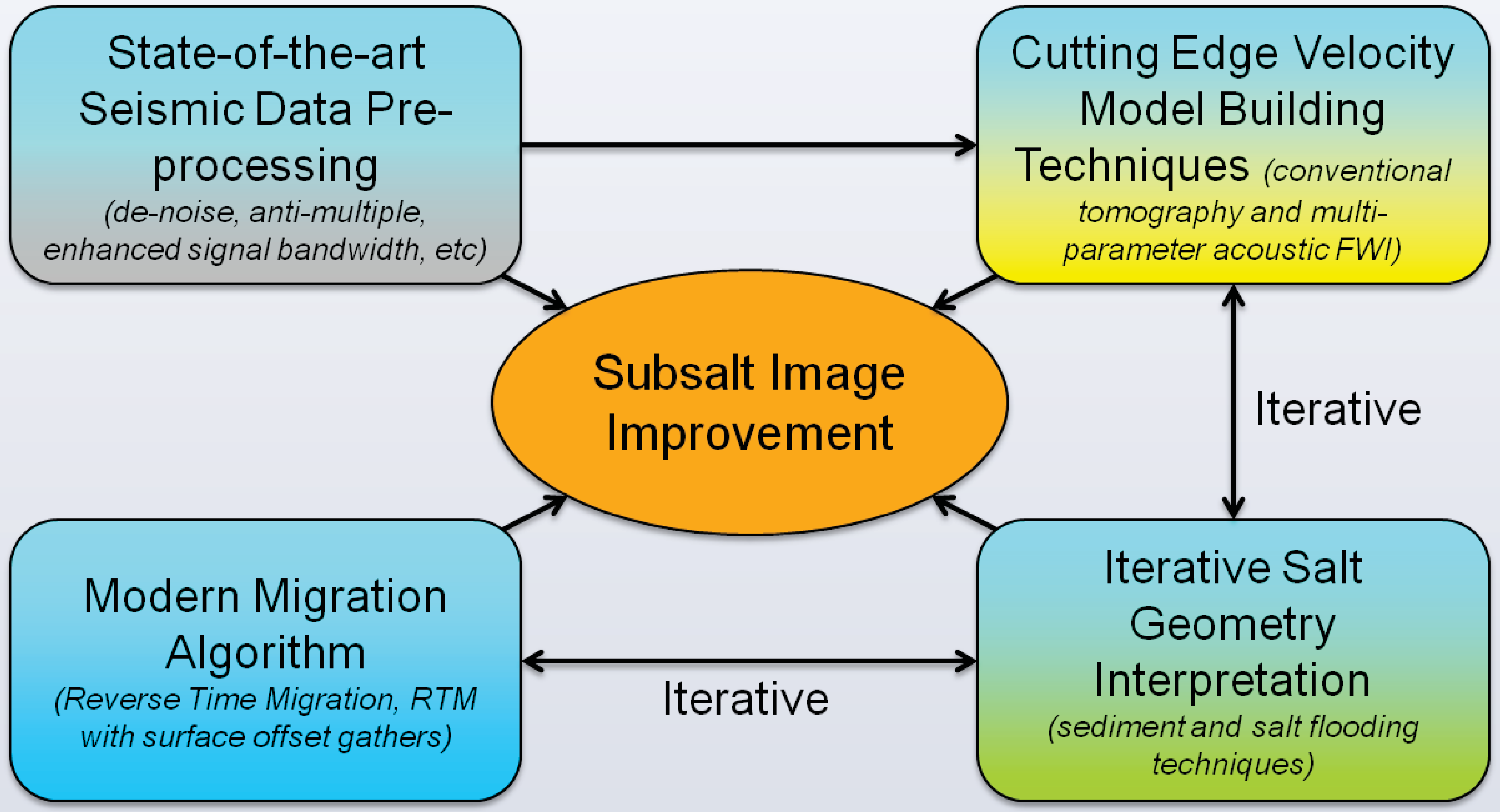
In conclusion, with the inherent difficulties in subsalt imaging, we are able to show the value of a multi-faceted approach to providing uplift in the subsalt image. For vintage acquired seismic datasets, modern pre-processing techniques such as deghosting, can add immense value. Combining this enhanced pre-processing with iterative seismic interpretation of allochthonous salt bodies, and multi-parameter acoustic FWI, helps achieve a global improvement of the image of sediments subsalt leading to better de-risking of exploration prospects.

GEOLOGICAL CONTEXT



- The field of study lies within a structurally complex domain in the contractional part of the above tectono-sedimentary chart, which is part of the gravity gliding system of a passive margin basin. This complexity is due to the gravity driven shortening recorded here i.e. 70km in ENE-WSW direction and associated with a big amount of shallow allochthonous salt bodies that covers a large part of the area. The shortening leads to complex thrusting geometries with duplicate or even triplicate post-salt series (i.e. the Albo-Cenomanian and Upper Cretaceous-Paleocene sedimentary series). There is also a huge quantity of allochthonous salt sheets amalgamated in canopies.
- The vintage depth imaging project conducted over this area in order to better understand the structural complexity still remained a challenge due to the multi-allochthonous salt bodies and the complex sediment deformation with very steep geometries.
- Thus an integrated approach to providing an uplift to the subsalt image was derived starting from state-of-the-art pre-processing of pre-migration seismic traces to the use of cutting edge velocity model building techniques and migration algorithm.

SUBSALT IMAGING WORKFLOW



Subsalt imaging projects can be long and tedious and as such an adaptive workflow is needed to sufficiently handle the subsalt imaging challenges. This process is iterative which allows better optimization of parameters for each phase of the workflow.

Working closely with seismic interpreters cannot be over-emphasized as it allows for an efficient process aimed at improving subsalt image towards petroleum exploration objectives.

The use of High Performance Computing (HPC) during this study allowed for more scenario testing both for velocity model building and salt geometry interpretation leading to increased confidence in the quality of delivered results.

Keywords: acoustic, deghosting, full waveform inversion, subsalt, reverse time migration surface offset gathers, tomography

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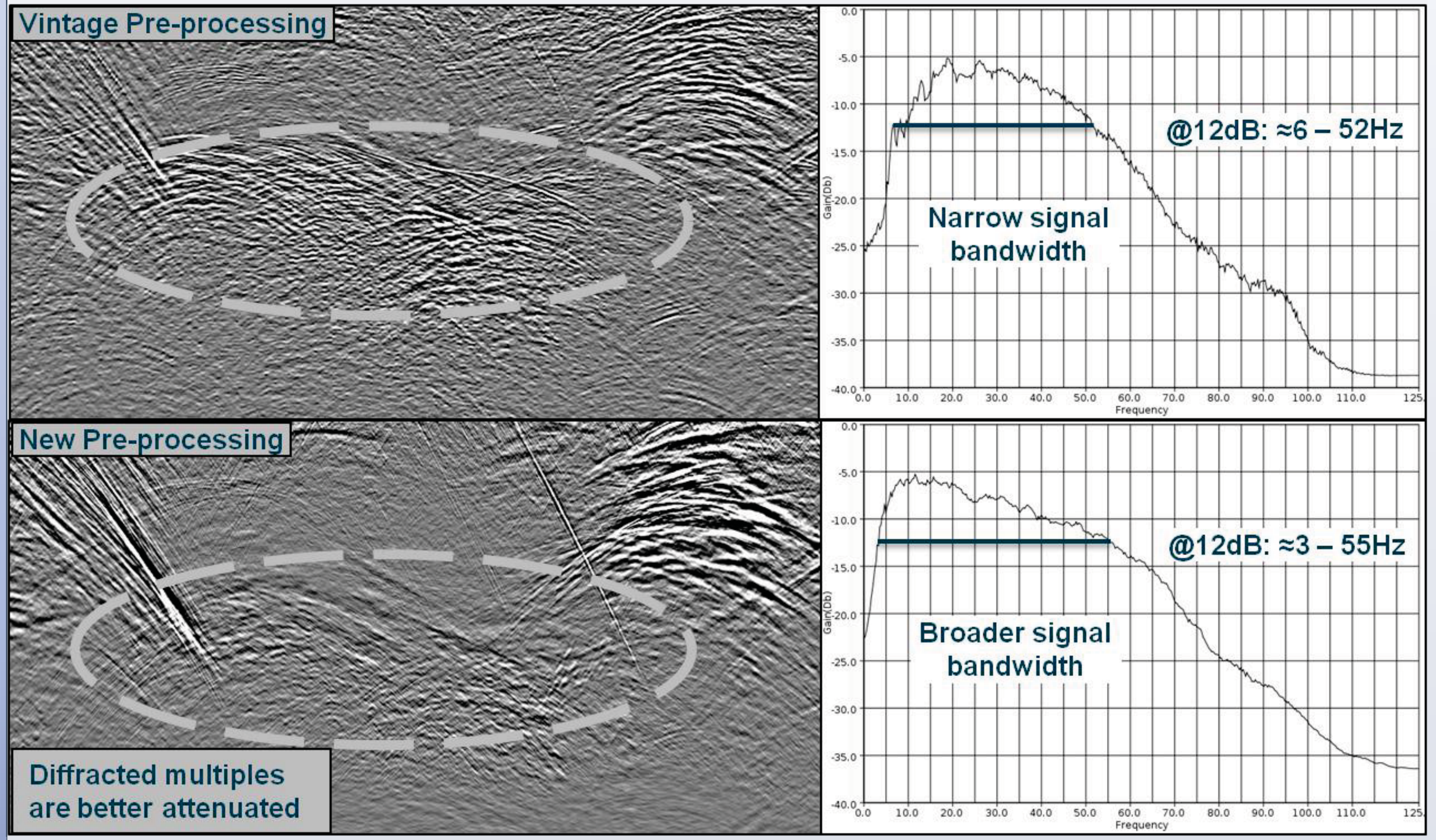
INPUT SEISMIC DATASET

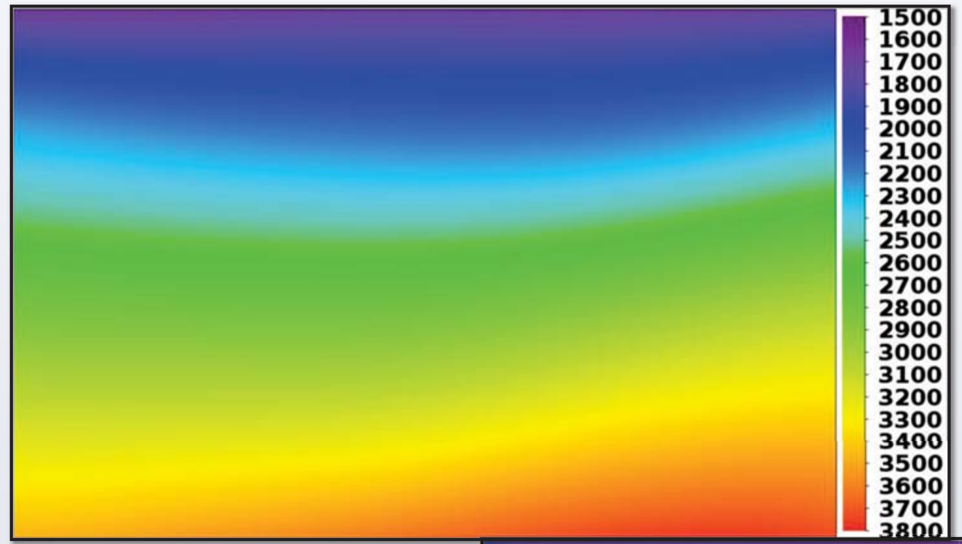


The first step in this PSDM study was to revitalize the vintage seismic dataset by means of an efficient pre-processing workflow. This vintage dataset was a Long-Offset Narrow Azimuth (LO NAZ) seismic acquisition. Some important steps in this workflow for the marine acquired data included:

- De-noising: low-cut filter, swell and linear noise attenuation, etc;
- Optimal multiple energy attenuation: free surface related multiples and related diffracted energy;
- Preservation of high frequency signal and enhancement of low frequency signal through the use of AVO friendly deghosting method.

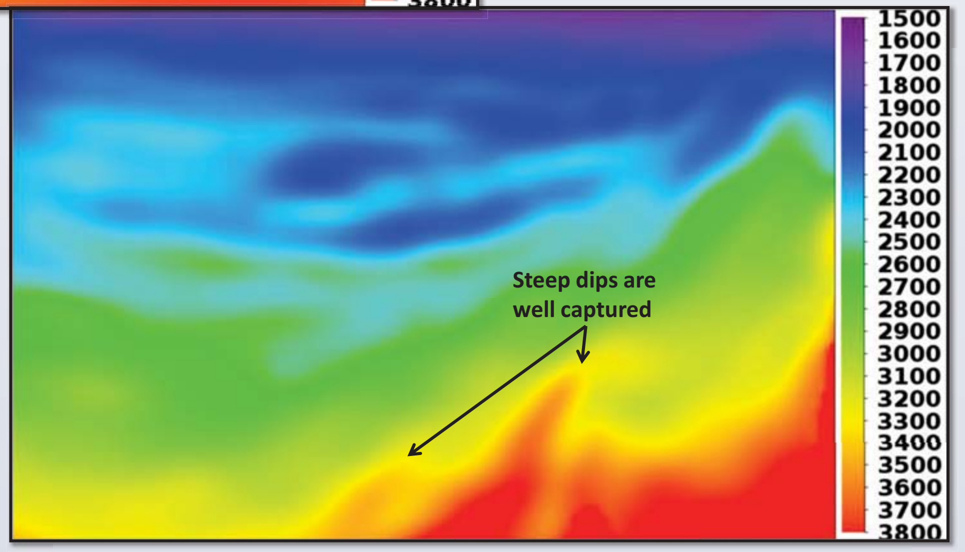
As is shown in the above image, we achieved a good result from this pre-processing as we reduce the impact of free surface related multiples and related diffracted energies. In addition we improve the seismic signal bandwidth needed to image deeper subsalt sediments.

VELOCITY MODEL BUILDING



Vintage Velocity Model
- Simplistic model

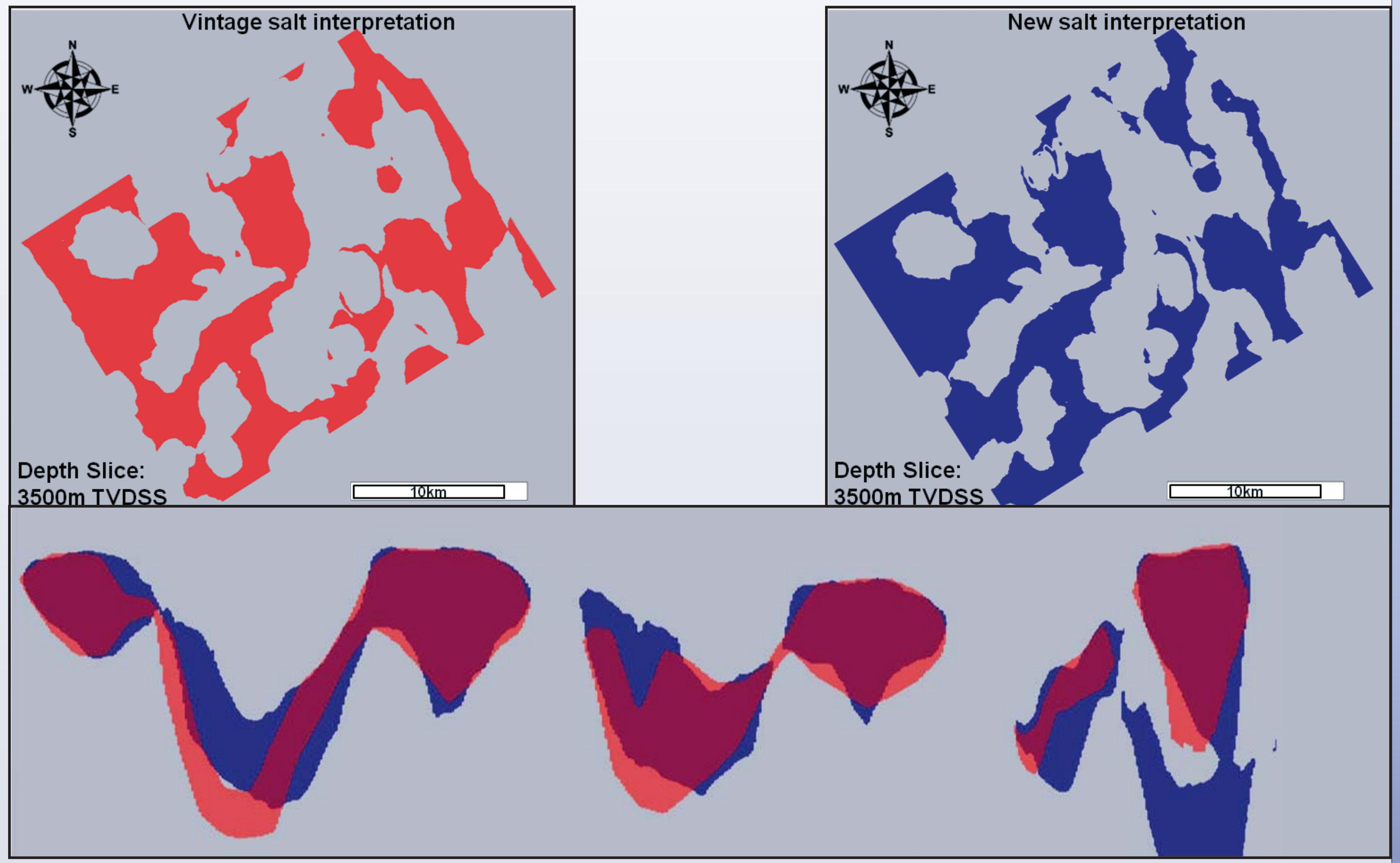
New Velocity Model
- Structurally consistent high resolution model



Thanks to an exhaustive approach to velocity model building, we were able to improve the velocity model in comparison to the vintage velocity model. The following steps were carried out :

- Several iterations of conventional tomography were achieved so as to solve for the long wavelength component of the velocity field, first in isotropic domain and afterwards in anisotropic domain;
- Once satisfied with the background sedimentary model, salt geometry interpretation commenced in order to constrain the salt bodies in preparation for multi-parameter acoustic FWI.
- Multi-parameter acoustic FWI was launched up to 8.8Hz in order to further improve the sedimentary velocity model, thus leading to an overall improvement of the seismic image.

SALT GEOMETRY INTERPRETATION



This step was very important as complex salt geometries are known to advertently affect the penetration of seismic signals thus leading to poor illumination of subsalt sedimentary packages. The following steps were done:

- Several iterations of allochthonous salt geometry interpretation from Top of Salt (ToS) to Base of Salt (BoS) which included capturing salt over-hangs and salt keels;
- Results from internal regional synthesis studies indicated that in this region, the salt bodies have varied compositions, thus giving rise to an average salt velocity of 4250m/s in comparison to a 4500m/s used in the vintage salt geometry interpretation. The salt flooding was done using average salt velocity of 4250m/s in this area.
- This gave rise to different salt geometry and thicknesses in comparison to the vintage interpretation.

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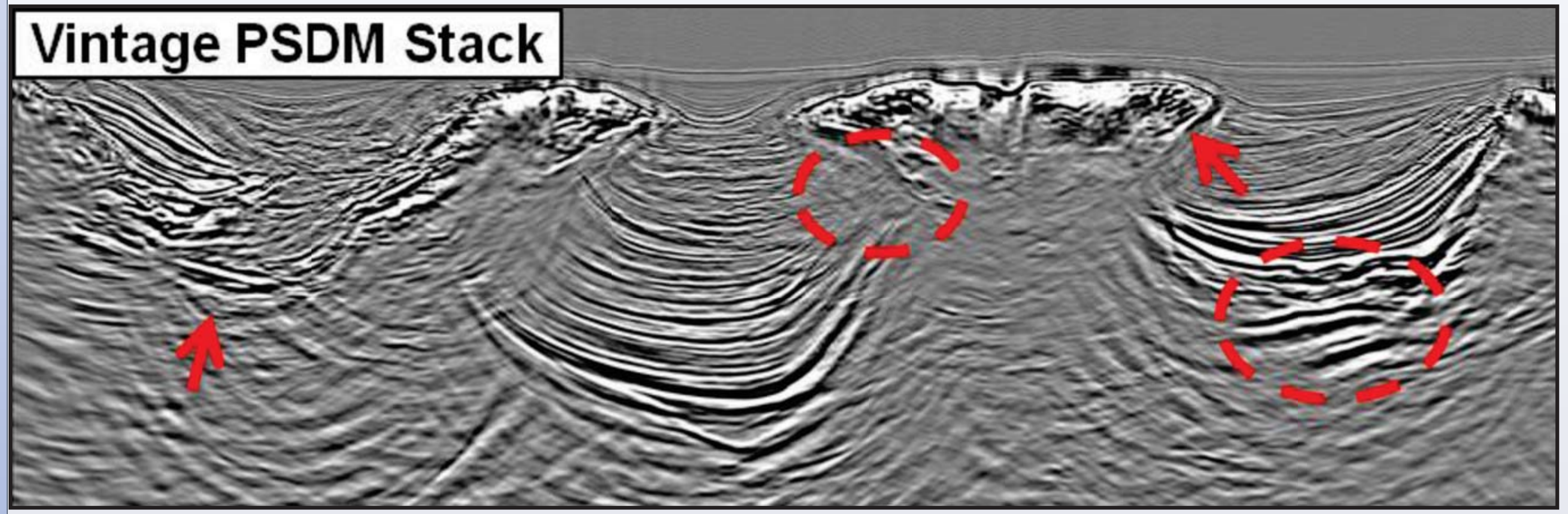
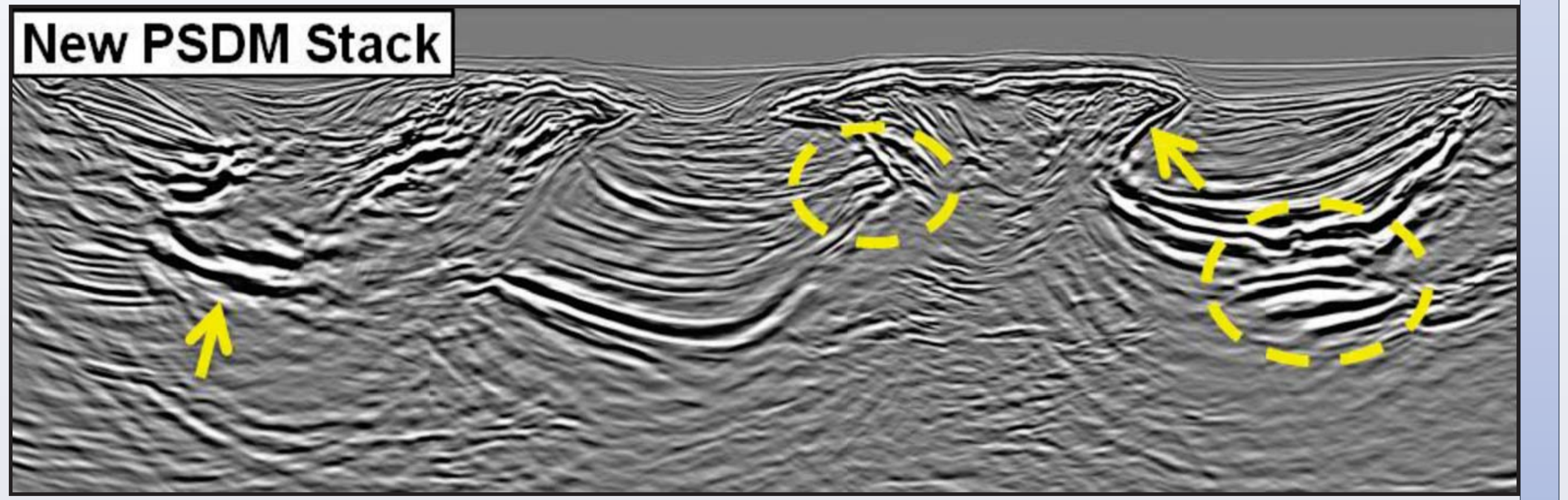
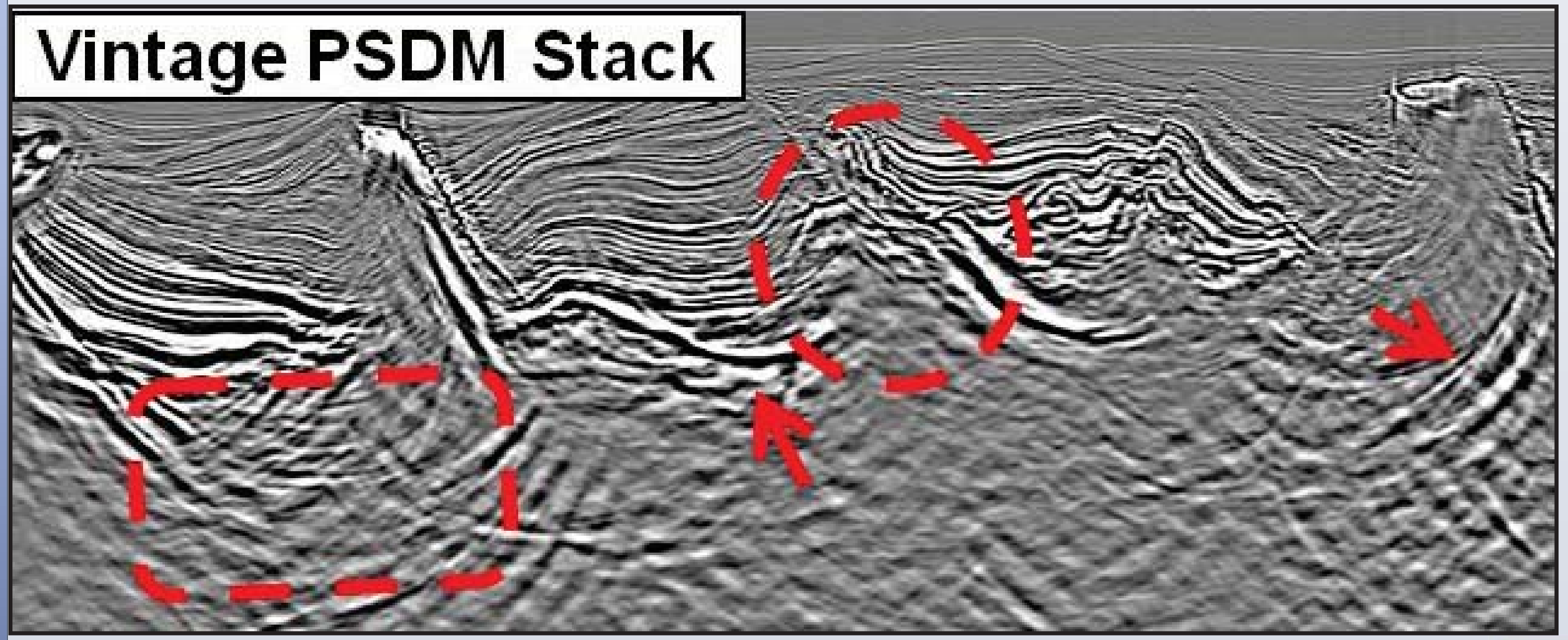
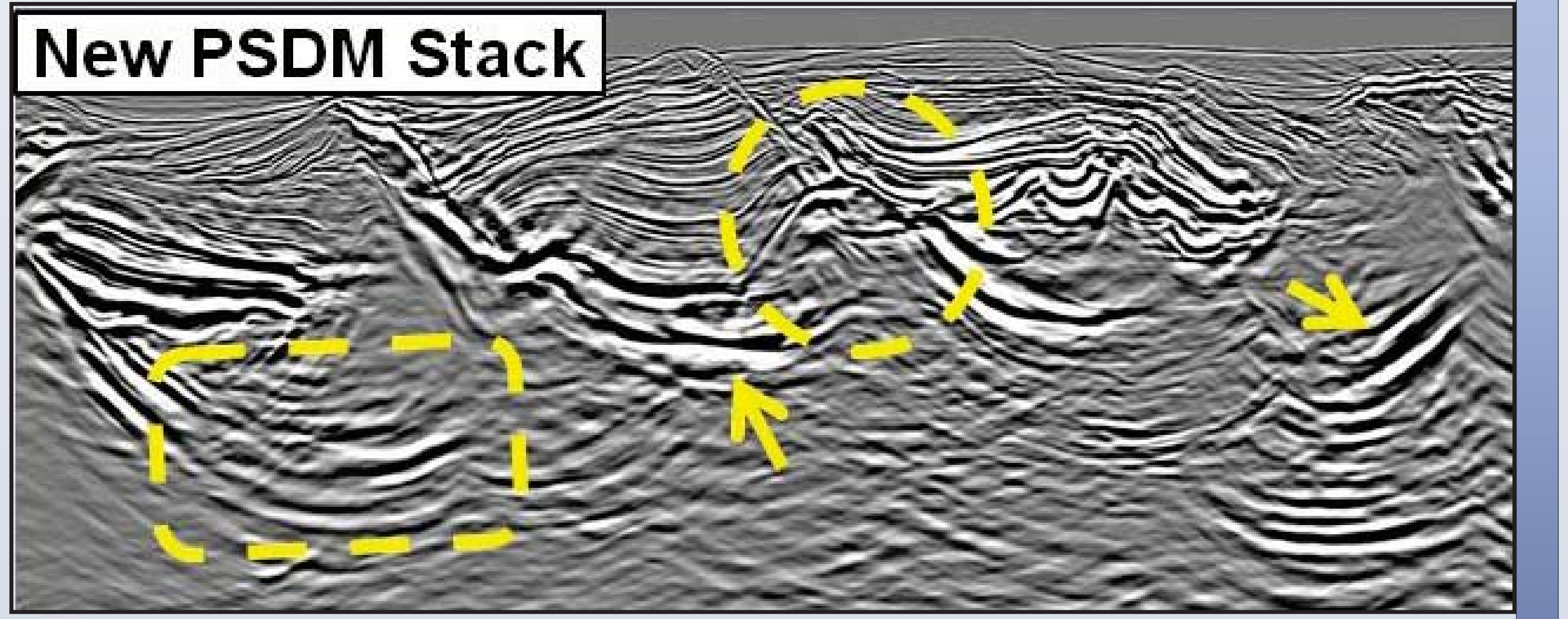
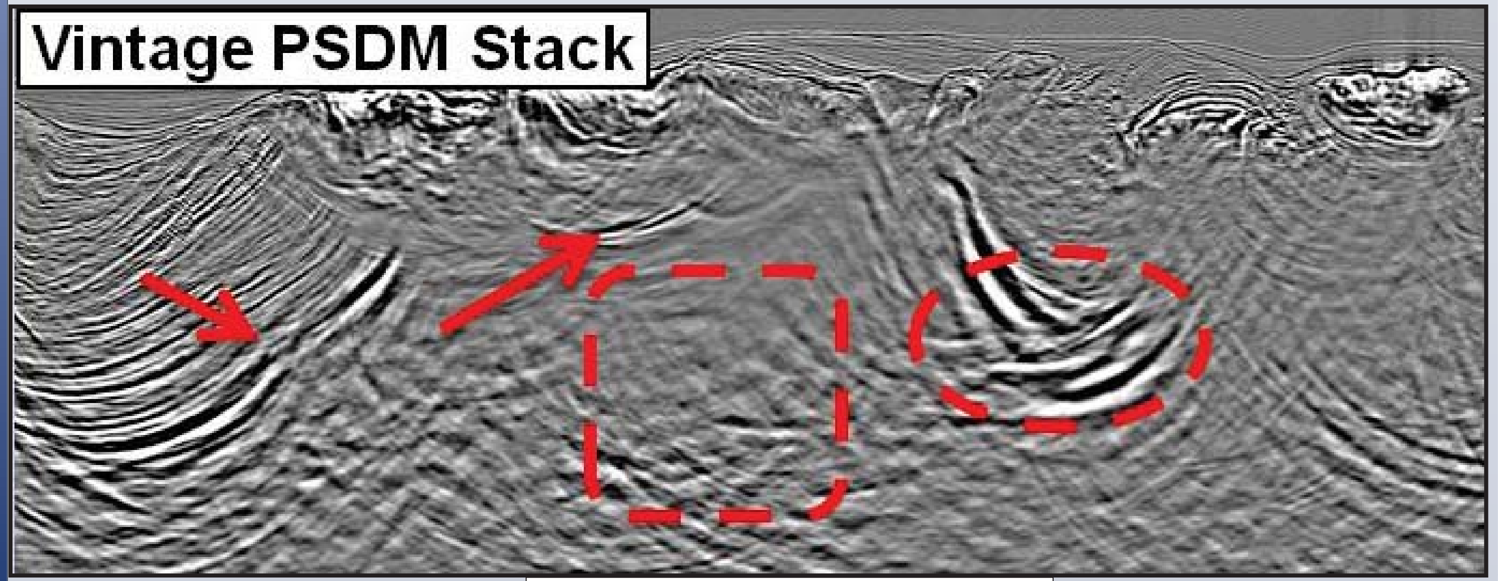
RESULTS





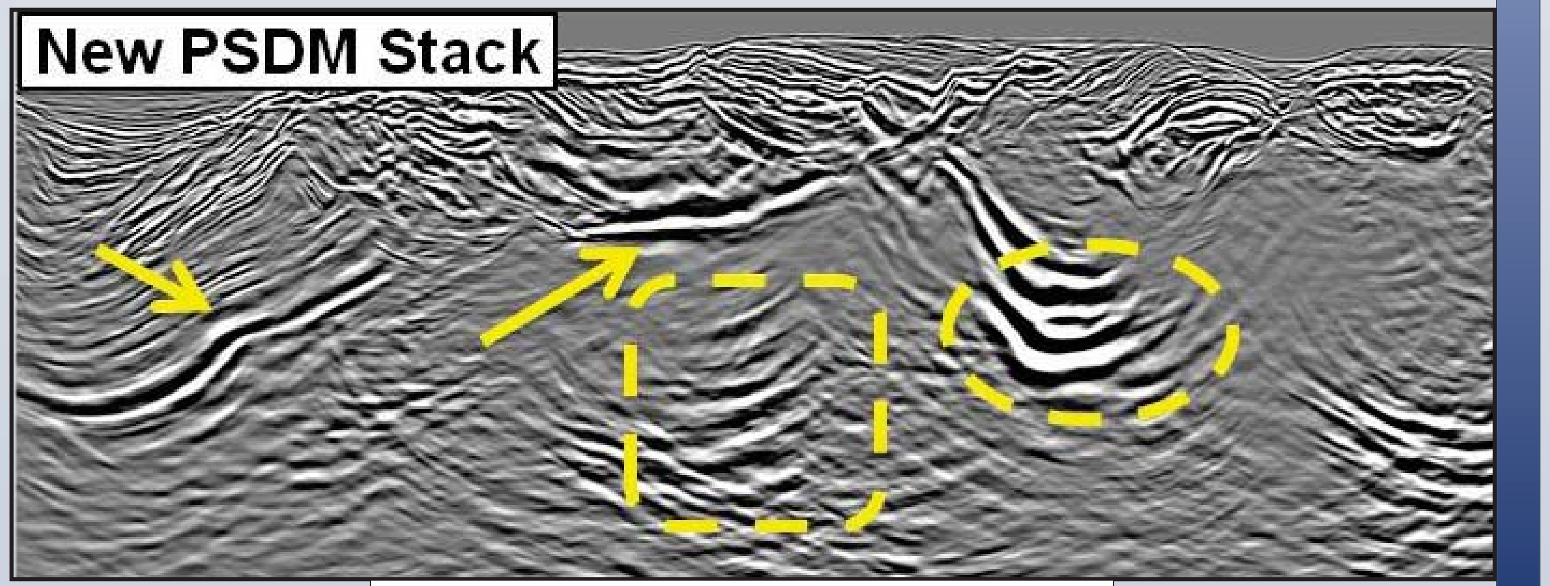






Common Azimuth Wave Equation (one-way)

The use of modern technology in seismic imaging, Reverse Time Migration (with surface offset gathers), was very instrumental in improving the seismic image. Steep dips are properly imaged with improved focusing and continuity of sedimentary packages in comparison to vintage dataset.



Reverse Time Migration with Surface Offset Gathers (two-way)

CONCLUSIONS

- DO NOT DISCARD VINTAGE DATASETS!!! With cyclic economic downturn in the petroleum industry and with the availability of modern technologies in seismic imaging, vintage datasets can be revitalized to yield some more value.
- With the already described methodology, we were able to globally improve the subsalt image which will lead to better definition of exploration objectives.
- In any case, for such a structurally complex domain, a game changer will definitely be needed, in terms of input seismic data by way of modern seismic acquisition techniques such as longer offset acquisition and wide-azimuth acquisition with enhanced seismic signal bandwidth.

REFERENCES

1. G. Poole, S. King and J. Cooper, 2016. “Simultaneous Source Designature and Receiver Deghosting in the Joint Shot-Receiver Domain”: 78th EAGE Conference and Exhibition 2016
2. F. Landolsi, B. Duquet, C. Rivera, and E. Bergounioux, 2016. “Multiparameter acoustic FWI: Marine carbonates case study”: SEG Technical Program Expanded Abstracts 2016: pp. 1263-1267, http://dx.doi.org/10.1190/segam2016-13779014.1
3. M. Giboli, R. Baina, L. Nicoletis, and B. Duquet, 2012. “Reverse time migration surface offset gathers part 1: a new method to produce ‘classical’ common image gathers”: 82nd Annual International Meeting, SEG, Expanded Abstracts, http://dx.doi.org/10.1190/segam2012-1007.1

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