9th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2012"

P-396

Sub-Basalt Imaging in Indian offshore - Concerns and Possible Solutions

C.Visweswara Rao*, S.Chandrashekar, P.S.N.Kutty, *ONGC*

Summary

Recent exploration successes in Kutch offshore warranted relook in to exploration in sub basalt in Indian offshore. Lot of work has been done in this aspect but a lot is yet to be done. In this study, a trial is made to put together all efforts made, discuss concerns still persisting and possible solutions for sub basalt imaging in Indian offshore.

Keywords: *High velocity basalt layer, velocity model, Sub-basalt imaging, geological settings and so iterative processing.*

Introduction

Indian offshore is covered with high velocity basalt layer to a large extent. Around 2000 Km. area in western offshore itself is covered with basalt layer. Conventional seismic methods proved non viable for imaging beneath the basalt. Experimentation with most of the available industry practices has led to little success imaging the basalt and below. With application of the latest methods and lessons learnt, search for possible solution is being thought of. This work is a step towards that angle.

High-velocity basalt layers in Indian offshore hamper the imaging of possible hydrocarbon reservoirs beneath them. The ability to image seismically the subsurface below the basalts is limited by the fact that basaltic layers are characterized by the poor penetration because of high reflectivity contrasts at the top of basalt and also due to intra basalt discontinuities, attenuation and strong internal scattering of seismic energy. The sea bottom and the high reflectivity of the basalt-sediment interfaces generate multiples that contaminate the primary near- offset P-wave reflections.

The issues related to sub basalt imaging are summarized as below:

- existence of inter-trappeans
- thickness variations / no. of basalt flows
- physical and mineralogical heterogeneity
- varied lithology below basalt
- existence of intrusive bodies
- unconformity related issues

The geophysical effects related to the above are given below:

- Discontinuous reflections
- multiples
- poor energy penetration
- difficult velocity analysis
- diffractions
- poor S/N Ratio
- mode conversions

It is difficult to image the structures beneath the massive basaltic layers with conventional seismic acquisition and processing methods as the complex basalts scatter and highly attenuate seismic energy. Also, generally weak sub basalt signal may be obscured by the short period multiples from intra- basalt boundaries.

There is no single acquisition model or established processing flow which can suit all the sub basalt imaging issues of all geological settings and hence extensive experimentation is required for each typical area of study.

603, 6th Floor, Priyadarshini building, ONGC, WOB, EE Highway, SION, Mumbai-400022:
choppallirao@gmail.com

To preserve the signal to noise ratio underneath the basalt and to improve the multiple suppression by addressing issues related to inter-bed and diffracted multiples are the challenges to be tackled in sub basalt imaging.

Methodology

Longer offsets and high volume guns have become a standard practice in sub basalt acquisition. Towing the streamer at deeper levels found to be helpful in increasing signal to noise ratio especially while dealing with ambient noise.

Tau-P linear noise attenuation and de-convolution with specific parameters for illuminating deeper events is a challenging task. Long predictive distances help but longer PD selection to the adequate value may again be suicidal. Long predictive distances allows lower frequencies which come from deeper levels but once PD crosses adequacy, and if still longer PD is selected, it may be as well equivalent to "All allow" condition. Hence proper selection of long PD is the requirement.

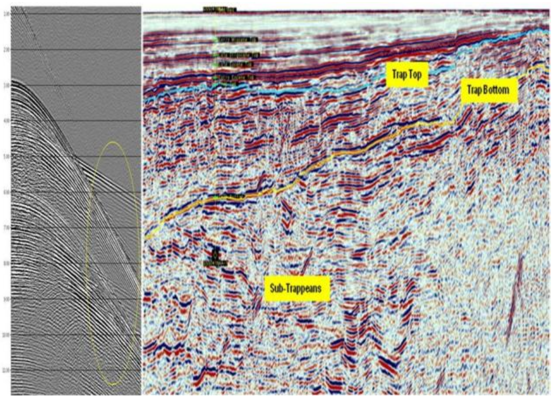

Fig:1: a) Raw shot gather and b) PSDM stack showing the top, bottom of basalt and possible Mesozoic reflections brought out through processing methods discussed.

Accurate estimation of intra-basalt seismic velocities and seismic velocities beneath the basaltic sequences is necessary for sub basalt imaging. Refined seismic velocity field plays a dominant role in illuminating the sub-basalt reflections. Velocity inversion is often important at the base of the basalt since it indicates the location of possible interface between the high velocity basaltic sequence and the low velocity sub basaltic units.

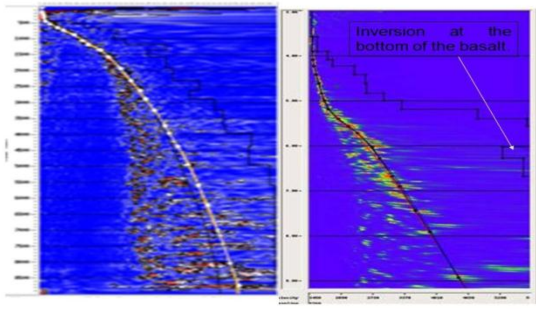

Fig:2 Velocity semblance without and with inner mute application.

Stacked basalt flows exhibit the low pass character to seismic waves. The large velocity contrast at the top- basalt boundary and the high impedance contrasts between the intra basalt layers are causing the significant loss of seismic energy.

Restriction of frequency ranges to the processing inputs at different stages helped in getting the clearer image. As the requisite frequencies for sub-trappeans are in the lower range and the noises are found to be of higher frequencies, filtering the higher frequencies at post and pre-stack levels by studying the frequency responses is applied. If the noise levels due to unwanted events are more, pre-stack, post migrated TVF for PSTM is found effective. For mild background noises, post stack TVF going lower below the basalt has helped in getting the events. In case of velocity analysis, application of inner mute and TVF to the input data to the velocity target lines has given better standouts for the semblances.

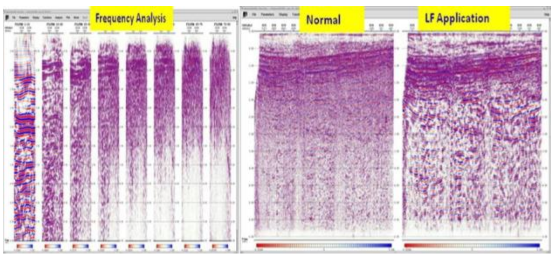

Fig:3 a) Frequency analysis and b) stack section comparing normal and low frequency processed stacks which shows that LF stack gives better image.

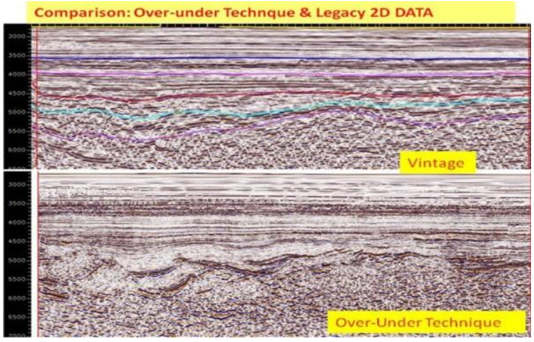

Fig:4 Comparison between a) Vintage and b) DISCover(OU) stack.

The fractured basalts and surface reliefs in the West Indian Coast displace the parabolic move-out to non- zero finite offsets. These diffracted multiples may not be addressed by standard applications like radon transform alone.

Since the high velocity contrast at a sediment basalt interface causes large ray bending at non normal angles of incidence, a significant part of energy appears at longer offset larger source receiver offsets than in regions without high velocity contrast. The near offset part of the wave field is influenced by the peg-leg multiple generated at intra basalt boundaries, either reduction or elimination of peg-leg energy through the application of inner mute can strengthen arrivals from the larger offsets.

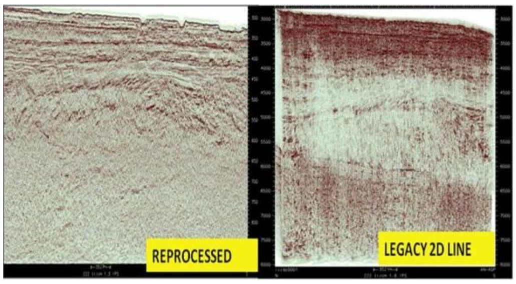

Fig:5 Comparison between a) reprocessed and b) Legacy stack.

The weak sub basalt PP reflections interfere with strong (surface-related and internal) multiples and converted-wave arrivals caused by dramatic elastic-impedance contrasts between the HVLs and surrounding relatively soft sediments. The precise mechanism to deal with the noise varies from case to case.

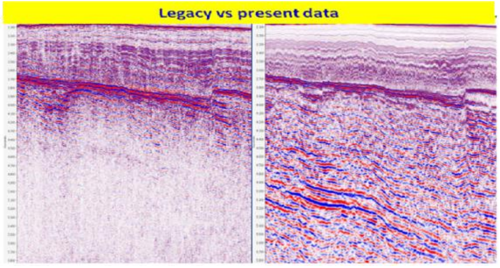

Fig:6 Comparison between a) processed and b) Legacy stack.

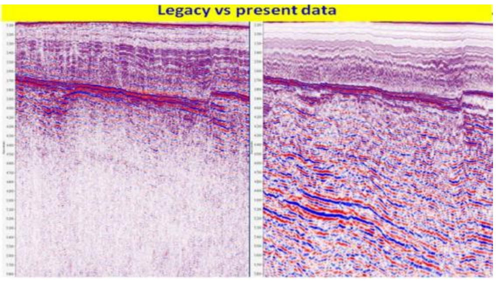

Fig:7 Comparison between a) processed and b) Legacy stack.

A major problem of building a velocity model for data such as these is the accurate mapping of the whole volcanic succession and the estimation of sediment velocities beneath the basalt structure. Since variety of multiples (water-bottom, peg-leg, inter- basalt, etc.) and converted waves have a significant impact on image quality, the choice of migration will depend upon the possibility of handling the arrivals that mask the primary signal. The need of model- based imaging and optimal velocity strategy is felt at this stage.

Sub-basalt imaging can be improved by careful application of Pre-stack depth migration which in- turn requires a detailed velocity model and an accurate travel-time calculation.

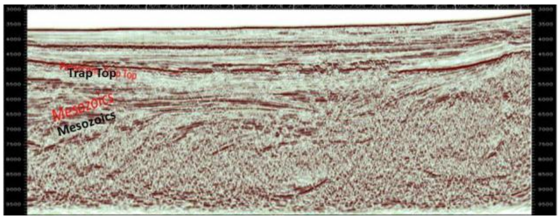

Fig:8 Beam PSDM processed stack showing trap top and mesozoics.

Pre stack depth migration (PSDM) handles multi- arrivals which produce quality imaging in complex geological settings. Building of the geologic model and the velocity field is the most critical step in PSDM processing. Beam Processing is attempted in different areas. The PSDM results in west coast could give some morale in identification of sub-trappean events but the problem of mapping the bottom of basalt layer is still there.

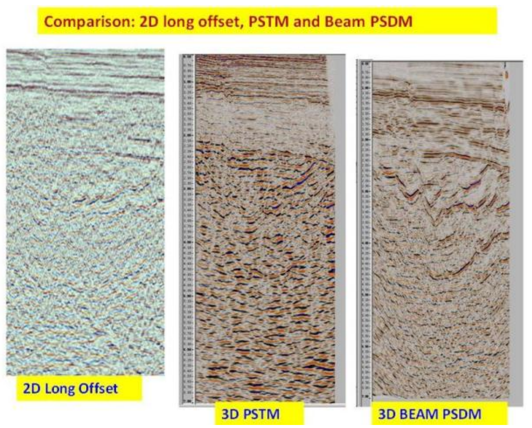

Fig:9 Comparison between a2D Long offset b) 3D PSTM and b) 3D Beam PSDM stack. Clear image in Beam stack.

Anisotropy (e.g., directional dependence of velocity at a fixed spatial location in a medium) plays a very important role in seismic imaging. It is difficult to know the presence of anisotropy in the subsurface geological settings from P-wave seismic data. The presence of anisotropy causes two major distortions of move-out in P-wave seismic reflection data. In anisotropic medium, first is normal move-out (NMO) velocity differs from the vertical velocity; and the second is substantial increase of deviations in hyperbolic move-out in an anisotropic layer. Conventional close grid velocity analysis does not provide enough information to determine the true vertical velocity in all media. Velocity analyses are to be done at closer intervals and it is ideal to go for velocity analyses at every location. Efforts are made in 2D long offset processing to go closer to 250m velocity analysis.

Application of lesser pass frequency bands by attempting time variant filters which gradually restrict the arrival of band of frequencies from top of basalt to sub basalt layers has helped in getting clearer image. Selection of frequencies was done by identifying the available frequency ranges at different subsurface levels, thereby restricting the entry of undesirable frequencies to the processing inputs at different stages.

Results & Conclusions

Sub-basalt imaging issues in Indian offshore have been less understood prior to the experimentation and while proceeding with application of different industry standard technologies, the understanding is developed and steps are taken towards better understanding of the subsurface c\scenario.

As said earlier in this study, there is no single acquisition method or established processing flow which can suit all the sub basalt imaging issues of all geological settings and so iterative processing and reprocessing techniques are to be adopted to reach satisfactory level in imaging the basalt and beneath the basalt. Information from the recently drilled wells may have to be incorporated while reprocessing the data for better understanding.

Recent successes in sub basalt exploration in western Indian offshore warrant the extensive exploration through the basalt, but authors warn that it is always to keep in mind that conventional processing methodology may not be helpful and object oriented cautious approach as discussed may be the solution to get the requisite imaging below the basalt.

The views expressed in this paper are exclusively of the authors and need not necessarily match with official views of ONGC.

References

2D Long offset data processing for sub basalt- A Case history, C.Visweswara Rao*, AVK Suryanarayana, 8th Biennial International Conference & Exposition on Petrolelum Geophysics, SPG India,2010.

Optimising acquisition geometries for sub-basalt imaging: a modeling study, Peter Hanssen 1, Xiang- Yang and Anton Ziolkowsky

Moritz M Fliedner and Robert S. White, First Break Volume 19.5 May 2001, Sub-basalt imaging in the Faeroe-Shetland basin with Large-offset data

Moritz M Fliedner and Robert S. White, Geophys. J int. (2003) 152,353-371, Depth imaging of basalt flows in the Faeroe-Shetland basin.

R.S White, R. Spitzer, P,A,F Christie & ISMM team, Petex 2004, Seismic imaging through basalt flows on Faeroe shelf.

A.V.K.Suryanarayana and C.B.Yadava, Petrotech 2003, New Delhi., Sub Basalt imaging using large aperture.

Reflection Seismics in Saurashtra region, Western India. A.V.K.Suryanarayana, CGT 2005, Imaging of sub basalt mesozoics in Kutch Offshore, India.

Acknowledgements

The authors sincerely acknowledge ONGC, Western Offshore Basin, Mumbai for assigning the job and for all the support extended during the period.