2D Long Offset Data Processing for Sub Basalt – A Case History

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Summary

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.

Application of the processing techniques innovatively applied on seismic profiles recorded with wide azimuths for imaging the sediments buried under basalt layers have been presented in this paper. The aim of processing is to image the sub basalt Mesozoic stratigraphic units in the shelfal part of the Kutch basin in western Offshore, India.

Special care is taken at every stage of pre-processing the data guided by the previous results of interpretation and other subsurface inputs, as the heterogeneity and thickness of the basalt flow are expected to control the limitations of subsurface imaging of pre-trappean sediments.

The paper deliberates the geological objectives and the attempts to achieve them through object oriented processing.

Introduction

The study relates to a 2D seismic data acquired with long streamer as input to a specialized processing in an area where basalt flows are sandwiched between tertiary sediments above and Mesozoic sediments below.

Kutch basin forms part of the north west coast of India where basaltic lava flows of Deccan traps separate the Tertiary sediments from the mesozoics below. These basalts are of Cretaceous age and are composed of numerous flows of varying composition and hence offer complex heterogeneity. The cretaceous clastic sediments underlying the basalts belong to Bhuj formation which is known to act as good hydrocarbon reservoirs, and are the targets in the present study.

It is difficult to image the structures beneath the massive basaltic layers with conventional seismic acquisition and processing methods. The complex basinal structure strongly scatters and highly attenuates seismic energy. Further, generally weak sub basalt signal may be obscured by the short period multiples generated at intra-basalt boundaries.

There is no single method 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. The work presented by the authors in this paper is a step in this direction.

Theory/Method

The issues related to sub basalt imaging can be

- 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 issues are

- discontinuous reflections
- multiples
- poor energy penetration
- difficult velocity analysis
- diffractions
- poor s/n ratio
- mode conversions

Stacked basalt flows typically exhibit the low pass character to seismic waves. Other typical characters are
the large velocity contrast at the top-basalt boundary and
the high impedance contrasts between the intra basalt
layers, both causing the significant loss of seismic
energy. To compensate for the energy loss, a low
frequency source signal is used by deploying high
volume gun array (6300 cu.in) and to maximize the
aperture for the reflected sub basalt wave field, a
streamer of 12 Km is used.

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. This far offset
part of the wave field is less influenced by the peg-leg
multiple generated at intra basalt boundaries, which
occur mainly in the near offset range of the recordings.
Therefore it is important to record arrivals at the larger
offsets.

Accurate estimation of intra-basalt seismic velocities and
seismic velocities beneath the basaltic sequences is very
much necessary for sub basalt imaging. Refinement in
the seismic velocity field plays a dominant role in
illuminating the sub-basalt lithology. Velocity inversion
is often conspicuous 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.

The generalized processing sequence used for the data is
as follows:

**PROCESSING SEQUENCE**

Reformat To Internal Format
Despike
Designature
Trace Drop And Resample To 4ms
3hz Low Cut Filter
T 2 Gain Recovery
Tau-P Linear Noise Attenuation
SRME
Q Compensation, Constant 200
Trace Interpolation
Linear Tau-P Deconvolution - Operator Length 400ms,
Gap 72ms
Parabolic Radon Multiple Attenuation
DBS - Operator Length 240 ms, Gap 28 ms

Velocity Analysis At 1 Km
Surface Consistent Deconvolution - Operator Length 240
ms, Gap 32 ms

Diffraacted multiple attenuation (RADON)
Kirchoff 2D migration and aperture optimization
Velocity analysis at 500 m using higher order correction
(4th order)
2D anisotropic migration using Kirchoff algorithm using
aperture 9000 m
Close grid velocity analysis (250 m) using 4th order
NMO
High resolution RADON de-multiple
Raw migrated stack (with inner and outer mute)
F-K filter
FX decon (rma filter)
TVF t in sec hz
0-1.8 10-12-60-70
1.8-5.0 4-6-40-60
5.0-9.0 2-4- 30-40

Time variant scaling

Extensive testing of velocity panels was conducted at the
velocity stages post decon, post radon and post PSTM
levels. First pass velocity analysis conducted at every
1km x 1 km pre decon was repeated for precision.
Velocities were subsequently picked at 500 m and 250
m, especially for time zone below trap. The implication
and effectiveness proper velocity picks can be seen in the
fig. below.
Low frequency processing keeping maximum frequency at 30-40 Hz below basalt is taken up for deeper prospects. Dense velocity analyses with complete manual picking anchoring at every crucial velocity pick points up to 250m X 250m are carried out as said above.

Pre-stack time migration (Kirchoff algorithm) with tested aperture was run using 500m velocities and the calculated anisotropic correction.

For application of high resolution RADON to attenuate the remnant multiples and noise which could hamper the strength of stacked data for pre-basalt units, parameters were tested thoroughly and selected for production processing. RADON mute was tested and selected for each line separately.

The final RADON applied migrated gathers were stacked with inner mute beside NMO mute. The application of inner mute in deeper part while stacking will attenuate the near traces which may contain events having relatively low reflection coefficient and some near trace multiples and thus enhance the reflections which are supposed to be stronger at farther offsets with high reflection coefficient.

Selection of inner mute to avoid near trace noise effects to strengthen the much needed far trace signal has really shown desired improvement especially at deeper sub basalt level imaging.

Three angle ranges for near, mid and far angles, stacks were generated and studied the behavior at different angles. Three different angle ranges 10-30, 20-40 and 30-50 were selected for better comparison of imaging at different angles.

Well data reference wherever available is taken from nearby wells drilled up to the trap in the area and surrounding areas for bringing out the analogy of trap top and possible trap bottom to the area of interest. PSDM was attempted on a few lines for understanding the subsurface lithology for better imaging of sub basalt in the area.

The PSDM tests show better definition of fault planes and resolution as a result of improved subsurface imaging below trap.
2D Long Offset Data Processing for Sub Basalt

It has been observed that the issues relating to shadowing of reflection events below basalts and proper positioning of fault planes are better addressed in PSDM.

Conclusions

Extensive tests carried out for 2D long offset data processing and the final PSTM data with selected parameters and accurate velocity picking. Efforts were made for quality improvement and every step summarized below has contributed in improving the data to the acceptable standards.

- Surface consistent Deconvolution
- Manual interactive and model based velocity picking especially below trap for every line.
- PSTM for 4th order velocity analysis at every 500m
- Precise High resolution RADON.
- 2D anisotropic Kirchoff Migration with high aperture of 9 Km
- Dense velocity analysis at every 250m
- Selected data dependent inner and outer mutes

Efforts put in have brought out improved imaging below basalt which could very well pave the road for probing sub basalt for detailed hydrocarbon exploration in future.

References

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


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