Interval Velocity Model Building – respecting the basics – A case study of Mumbai High

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Summary

Respecting the basics of Seismic data Processing and Geology can help achieving a robust and confident velocity model building for PSDM. These are simply: satisfying the basic requirements of migration and velocity picking. By trying to input as much as possible noise free data, and building an initial model from RMS velocity which are reasonably smooth and choosing geological / seismic horizon boundaries which satisfactorily account ray bending from top to target level. In the present case study the input CMP were processed for best possible noise elimination and fairly good results have been achieved using Kirchhoff isotropic PSDM. Throughout the velocity refinement, basic concepts were adhered to and things have been kept simple like avoiding anisotropic effects if any.

Keywords: Noise attenuation, respecting the basics, smooth velocity field, structurally consistent.

A brief description of the area

The area falls in western offshore Basin of India and is the leading producer of hydrocarbon. The data was acquired in 1997 with OBC mode. Being the top producing block, the data had big acquisition irregularities because of existing platforms and pipelines. Water depth varied between 30 to 100m. The data was reprocessed at SPIC, ONGC, Mumbai with the geological objective as:

1) To improve imaging through LIII facies prediction.
2) To Improving imaging of sub LIII layers with special focus on mapping of Basalt clastic & fractured basement.
3) To improving the imaging along Bombay High East fault with special focus on delineating wedge-out prospect along BHE fault.
4) To identification of fracture within basement

The area is highly prospective and a number of are gas and oil producing. The proper imaging of the reservoir and basement was challenging in reprocessing.

The geological target and basement are expected to be in the time range of 900 to 1700 ms/ 800m to 1800m. The structure is a Paleo high. The reservoir is limestone and the source rock Panna in this area is only a few meters thick.

Aquisition Parameters

<table>
<thead>
<tr>
<th>System</th>
<th>1D-24 bit digital fiber MxN cassettes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data format</td>
<td>SEG-D 8058 IEEE rev. 1</td>
</tr>
<tr>
<td>Media</td>
<td>20GB 3590E cartridges, 256 tracks</td>
</tr>
<tr>
<td>Number of channels</td>
<td>8*206 + 88 auxiliary channels used</td>
</tr>
<tr>
<td>Low cut Filter</td>
<td>4 Hz at 18 dB/oct</td>
</tr>
<tr>
<td>High cut Filter</td>
<td>206 Hz at 264 dB/oct</td>
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<tr>
<td>Record length</td>
<td>5170 m</td>
</tr>
<tr>
<td>Sample interval</td>
<td>2 ms</td>
</tr>
</tbody>
</table>

Energy Source

| Type of energy source         | Solar+G-Gas (Air Guns)              |
| Mode                         | Fly-by-wire (Even Port)             |
| Shot point interval          | 25 m                                |
| Number of sources            | 2 sources (2 sub-arrays per source) |
| Volume source                | 25.50 cu in., array                 |
| Air pressure                 | 2000 psi (136 bar)                  |
| Source depth                 | 5 m (+/- 1m)                        |
| Source separation            | 50 m (Array centre separation)      |
Seismic Data Processing

Seismic Data Processing involves a sequence of steps through which the data is passed and for each of these steps there exist a multitude of different approaches, assumptions, advantages and limitations which the processor takes proper care to preserve the integrity of the data while trying to improve the signal to noise ratio, improving frequency and lateral positioning of the various reflecting events. The processing flow used for this project is listed below.

1. De-spiking (big and small window) in shot domain
2. De-spiking (big and small window) in receiver domain and Linear Noise attenuation in receiver domain
3. Linear Noise attenuation in shot domain
4. Summation of geo- and hydro-phone data
5. De-spiking (big and small window) Noise attenuation in CMP domain and fold regularization
6. Radon de-multiple
7. Tau-p decon.
8. 2nd pass of linear noise removal in CMP domain and radon de-multiple.
9. Three pass of PSTM velocity refinement (250m x 250m/ 50m x 50m) over the earlier picked and refined RMS velocity.
10. Three pass of PSTM velocity refinement (250m x 250m/ 50m x 50m) over the earlier picked and refined RMS velocity.

These processing steps can be briefly described as an attempt to reduce linear noise as much as possible before summation to exploit the advantages offered by an OBC survey. Further short period reverberations ignited by sea bed were attenuated using 2D-SRME and de-convolution, and radon has been used to suppress multiples.

Discussion

Initial velocity Model Building and refinement:
The conditioned CMP gathers processed as above, and the closely picked refined and smoothed PSTM velocity field of the earlier processing was taken as input. Initial velocity depth model was built using DIX transformation along some of the interpreted horizons. The PSTM driven RMS velocity and horizon interpretations of 5 layers up to the basement were taken as input. The PSTM velocity had been refined three times at very close grid of 50m x 50m and it had produced good flattening to the PSTM gathers up to basement practically everywhere. Water bottom (WB) depth map was created from the bathymetry provided by the acquisition crew. Of the available horizons of interest, the shallowest horizon after the WB was at about 800ms deep. Hence three layers, each about 200-300ms thick were picked to capture the part of ray bending up to 1sec TWT. Of the available horizons below 1s (equiv. of 1km approx.) and up to basement, horizons spaced at about 250-350ms were taken for the initial model building. Dix converted interval velocities were smoothen with very large wavelengths: 4000m x 4000m. Through image ray migration, depths were calculated and the initial velocity model was built.

Velocity-Depth model up to 1km approx. was refined through three iterations of horizon based global tomography run with residual depth move-out inputs (picked along these horizons at every 500m). The residuals and the interval velocities maps from horizon tomography were smoothened by up to 4km x 4km. This fairly flattened the PSDM gathers up to depth of 1km. To avoid anisotropic play, gathers were flattened only up to 27 deg. The refined interval velocities up to this depth were about 5% lower than the initial estimates from RMS velocity. Thus Dix converted velocities for remaining layers (up to basement top) were also lowered by 5% to 8% and depth maps were calculated using image ray migration. Three
more iterations of refinement based on horizon based global tomography were run to reasonably account for ray bending up to basement top.

Based on geological studies of the area, a formation of thickness 500m with velocity of 3200m/s was created at basement level. This layer was meant to capture any lowering of interval velocity at the basal clastic/basement level. In the next iterations this layer’s velocity too got refined.

After 8th pass of velocity refinement using horizon tomography, horizons were re-picked, to improve upon the better positioning of events particularly near main MH fault. Finally inter bed layers which included horizons of interest were introduced and global grid tomography was run to create the updated velocity depth model.

It was encouraging that the output depths were within 11/2 % of well marker, indicating that velocity model has avoided anisotropy, if any, as well as, has minimized travel time errors, to give a reasonable and reliable analysis of velocity at within target level. This has helped in improved imaging. The velocity tends to match with the VSP data at various wells. The following figures are self explanatory.
Fig 4b. Interval velocity map refinement during various iterations: from a not so resolved velocity (top left), a structurally consistent velocity has emerged (bottom right).

Fig 5a. Interval velocity model after 8th pass of horizon tomography.

Fig 5b. Updated Interval velocity model after Grid tomography run after 8th iteration of horizon tomography.

Fig 6a. Final PSDM gather after Pass-2 and pass-8 for approx. depth=offset

Fig 6b. Present raw PSDM section of line ccccc. The fault delineation and resolution of various reflectors has improved.

Fig 7. Comparison of velocities from PSDM and well Log at well BH-aa – indicating that a satisfactory model has been built from seismic.
Conclusion

With efficient noise reduction, data driven velocity guided by the interpreter’s concept, VSP and well data has enhanced imaging at all the levels of interest. The present processing has brought out better sub-surface image compared to earlier vintage. Faults are better imaged/delineated through reprocessing. Further with robust velocity, noise and multiples were better attenuated. The below gas imaging has also been considerably improved. The attribute interval velocity has also been produced with good degree of confidence over the area which is in broad agreement with well velocity. It was encouraging that the output depths were within 1\(1/2\) % of well marker, indicating that velocity model has avoided anisotropy, if any, as well as, has minimized travel time errors above basement, to give a reasonable analysis of velocity at/ within target level. This has helped in improved imaging. We conclude that following factors have helped in producing superior results. These we emphasize are a reiteration of respecting the basics:

1. Fairly noise free data has helped in making better velocity estimates during successive tomography.
2. Picking of closely spaced-geologically and seismically sensible horizon layers of thickness~ 300m or less to reduce errors due to ray bending
3. Building of a very smooth initial velocity field velocity which was refined several times for the shallow part, before concentrating at the deeper level.
4. Avoiding anisotropy by desisting to flatten the gathers at offsets > depth. (The beds in this area have gentle dips) The anisotropic implementation can be done only when isotropic treatment has been satisfactory.

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Views expressed in this paper are those of the authors only and not necessarily be of ONGC.

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