Sub-basalt Imaging Using Wide-angle Reflection Data In Tau-p Domain - A Case Study

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Summary

In western India, Mesozoic sediments are covered by late Cretaceous basalt flows. Inhomogeneous basalt causes severe scattering and restricts seismic energy to penetrate through it. Its high velocity contrast with overlying Tertiary sequence limits the P-wave energy penetration at short offsets; whereas wide-angle reflections, recorded at very long offsets, have their own processing problems.

In the present work, processing of wide-angle reflection data of a profile, falling at the western margin of Cambay basin, was attempted in Tau-P domain. All the useful offsets were processed together without bifurcating the data into near offset reflection and wide-angle reflection. Tau-P deconvolution, refraction filtering and Tau-P move out correction have yielded much better picture of sub-basalt features in comparison to x-t domain processing.

Introduction

Mesozoics are world's most prolific producer of hydrocarbon, but in India, exploration for Mesozoic prospects has not yet yielded desired success. In western India, Mesozoic and older sediments are covered by the basalt flows. Thick heterogeneous basalt restricts the seismic energy to penetrate through it. This makes the conventional reflection seismics ineffective to map the sub-basalt formations, although their presence is well proved by several wells drilled in the area. Wide angle reflections are free from Tertiary generated multiples and sub-basalt reflections are easily identifiable in wide-angle cone data. A few seismic lines were shot with spreads ranging from 6 km to 18 km at the western margin of Cambay basin for exploration of Mesozoic sediments which are overlying the granitic basement (figure-1). These sediments are covered by basalt flows, known as Deccan trap, of late cretaceous age. Tertiary and Quaternary sediments of varying thickness form the thick cover over the Deccan trap.

These lines were processed in two parts generating separate sections for near offset reflections and reflections present in wide-angle cone. Finally a composite section was generated from two outputs by cut and paste approach, also called post stack compositing (Suryanarayana et al, 2003). But this processing approach had several limitations, which prompted to take up the present study.

Limitations & challenges

Long offset data acquired in the area shows identifiable hyperbolic events in wide-angle cone of the data. Conventional processing fails to use these reflections because of the stretching problem as shown in a gather of eight km far offset in figure-2. Long offset data acquired in the area was processed adopting the two set processing approach and post stack compositing. This approach had several limitations as :

(i) When basalt thickness is very large, Mesozoic reflections and basalt refractions were well separated and it was possible to map the Mesozoic top. But in usual case, these two events were very close and the Mesozoic reflections were also muted while manual muting of the basalt refraction.

(ii) Presence of the high amplitude guided waves and a part of basalt refraction generates the false image in the stack of wide angle reflection cone.

(iii) Post stack compositing always suggests the presence of a false horizon at the junction of the two stacks, because of the difference in amplitude and frequency content of the two stacks.

Due to these limitations, there was a need to explore an alternative processing methodology. Different processing sequences were suggested such as Angle Stack (Sarkar et al, 2004) and Pre-stack Compositing (Yadava et al, 2004). These ideas could address the problem of false horizon but failed to address the problem of guided waves and proper imaging technique suitable for all basalt thicknesses.

To address these problems of sub-basalt imaging, a study was taken up along a seismic line marked as profile-B in figure-1a. Figure-1b shows a representative shot gather

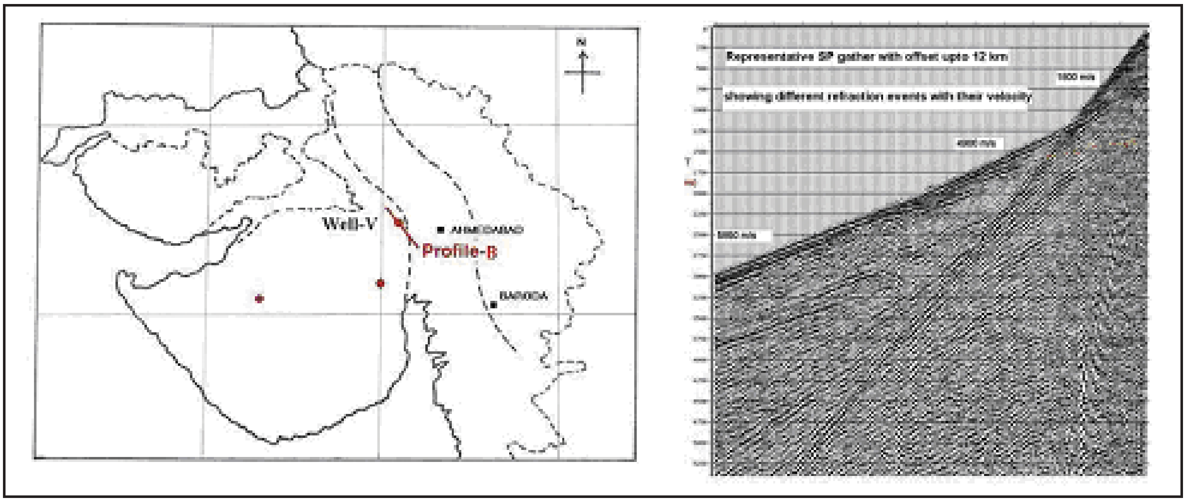

Fig.1 : (a) Area of study with profile-B passing through well-v, (b) Representative shot gather

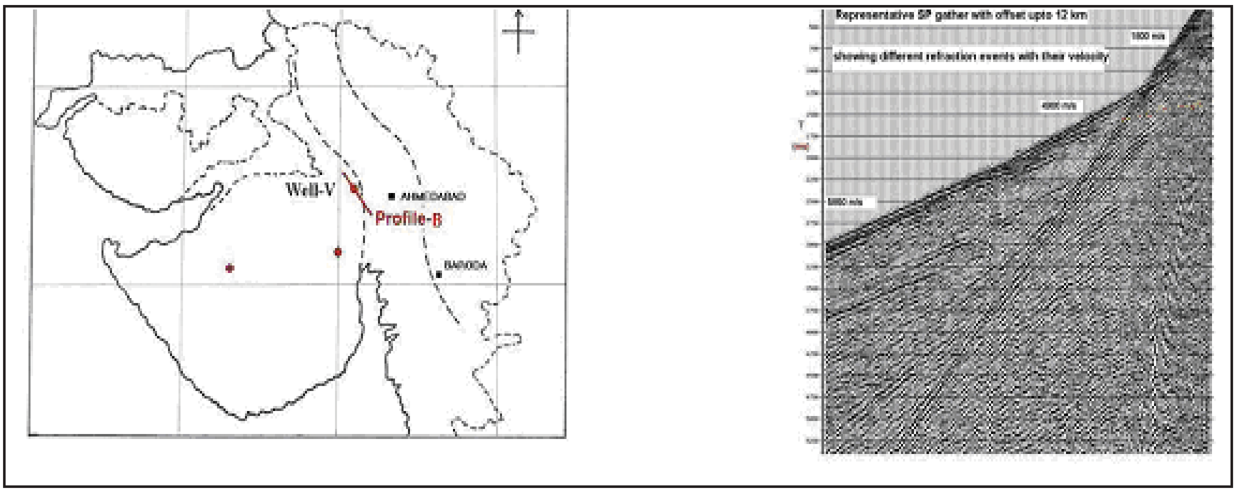

Fig.2 : (a) Representative CMP gather , (b) After fitering direct arrivals (c) After NMO correction

from this profile. The profile passes through well-V which has been drilled upto a depth of 1182 mt. The well passes through 607 mt of tertiary sediments, 346 mt of basalt and terminated after drilling 229 mt of Mesozoics.

The data was acquired using 450 channels with 40 mt group interval and 12.5 kg explosive shots using single hole pattern. Conventional processing brings out the image upto basalt top very clearly. Figure-5 shows the DMO stack of the profile. Basalt top reflection comes at 620 ms two way time on this section near well-V. Considering the formation velocity of basalt of the order of 4500 meter per second, reflection from Mesozoic top is expected near 770 ms but it is not identifiable on this section.

Model and Based Analaysis

To devise a suitable imaging technique using long offset data, a model based analysis was carried out. A simple geological model was created with three layers of Tertiary, Basalt and Mesozoics above the basement. Density and P-wave velocity for different formations were taken from the information available in various literatures and refraction data, whereas S-wave velocity was taken arbitrarily. This model is shown in figure-3b and gives all the details of the parameters used.

Synthetic gathers were generated at different locations on this model using finite difference modeling

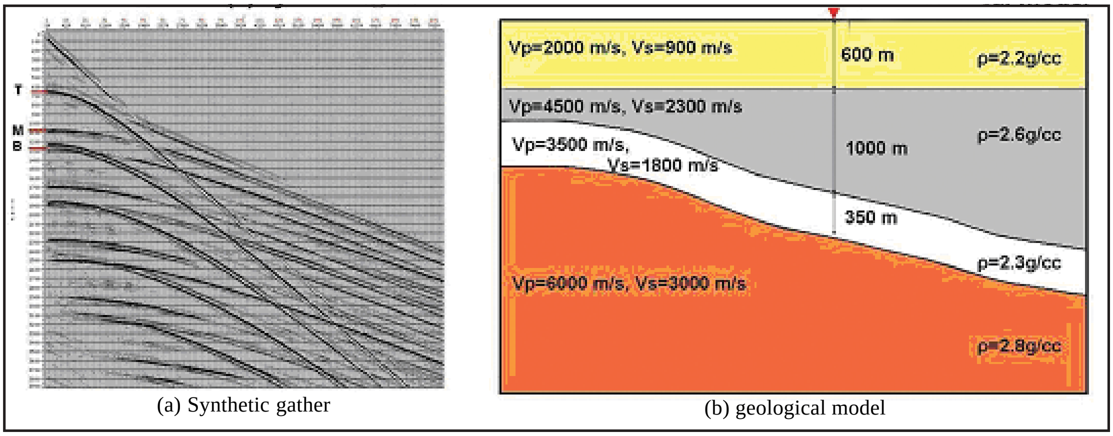

Fig.3 : Synthetic gather with reflection events marked as T,M,B along with the model used to generate it

algorithm satisfying dispersion condition and stability criterion. Figure-3a shows a synthetic gather generated for the location marked by red triangle on the model. T, M &B are the primary reflection events from trap top, Mesozoic top and basement. First order multiple of trap top also falls at the time of basement reflection in the near offsets.

Figure-4a shows the Tau-P transform of the synthetic gather. In Tau-P domain, reflection hyperbola gets mapped as ellipse, whereas linear events become a point. Direct arrivals have been mapped as high amplitude zone in right top corner of this figure. Basalt refraction was expected to be mapped as a point, but because of the dips involved, it has been mapped as a small smeared zone with high amplitudes marked by oval shape. Guided waves running parallel to basalt refraction will be mapped with the same P value but with higher Tau value and will fall below the oval shaped zone on Tau-P gather. Mesozoic reflection and basement reflection have been mapped in the left half of the Tau-P gather and terminate near the basalt refraction zone.

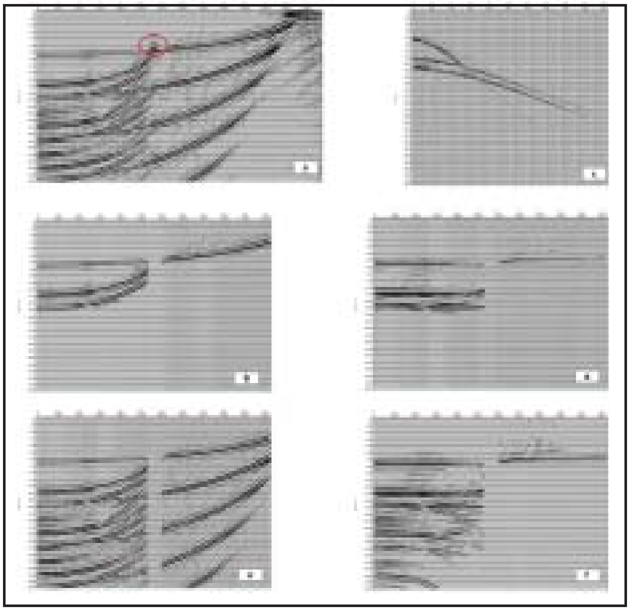

Fig.4: (a) Tau-P transform of synthetic gather of figure 3a with basalt refraction zone marked by red oval zone; (b) Tau-P gather after removing events corresponding to direct arrivals, basalt refraction, guided waves of wide angle cone and prominent multiples; (c) Time domain gather corresponding to figure 4b; (d) Gather of figure 4b after Tau-P move out correction; (e) Tau-P gather as in figure 4b without any treatment for multiples; (f) Gather of figure 4e after Tau-P move out correction

Figure-4b shows the Tau-P gather after zeroing the P traces which contain the basalt refraction, guided waves and removing very high P value traces corresponding to direct arrivals. A mute has also been applied in Tau-P domain to remove most of the tertiary multiples. Figure-4c shows the time domain equivalent of this cleaned Tau-P gather, which now contains mainly the reflections from three horizons. Figure-4d is the Tau-P gather of figure-4b after application of move out correction in Tau-P domain. It is observed that most of the energy associated with reflection events from Mesozoic top and basement gets aligned; whereas a sizable part of this energy was wasted in X-T domain due to stretching.

Figure-4e is the same Tau-P gather but without any treatment for the multiples. Tau-P domain move out correction on it generates the output shown in figure-4f. It is observed that a major portion of the Tertiary multiple energy, falling in right half of the Tau-P panel, is automatically zeroed; whereas multiples falling on left half of the panel, corresponding to short offsets, remain under corrected and will get suppressed while stacking.

Processing of Data

Shot gathers from profile-B were analyzed for different hyperbolic events and it was decided to use the traces having offsets from 0 to 8 km. Initially conventional processing was carried out and DMO stack was generated, which is shown in figure-5. Location of well-V is marked on this section. Trap top comes at two way time of 620 ms on this section. Reflection from Mesozoic top was expected between 750 to 800 ms near the well, but no such corelatable event is observed.

Data was processed in Tau-P domain using the methodology discussed under topic Model Based Analysis. General processing sequence is as below-

Format Conversion & Statics application
Spherical Divergence correction
CDP sorting
Tau-P transform
Tau-P deconvolution
Zeroing of P traces of basalt velocity
Tau-P move out correction
Stack
Band pass filter

Tau-P processed output is shown in figure-6 which has all the details of tertiary sequence and Trap top. Sub-basalt reflection has been brought out nicely and matches with the well information near well-V.

Conclusions

Processing the long offset data in Tau-P domain has brought out much better image of sub-basalt features. All the useful offsets of the gather, containing near vertical and wide-angle reflections, were processed together without loosing any significant portion of the sub-basalt reflection. Risk of stacking the guided waves and part of basalt refraction has been eliminated. In the present work, contaminated P traces were zeroed, so amplitude preserved processing needs further study. However, primary objective being the imaging of sub-basalt features, amplitude preservation is not an issue for the time being.

References

A.V.K. Suryanarayana, C.B. Yadava, A.K. Sarkar, M.B. Singh; PETROTECH-2003; Sub-basalt imaging using large aperture reflection seismics in Saurashtra region, Western India.

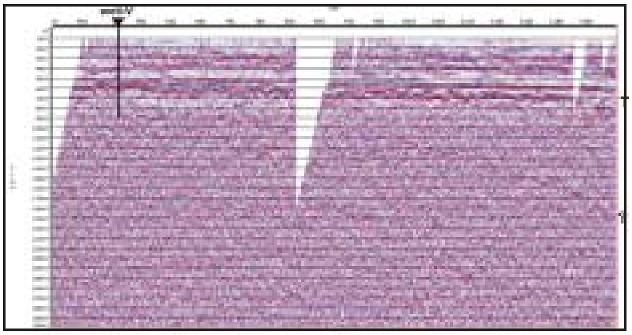

Fig.5 : DMO stack of profile-B

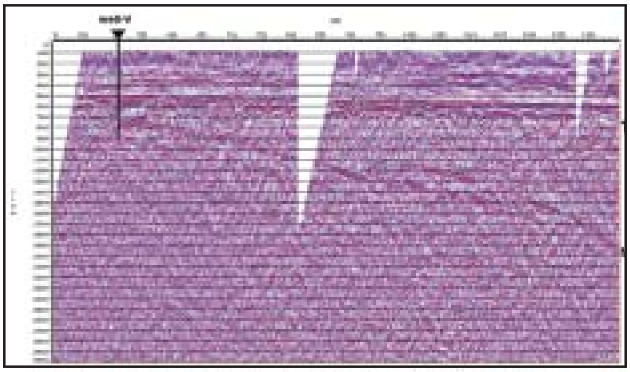

Fig.6 : Tau-P domain processed output of profile-B

A. K. Sarkar, R. Mohan; SPG-2004;Sub-basalt imaging using low frequency processing and angle stack in Saurashtra region, Western India.

C. B. Yadava, U. K. Chatterjee, Dr. S. Viswanathan; SPG-2004;

An alternative approach to process the wide-angle reflection data by pre-stack compositing of gathers for sub-basalt imaging.

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