Imaging Technique for Minor Faults : A Workflow for running Coherency Attribute

D. Manna , A.K. Arya & N.K. Verma

INTEG, GEOPIC, ONGC, Dehradun, India

SUMMARY

This study provides a method for improved mapping of minor faults in a 3D seismic dataset. Besides conventional attributes like spectral decomposition, coherency attributes which are used for minor fault mapping, a workflow is designed for running Coherency attribute which gives clarity in mapping minor faults through coherency time slices. A 3D land dataset pertaining to Charali - Changmaigaon area of North Assam shelf of Assam-Arakan Basin of India is used. The target reservoir is Tipam sand which is subdivided into blocks by NNE-SSW major faults and the NW-SE cross faults. The NW-SE cross faults are of minor nature which are associated with NNE-SSW major faults and are mainly responsible for compartmentalization of Tipam reservoir. These minor faults are difficult to be mapped by conventional interpretation tools. Spectral decomposition and coherency attribute which are generally reported for minor fault detection are used . Coherency drawn from inversion volume was also studied as a tool for fault delineation . Coherency attributes run on noise processed instantaneous / cosine phase data produced the best imaging of minor faults.

Introduction

Mapping of minor faults may be difficult sometimes in a 3D seismic dataset due to low signal to noise ratio, existence of multiples or different form of noises etc. in the dataset. Although they are minor in nature, these faults play significant role in entrapment of hydrocarbons. They may not appear as a discontinuity in normal seismic section and may manifest in the form of certain change in waveform near the faults. In our study, a 3D land dataset pertaining to Charali-Changmaigaon area of North Assam shelf of India is used. The target reservoir is Tipam sand which is dissected by by major faults in NNE-SSW direction and cross faults in the NW-SE direction . The cross faults which are of minor nature are difficult to be mapped manually in this area and are responsible for producing fault blocks. In this study, it is attempted to bring out minor faults by using ESP slices of different attributes of seismic data. Conventional time-horizon based attributes like dip magnitude, azimuth etc. are derivative attributes which rely on the time position of the adjacent picks and give somewhat moderate picture. Although these maps help to bring out the broad structural framework of the prospect, the non horizon based attributes like Spectral Decomposition and Coherency attribute reveal more information. Spectral decomposition, though a window based attribute, is very effective in detecting minor faults. This technique uses Discrete Fourier Transformation (DFT) to decompose the recorded seismic wavefield into discrete frequency slices. The DFT amplitude spectra delineate temporal bed thickness variability and phase spectra indicate lateral geological discontinuity (Partyka et. al.). However , in our case no qualitative difference is observed between DFT amplitude and phase slices. Coherencey attribute measures trace to trace coherence coefficients by calculating localized waveform similarity in both inline and cross-line directions. The traces which are cut by faults have generally different seismic character than the neighbouring traces. As a result, a continuous horizon shows high coherence values while a broken horizon, due to faulting or fracturing, exhibits low coherence value. In our study, it is observed that Coherency program run on normal seismic data have poor to fair visibility for minor faults' visualization, but after applying noise reduction filter on the seismic data, visibility improves appreciably. Coherency attribute applied on inversion volume sometimes produces good imaging of faults and stratigraphic features (Chopra et. al.). Coherency program was also run on inversion volume in our study , but that did not produce any remarkable result. Appearance of faults was comparable to Coherency applied on normal (without noised processed) seismic data. A workflow (Fig.1) is made for visualization of minor faults by applying Coherency attribute on noise processed seismic data. A suitable noise processing filter before generating Coherency attribute and even the instantaneous /cosine phase attribute as input to the Coherency attribute provide requisite clarity in minor fault detection. All minor fault are not seen in the Spectral decomposition attribute although both the major faults and a few minor faults are depicted on the slice (Fig. 5a & 5b). The DFT Phase attribute slice could not divulge any further detail than the DFT Amplitude slice. It is necessary to mention here that Spectral Decomposition and Coherency attribute which are displayed in the form of time slice could not offer actual orientation of the dataset due to limitation of software. In the Spectral Decomposition attribute, no fault splays (minor faults) are seen in the northern part of major faults. But if we observe the Coherency attribute slice from noise processed data in Fig.7b , we are able to see them clearly.

Other Techniques

Sometimes conventional techniques like Dip-Azimuth attribute give very good picture of structural interpretation although in our case it helped to produce only broad picture of structure. Dip magnitude is computed corresponding to top portion of the Tipam sand (TS 2 sand level) as shown in Fig.3. Two major faults running NNE-SSW directions are depicted very clearly having throw ranging

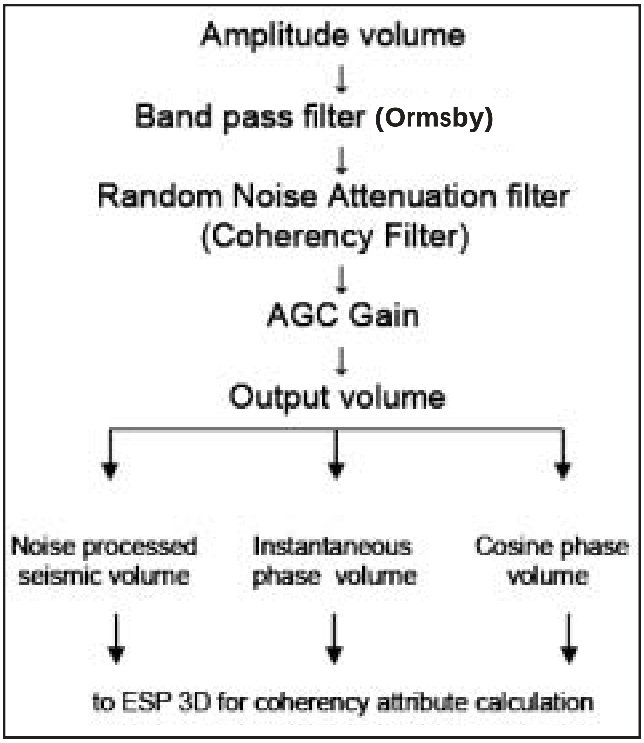

Fig. 1. Showing Workflow of the process in imaging minor faults.

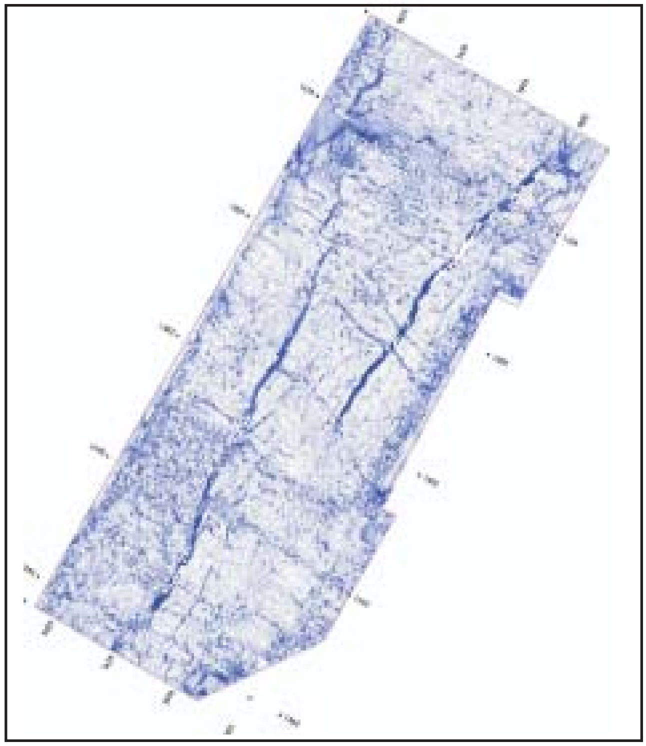

Fig. 3. Dip attribute showing the broad fault trends

from100 ms. to150 ms. and are easily correlatable manually in the seismic section. Minor faults (NW-SE) which run almost in orthogonal direction to the major faults, a few are visible in the Dip attribute. These minor faults are rarely spotted in the seismic section (Fig.2). The yellow horizon is the level of interest. The elliptical portion shows some dip change in seismic section but it is difficult to put fault in the manual interpretation. In such case, idea of mapping of faults can be taken from running different attributes for faults, like Dip, Azimuth and Coherency methods. In our case in the Dip attribute map (Fig.3), the cross fault in the NW-SE direction which is shown by arrow in (Fig. 8a) is not visible clearly.

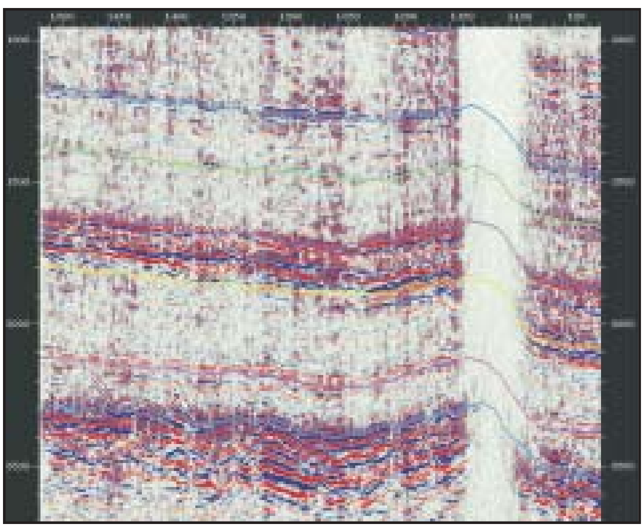

Fig. 2. Seismic section in the NNE-SSW direction from the dataset. Elliptical portion where a fault can be mapped but it is not easy sometimes for taking decision to put a fault or not without seeing any attribute slice for faults. This fault is marked by an arrow in Fig. 8.

Workflow for processing coherency attribute:

Visibility of faults in time slice derived from the Coherency attribute may be poor if the faults are minor in nature or the seismic data set is noisy. An introduction of band pass filter followed by random noise attenuation filter and suitable gain for the seismic data set before running Coherency program can improve the visibility of the minor faults in Coherency time slice and help in aligning the fault trends. A band pass filter is applied for removal of high and low frequency noises. Filter is chosen such that optimum frequency bandwidth is nearly preserved in the dataset (Fig.4). A noise reduction filter for eliminating random noise and preserving useful energy in the data enhanced the signal strength . As a random noise attenuation procedure, a coherency filter is adopted in this study. This filter shapes the amplitude spectrum of the data based on the signal to noise ratio. The signal to noise ratio is estimated from the ratio of the zero trace lag auto correlation to one trace lag auto correlation function. For this purpose, the data is transformed to the frequency domain and the scalar is determined for each frequency based on auto correlation of the data within a specified window. Besides coherency filter a number of different types of noise reduction filters like F-K weighting, Dip-scan-stack filter etc. were attempted on the dataset F-K weighting filtered data produced smearing effect and looked like synthetic traces. Dip-scan stack filter also did not show any improvement in seismic data quality.

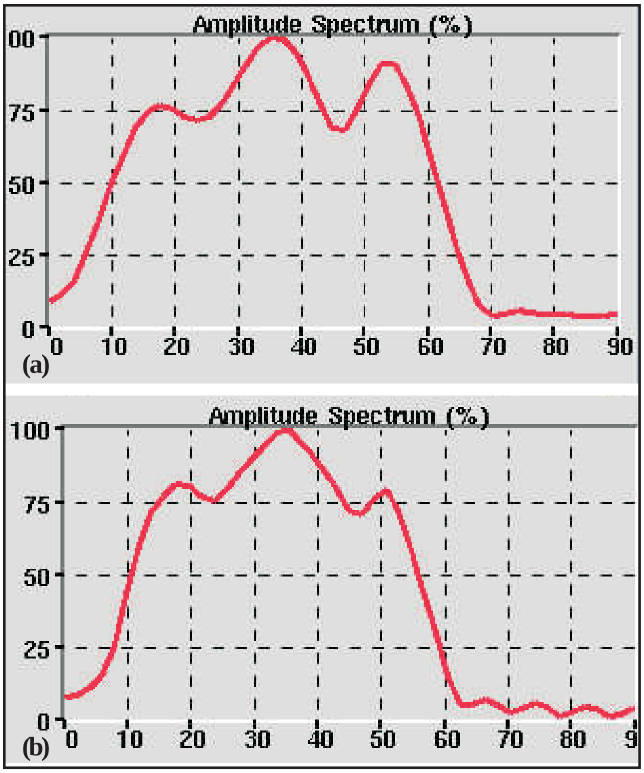

Fig. 4. (a) Amplitude spectrum before filtering (b) after filtering showing the frequency band is almost preserved

Coherency filter for noise reduction was finally adopted as it enhanced the signal strength and the data look was also realistic. The Coherency filter was chosen with a horizontal window length of 20 traces and with time window of 300 ms. which produced the best output. As the filtering process

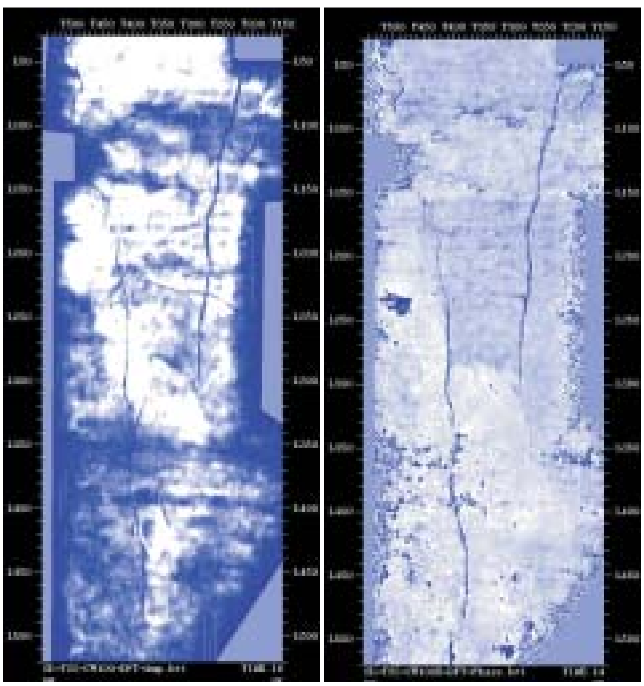

Fig. 5. (a) DFT Amplitude slice from Spectral Decomposition at the level of TS2 (yellow horizon) (b) DFT

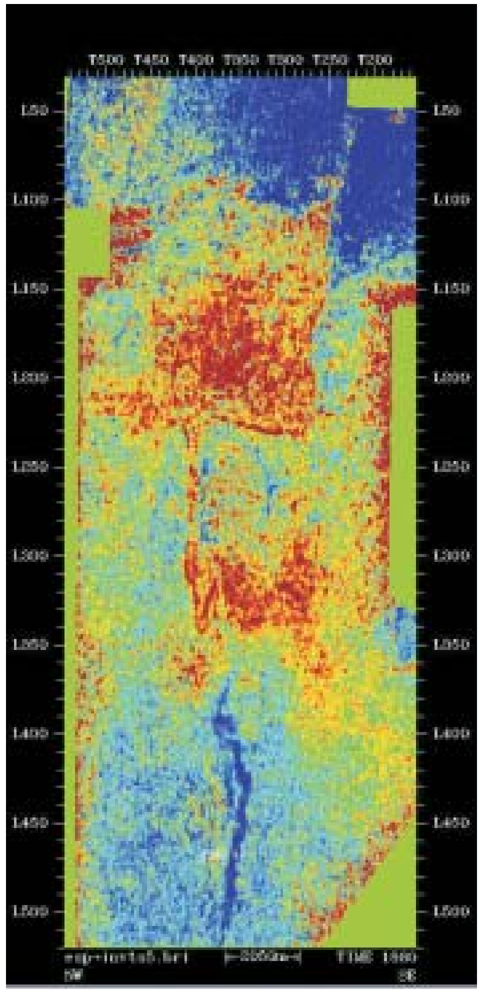

Fig. 6. Time slice at 1880 ms. derived by running coherency attribute on inversion volume

scales down the amplitude level, an AGC gain was applied consequently and the output is taken for the Coherency attribute calculation. As the Coherency attribute displays the area of dissimilarity whether it is a fault or sratigraphic boundary (Bahorich.et al 1996), fault with a detectable or minor vertical throw generates wave field distortion and in turn produces low similarity of traces in the fault zone. ESP 3D program uses semblance and Manhattan distance to predict the the similarity. Two options are available one for dipping reflector case (Planar dip constrained) and other for non dipping case (unconstrained). For the first case, two, four or eight neighboring traces option are available for semblance calculation with reference to the centre trace and best estimate of semblance trace taken as target trace. In this case Planar dip constrained with eight neighbours option is used . Then the Manhattan distance is calculated between target trace and centre trace and this Manhattan value is output to the middle sample of the centre trace window. For plane reflector case, semblance is calculated between the neighboring traces and multiplied by 100 for display purpose. High value of Manhattan distance corresponds to low semblance and thus low similarity. A filtered, noise- processed seismic volume after applying gain is input for ESP 3D

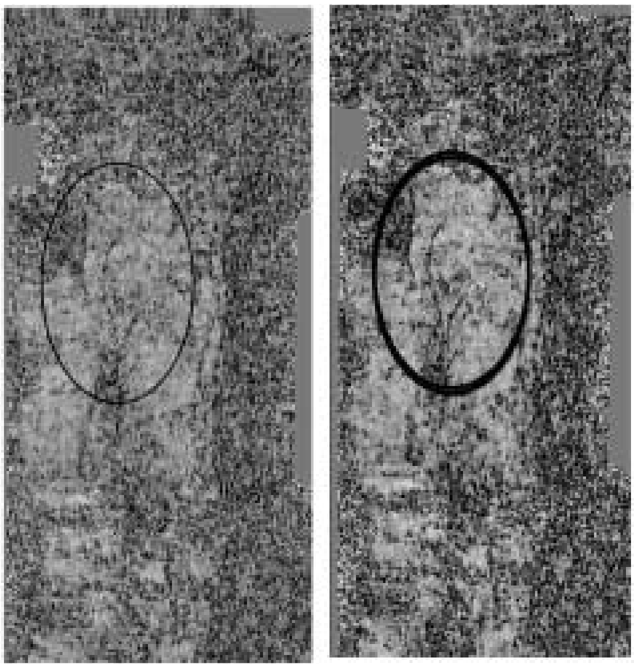

Fig. 7. (a) ESP slice at 1880 ms. of normal amplitude data (b) same slice for noise processed seismic data. NNE-SSW faults are clearly visible (elliptical portion) .

program and improvement in fault imaging is displayed in Fig.7. Similarly, Instantaneous phase and Cosine phase attribute calculated for the same dataset (i.e. noise processed) is input in the same workflow before running Coherency program. The resulting enhancement in fault imaging is evident in Coherency slices (Fig. 8) . Coherency volume was also generated from acoustic inversion as input and the result is displayed in Fig. 6 as representative time slice . The conspicuous NNE-SSW fault trend is visible with the aberration on minor faults. Thus after trying all possible methods and a number of trial runs, authors optimized a workflow to help image the minor faults in tectonically disturbed area (Fig. 1).

Discussions

The ESP time slices (Refer: Fig..5 -8) belong to Charali - Changmaigaon- Disangmukh area. The elongated NNE-SSW fault (in western part of figures) viz. Charali fault is conspicuously seen in Coherency volume drawn from amplitude volume(Fig.7a). But the splays Fig. 7-8 (a & b) associated with this fault (which are of minor throw) require above work flow to improve their display. Another set of NW-SE faults (which are not seen clearly in the normal amplitude volume and it's associated Coherency volume) which have minor throw are also brought out properly on using the workflow. The workflow has given improved results in imaging of minor faults in this case . However the workflow is designed to improve in general imaging of minor faults of other seismic datasets also pertaining to other areas. Fig. 7a is a coherency time slice at 1880 ms. from normal seismic and Fig. 7b is a coherency slice from noise processed seismic which shows improvement over previous one. Similarly, time

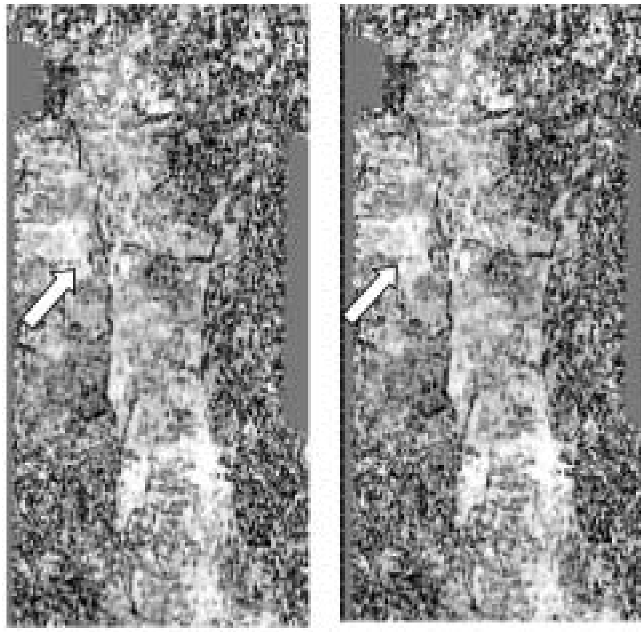

Fig.8. (a) ESP slice at 1880 ms. instantaneous phase (from noised processed data) as input to ESP3D processing of (b) ESP slice from cosine phase (from noised processed data) as input to ESP 3D

slices from Coherency volume calculated from the instantaneous phase volume and cosine phase volume are shown in Fig. 8a and Fig. 8b respectively. The cross fault (marked by arrow) which is not clearly visible in the Fig.7 is now visible. This minor fault is having faint impression in the Spectral Decomposition slice (Fig. 5).The same fault appears as blurred dotted zone in Coherency attribute run on inversion volume (Fig 6). Although Coherency slices generated from the instantaneous phase and cosine phase give better picture with respect to Coherency slice from normal seismic data, but the best results are obtained if the seismic data volume is noise processed prior to generating instantaneous or cosine phase volume. Selection of particular noise reduction filter is also very important for effective noise processing. It is also observed that the instantaneous phase and cosine phase attribute calculated from the noise processed data and subjected as inputs to the Coherency attribute ESP 3D program produced output providing clear visibility of minor faults. Coherency time slice derived from cosine phase has more clarity than the Coherency time slice from instantaneous phase as input (Fig. 8) . Why cosine phase input to ESP 3D produce better clarity than instantaneous phase as input to ESP 3D ? Instantaneous phase describes the angle of phasor which is a rotating vector formed by the real and imaginary axes and its value varies between -180° and +180°. As a result instantaneous phase trace has a discontinuous, saw tooth character by phase wrapping between -180° and +180° and the trace bears a phase information. Phase difference is depicted in the trace from the normal area to the faulted zone which gets enhanced in the semblance calculation. Cosine phase trace looks oscillatory varying between -1 and +1 like normal seismic amplitude trace which may be more convenient for semblance or Manhattan distance calculations.

Conclusions

- Coherency attribute run on inverted seismic volume could not produce any remarkable result as far as minor faults are concerned.
- Major faults are seen on Coherency time slice but minor faults are not visible when coherency volume is obtained from noisy seismic volume. Removal of noise and gain application prior to calculation of coherency volume can help reveal minor faults.
- Instantaneous phase / Cosine phase attribute as input to the Coherency attribute calculation produces better picture for minor fault delineation than that of amplitude volume as input.

Acknowledgement

Authors are thankful to Shri D.K. Pande Director (Exploration), ONGC and Shri S.K.Das, G.G.M.- Head GEOPIC for permission to present this work.

References

Bahorich, M. S. and Farmer,S.,1995 "3-D Seismic coherency for faults and stratigraphic features", The Leading Edge,1053-58.

Carter, N and Lines, L.2001 "Fault imaging using edge detection and coherency measures on Hibernia 3-D seismic data" The Leading Edge 64-69.

Marfut, Kurt, J., Kirlin,R.L., Farmer, S and Bahorich, M.S.,1998 "3-Dseismic attributes using a semblance-based coherency algorithm", Geophysics 63 no.4,1150-65.

Neves, Farnando A., Zahrani,M.S. and Bremkamp,S.W.,2004 "Detection of potential fractures and small faults using seismic attributes", The Leading Edge, 903-906.

Chopra, S.2001 "Integrating coherence cube imaging and seismic inversion",The Leading Edge, 354-362.