3D Seismic Reconnaissance Workflows for Rapid Prospect Generation – US Gulf Coast

J Henderson*
ffA, Newcastle upon Tyne, United Kingdom
J Henderson@ffa.co.uk

GS Fisher
ffA, Newcastle upon Tyne, United Kingdom

and

BC Birdsall
Bayou City Exploration Inc., Houston, TX, United States

Introduction

The extremely high levels of activity in the US Gulf Coast onshore area, combined with the gradual dwindling number of attractive opportunites, means that tools which can provide the ability to identify new and overlooked prospects and risk them rapidly, without compromising integrity, can confer great commercial advantage on the companies using these tools. Access to large libraries of 3D seismic data has provided many companies with the data required to explore effectively. However, it is still a significant challenge to effectively and thoroughly review the potential in areas covered by such enormous amounts of data.

A common and productive approach to prospect generation in the US Gulf Coast is anomaly identification and relating detected anomalies to structure. Seismic volume image analysis and 3D visualisation techniques can be combined to greatly increase the efficiency of this process. Furthermore, once potentially interesting anomalies have been identified volume image processing techniques can be used to delineate the 3D geometry of the anomaly, estimate its gross rock volume and analyse the 3D relationship between the anomaly and faulting. This can all be done prior to carrying out any conventional mapping. Combining these techniques with geophysical and local geological expertise enables much faster prospect generation without any loss of technical integrity. This paper describes the seismic volume image analysis techniques utilised in the prospect generation workflow and presents results from the application of the workflow to approximately 400 sq miles of US Gulf Coast data .

The 3D Image Processing Workflow

The application of image analysis techniques to almost any type of data, including 3D seismic, follows a fundamental workflow: Remove noise and condition the data, highlight features of interest, extract the features of interest as objects, analyse these objects. The reconnaissance workflow described here follows just this pattern. Importantly it is not a "black box" workflow as it is applied in a number of steps and allows QC of the results and extensive user control over the processing techniques and associated parameters. Despite this, the workflow is not laborious to apply.

Data Conditioning: Removing the Noise

Signal to noise ratio is the first issue to be addressed. Application of noise cancellation workflows makes it easier to identify subtle but potentially important stratigraphic features, understand event continuity and delineate small scale faults. This can have a large impact when it comes to prospect risking and assessment of volumetrics. The reconnaissance workflow allows for the application of a number of structurally oriented edge preserving filters designed for removing random noise and high (spatial) frequency structured noise. These are applied iteratively, individually or in combination, allowing the effect of the filtering to be assessed at each iteration either through direct visual comparison of the original and filtered data sets (figure 1) or by creation of a difference data set.

Highlight Features of Interest: Structural and Stratigraphic Reconnaissance

The second stage in the reconnaissance workflow is to provide detailed information on the subsurface structure to show the relationship between areas showing a high amplitude response and potential structural trapping mechanisms such as faults or 4 way dip changes. This is achieved by creating two composite attribute volumes, DipAzi and DipEnv. Both these volumes are generated through the application of 3D image analysis filters and do not require any prior interpretation.

The DipAzi volume (figure 2a) uses a 2D colour map (figure 2b) to encode both instantaneous dip (saturation) and instantaneous azimuth (hue) into one data volume. The DipAzi volume provides an enourmous amount of information that would otherwise only be available once the interpretation process had progressed for some time. For example, structures such as, large scale faults, subtle fractures, inflexions, regions of contra-regional dip, channel margins, clinoforms etc can be readily identified within DipAzi volumes. This very quickly provides the information needed to determine those areas within the data set that show the structural characteristics important to support an assessment of prospectivity.

The key stratigraphic indicator for the reconnaissance workflow in many parts of the US Gulf Coast, where the target is relatively shallow gas accumulations, is amplitude. To be prospective, areas of high amplitude need to be anomalous and constrained by structure. The DipEnv volume enables the available 3D seismic data to be efficiently and thoroughly "mined" for such structurally constrained amplitude anomalies. Like the DipAzi volume the DipEnv volume (figure 3a) makes use of a 2D colour space (figure 3b) to present the correlation between independent quantities, in this case, instantaneous dip and Envelope (instantaneous amplitude). Dip is shown by saturation and envelope by hue. Simply scanning through the DipEnv shows any regions in which high amplitude areas may be fault controlled.

Object Delineation: Fault Imaging and GeoBody Detection

Whilst the DipAzi and DipEnv volumes are powerful scanning tools, it is important to examine the anomalies and potential controlling faults as 3D objects. This enables a true appreciation of the fault and potential prospective trapping geometries and their connectivity.

Extraction of the imaged fault network is a multi-stage process involving generation of a fault attribute cube in which the potential faults are clearly highlighted in a way which represents the likely connectivity of the faults in both the X, Y and time / depth directions. This means using “fault attribute” processes which go beyond the conventional coherency or semblance methodologies. The tools used in this workflow are robust to variations in data quality in the types of faulting imaged and their seismic fault expression by providing access to multiple fault attribute generation techniques. Once a suitable fault attribute has been generated the next stage in the process is to delineate the fault network to provide a 3D object representation of the faulting. Again the user has control over parameters which allow for simple data specific optimisation of the results.

Geobody delineation is carried out in parallel with the fault delineation. In this instance, geobody delineation was based solely on envelope. However, it is often valuable to be able to use multiple attributes to constrain a set of geobodies. To support this a suite of interactive, intuitive tools have been developed based on 2D/3D cross plotting and on multi-attribute volume RGB visualisation (Henderson et al 2007). The geobodies enable the geometry and connectivity of individual anomalies to be examined. The utility of the geobody delineation is increased further by combining the delineated 3D fault network with the anomaly geobodies (figure 4) to give a full 3D appreciation of the relationship between structural and stratigraphic elements of the potential prospects.

Measurement

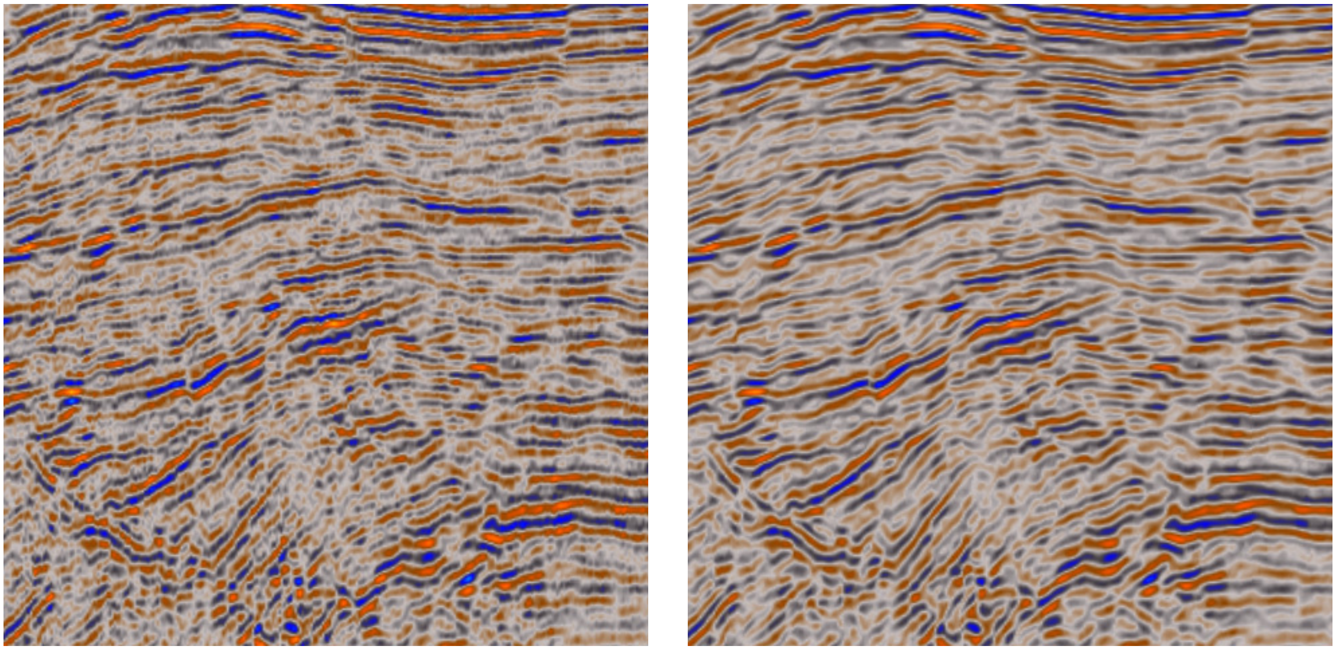
In the reconnaissance workflow the primary measurements of interest are volumetrics. The volume of the anomaly geobodies can be measured easily within the workflow and with the availability of appropriate time to depth information converted to a gross rock volume, supplying the basis for more detailed volumetric analysis.

Summary

Image processing techniques combined with 3D visualisation can form the basis of a simple but very powerful data reconnaissance workflow that can dramatically reduce the time taken to generate a lead inventory from 3D seismic reflectivity data. The attraction of this approach is that the gains in productivity are achieved in parallel with being able to introduce greater objectivity and integrity into the evaluation process providing increased confidence in the final interpretation.

References

Henderson, J., Purves, S.J., and Leppard, C., 2007, RGB visualisation based delineation of geological elements from volumetric spectral decomposition of 3D seismic data: First Break, in press.



(a) (b)

Figure 1. Application of 3D structurally oriented, edge preserving noise cancellation filtering can greatly increase the clarity of important structural stratigraphic information. (a) Original data, (b) Noise cancelled data.

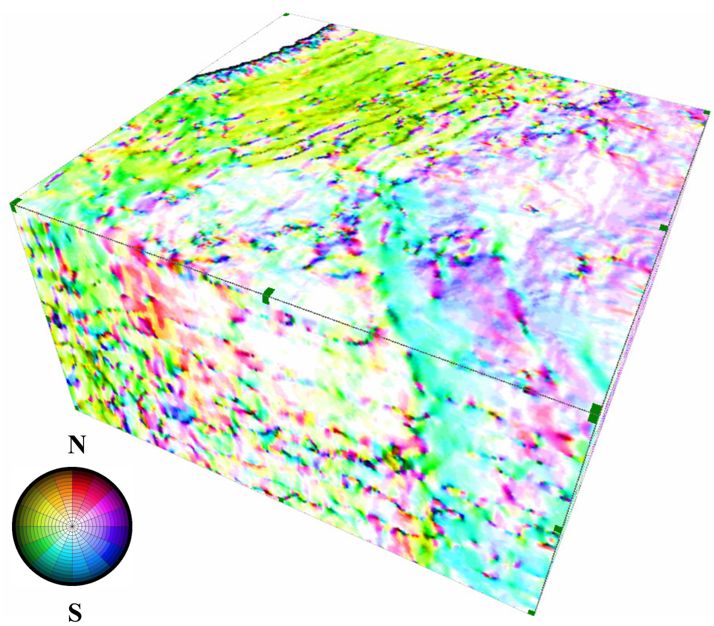


Figure 3. Structural features such as faults, flexures, channel margins and clinoforms can be easily visualised using the DipAzi volume.

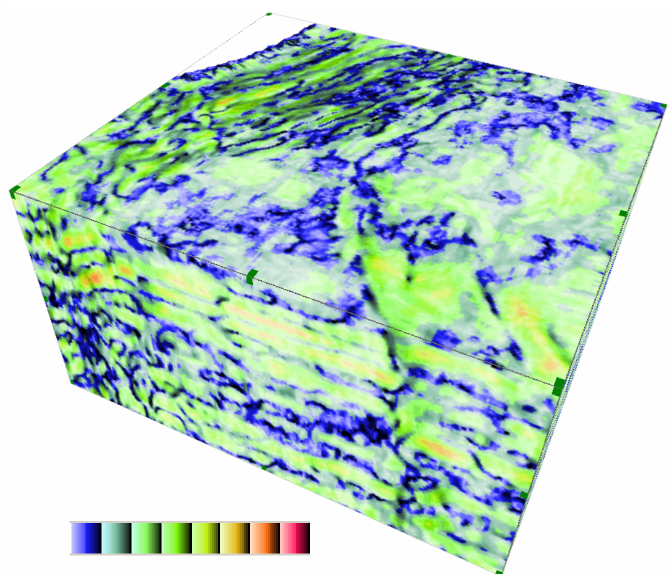


Figure 4. The DipEnv volume enables visualisation of structurally constrained amplitude anomalies. Faults are indicated by dark lineations, high amplitudes by green – red colours.

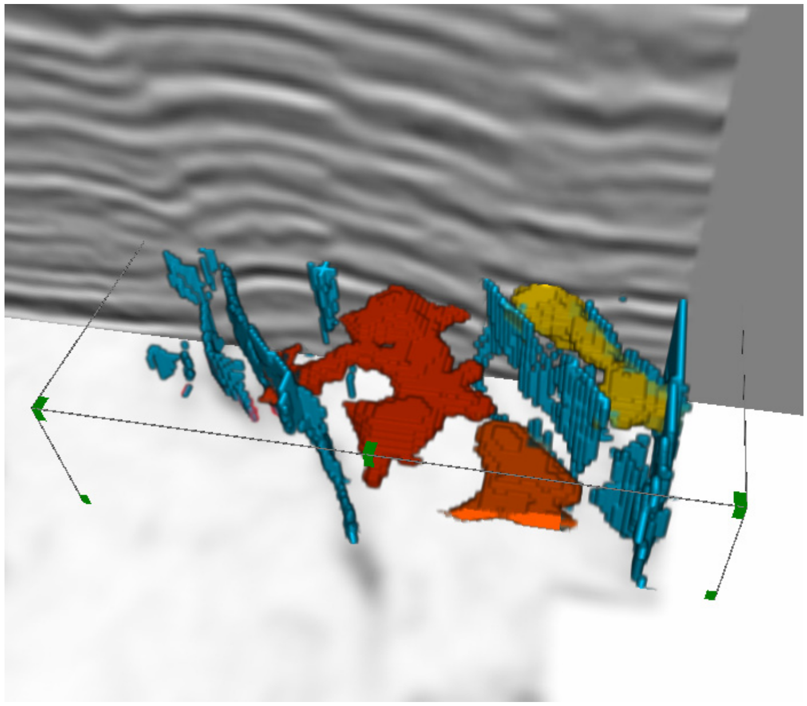


Figure 5. The combination of amplitude anomaly geobodies with the detected fault network enables rapid, detailed 3D analysis of key prospectivity indicators