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SEISMIC VOLUME PROCESSING FOR GEOLOGIC INTERPRETATION : A review of its use with 3D visualization software.

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Introduction:
As 3D data coverage expands worldwide, large "super merge" 3D surveys increasingly reveal the structural and stratigraphic framework for entire petroleum systems, and form the basis for a regional prediction of source, reservoir, and seal. Conventional seismic interpretation, relying on the tracking of horizons (geologic surfaces), is increasingly proving unable to image geology and extract rock and fluid information efficiently. Therefore, it is being complimented by volume seismic interpretation, based on the extraction of 3D objects (geobodies) from the seismic data using seismic volume processing, and their display using 3D visualization. Fold and fault geometries, stratal architecture (stratigraphic sequences and their associated boundaries) and large-scale depositional elements (e.g. channels, incised valley-fill, and turbidite fan complexes) are often difficult to see clearly within seismic reflectivity data, but can be spectacularly imaged by the application of seismic volume processing.

In this paper, we show how integrated poststack refinement, volume image processing, and volume visualization techniques can be used to improve interpretation efficiency and squeeze more information from 3D seismic data.

Seismic Volume processing options:
We define Seismic Volume processing to be a mix of 3D Poststack and 3D Voxel processing techniques. 3D Poststack processing includes large aperture calculations such as those used in the creation of regional dip and azimuth volumes for identifying gross structural architecture as well as small aperture calculations such as the cross correlation of neighbouring seismic traces to highlight fault breaks. 3D Voxel or "volume image" processing options include smoothing, automatic voxel cloud detection and isolation, binary morphology voxel body manipulation, voxel body skin creation and shape cutting (sculpting).

Workflow examples:
This paper presents several examples of workflows that combine seismic volume processing with 3D visualization to reveal 3D structural geometries within a large 'basin scale' seismic volume from a structurally-complex province in the Northern Norwegian Sea.

Example 1: structural analysis.
Fig (1) shows the result of Poststack processing which was used to generate both "smoothed local azimuth" and "key peak and trough" volumes, which we merged together into a combined volume for visualization and interpretation.

Dip and azimuth volumes can help us identify gross structural architecture and can often impact our interpretations of subtle structure. Voxel sculpting, using this combined volume, isolated the South Easterly dipping data within a user defined target sub volume. This South Easterly dipping volume was then displayed, using 3D visualization software, with its own custom colour bar and opacity filter, within a partially transparent original seismic volume (Fig (2)).

Example 2 : pinchout analysis.
Focusing in on the onlapping sediments from the West, Fig (1), this second example illustrates the use of instantaneous frequency to view seismic event termination. Fig (3) shows the result of Voxel sculpting to extract just the onlapping events above an interpreted sequence boundary. This subvolume was input to Poststack processing , instantaneous frequency calculation (see Fig (4)), which highlighted pinchouts as high frequency zones. Voxel cloud detection could then be used to isolate the largest and most continuous pinchouts and 3D visualization allowed us to display these as "objects" within our initial onlapping seismic subvolume Fig (5). Events appear to terminate parallel to the onlapping sediment strike at the top of the structure but parallel to faulting off structure.

Example 3 : fault zone analysis.
Fig (6) & (7) illustrate seismic volume processing and 3D visualization , this time on a much smaller ''well target'' sized seismic volume, applied to extract , visualize, and utilize the bad data zone around a fault. Normally we just draw a fault surface somewhere in the bad data zone or roughly following one of its edges. With this workflow we can isolate the whole bad data volume as an object and study its internal architecture. If , as appears more likely in this example, the bad data zone results from poor seismic imaging and does not help us with our geologic interpretation, we can make this same object a barrier to stop horizon auto trackers and a visual control or no go area for any well planning.

Fig (6) shows the result of Poststack processing to enhance the fault zone characteristics and Voxel body skin creation to extract the fault zone edges which are displayed along with an earlier attempt at fault surface interpretation. Poststack scaling of the original seismic volume to reduce its amplitude range to +/- 120 instead of +/- 127 allows the insertion of these fault zones edges back alongside the seismic data , into a new combination volume, as voxel values of +127.
Fig (4) These +127 voxels can now be used as barriers to autotracking.

These 3 examples of seismic volume processing combined with 3D visualization illustrate how today's seismic interpreters have access to a rich toolkit that can be used to highlight and isolate specific geologic features, and customise their seismic volumes for enhanced 3D interpretation.

References:
1) - Volume Interpretation and Seismically-Driven 3D Modeling of a Deep-Water Channel Complex, Offshore Angola - Christophe Basire(1), Christophe Casadebaig(1), John Kerr (2), Lars H. Nordby(1), Bill Shea(1), andØyvind Steen(1),
(**1**) Statoil Technology, Trondheim; (**2**) Landmark Graphics, London - 3D Volume Interpretation & Visualization , FORCE seminar Nov 2000 Norway
2) - ''Probing your applets'' – capturing information in 3d seismic using image processing, visualisation & interpretation tools. - D Hood(1), C Simmons(1), Dick Dalley(2)
(1) – Angola exploration business unit, BP, Sunbury (2) – Foster Findlay Associates Ltd, Newcastle. 3D Seismic International conference , Geol Soc, Nov 2001 London
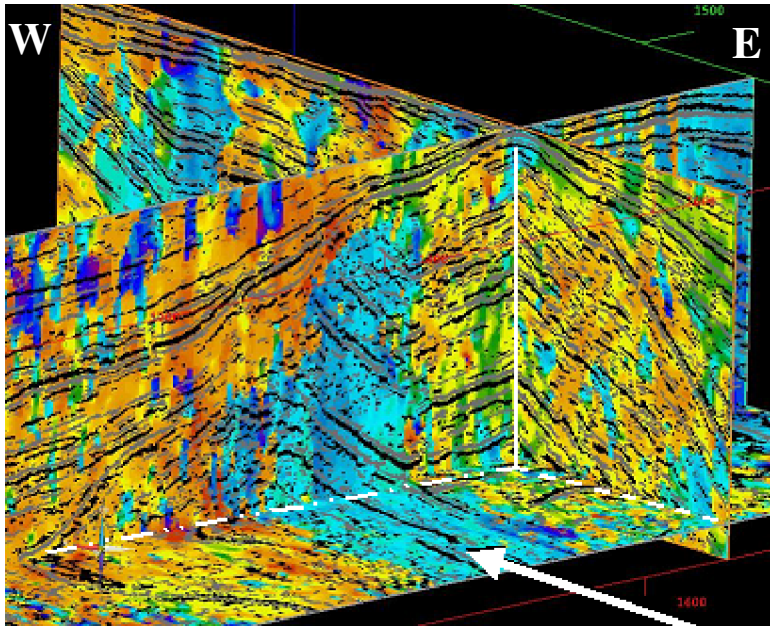
Fig (1)
Seismic peaks and troughs combined with azimuth into 1 volume.

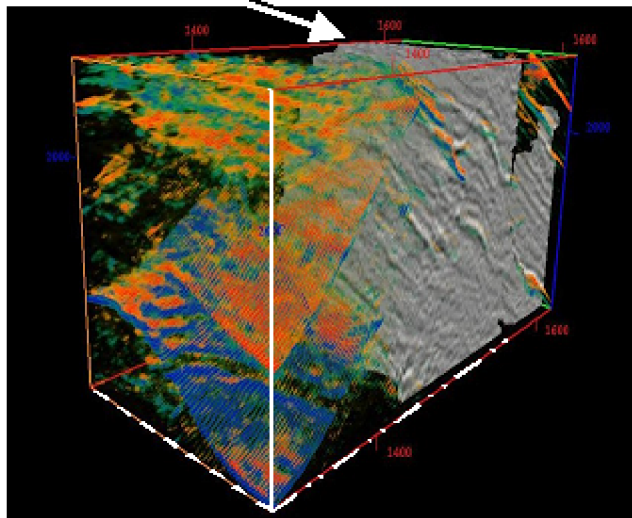: volume displayed using orthogonal 2D panels.

(Blue indicates an easterly dip ;
grey = troughs ;
black = peaks)

Fig (2)
Seismic peaks and troughs separated into easterly dipping events and the rest inside 1 volume.

: volume displayed using 2 3D probes to allow a fully opaque easterly dipping fault block to be seen inside a transparent seismic volume.
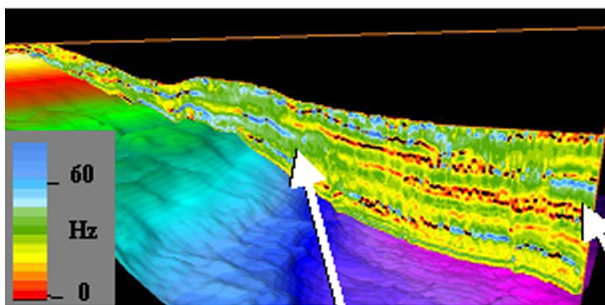
(A grey scale colour bar is used for the opaque fault block and a blue to red colour bar for the rest of the volume.)
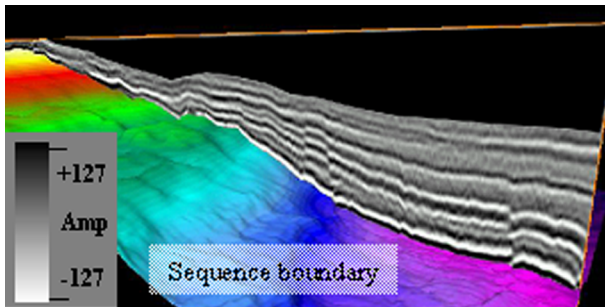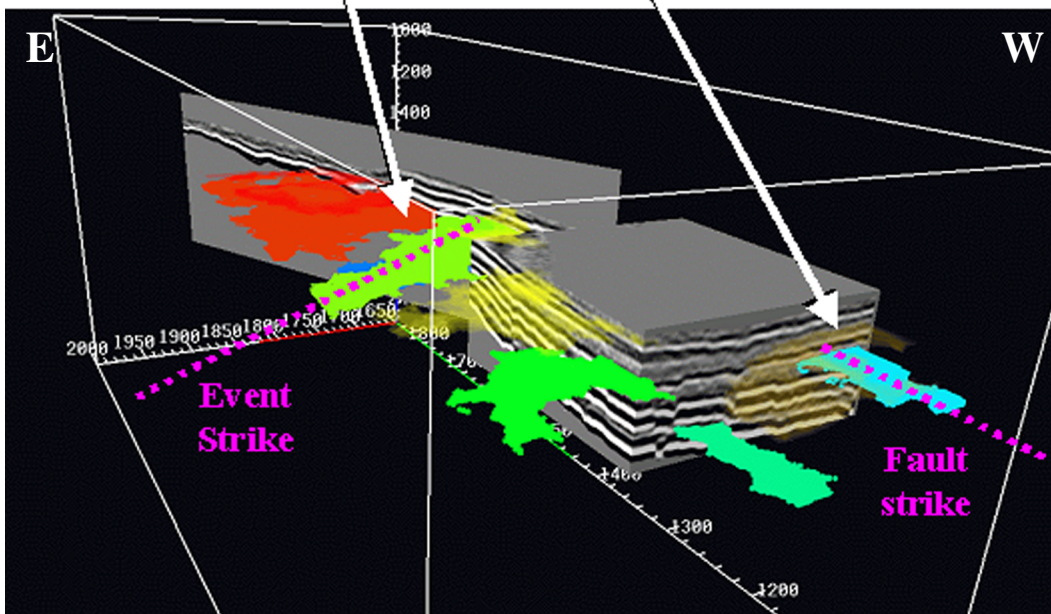
Fig (3)
Seismic sculptured to show
onlap dipping events only.

: volume displayed using 1
orthogonal 2D panel.

Fig (4)
Instantaneous frequency
Poststack processing
highlights pinchouts.

(pinchouts = high frequency ,
eg blue)

Fig (5)
Voxel cloud detection isolates largest high frequency "objects" which
show pinchouts parallel to event strike (red & light green) and parallel to
faulting (blue & dark green)

: seismic and voxel "objects" displayed using 2 3D probes
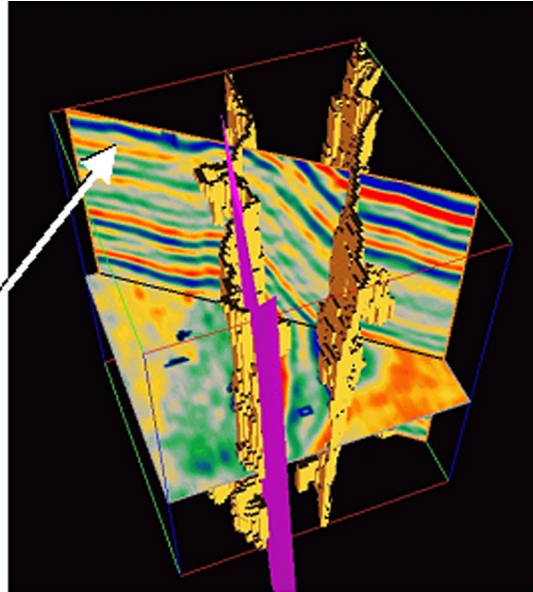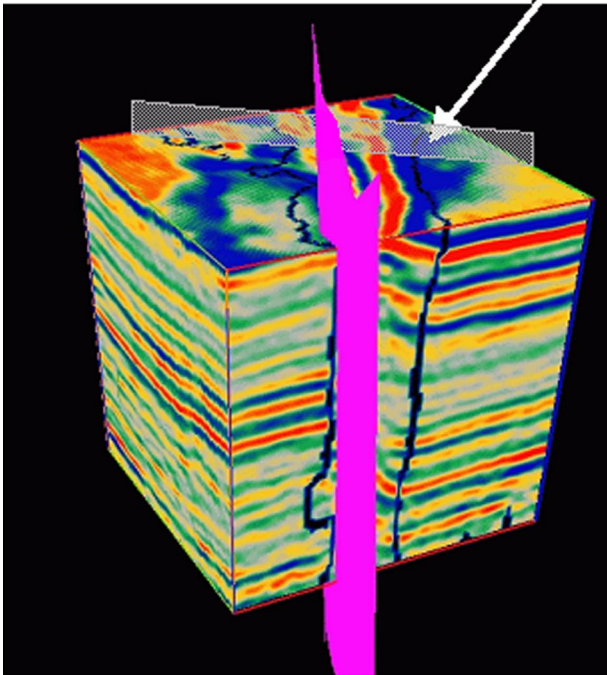and a diagonal 2D panel.

Fig (6)
Original seismic volume with fault zone edges extracted into 2 voxbodies shown with an earlier manually picked fault surface

: seismic displayed using diagonal and time slice 2D panels.

(Gold bricks = voxbodies,
pink surface = fault)

Fig (7)
Fault zone edges and the original seismic data are combined into 1 custom volume.

: volume displayed using a 3D probe.

(A value of + 127 is given to fault edge voxels, whilst the original seismic amplitudes are reduced to +/- 120 instead of +/- 127)