The Geophysical Corner is a regular column in the EXPLORER, edited by Satinder Chopra, chief geophysicist for Arcis Seismic Solutions, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer. This month's column examines how dense horizons define stratigraphic attributes.

Dense sets of seismic horizons

A New Approach to Stratigraphic Interpretation

By FARRUKH QAYYUM, NANNE HEMSTRA and PAUL de GROOT

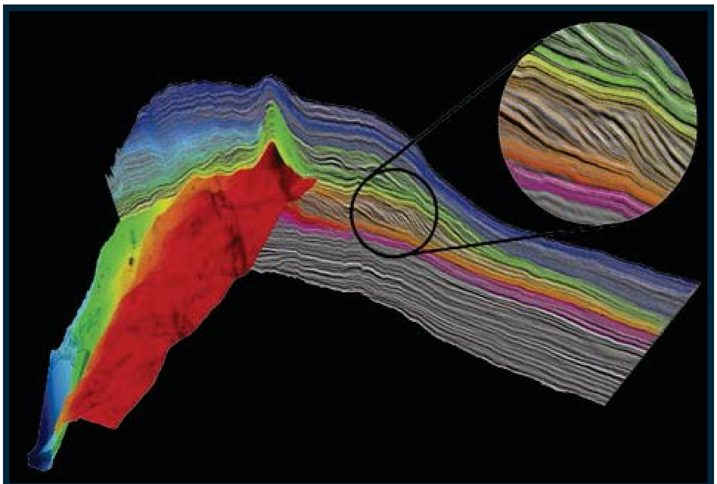

Figure 1 – A HorizonCube consists of a set of auto-tracked seismic horizons using a pre-computed dip volume. This is an exponent of an emerging group of global interpretation techniques.

This article introduces a new set of seismic attributes that play an important role in extracting detailed stratigraphic information from seismic data.

The attributes in question are derived from a HorizonCube, one of the emerging interpretation techniques that provide fully interpreted seismic volumes (figure 1).

In this particular technique, horizons are automatically tracked between a given set of framework horizons and faults. The tracking is done using a seismic dip volume.

Compared with conventional amplitude tracking, this algorithm is more robust in areas with low signal-to-noise ratio, where diachronous events can be tracked as well as events that are phase inconsistent.

As these horizons are guided by a continuous dip-field, they may converge and diverge according to the dip of a seismic reflector. In this way, the key geologic features such as unconformities, pinchouts and condensed sections are highlighted.

Horizons can be tracked in two different modes (figure 1):

- As continuous horizons that stay together when they converge and never cross each other.

Such horizons help identify unconformities and condensed sections – particularly useful in 3-D attributes visualization and reservoir modelling.

- As truncated horizons that may stop when they meet each other in space based on a user-defined threshold.

This helps to identify stratigraphic lapouts (onlaps, downlaps and top laps). These also are useful in Wheeler diagram creation and sequence stratigraphic interpretation.

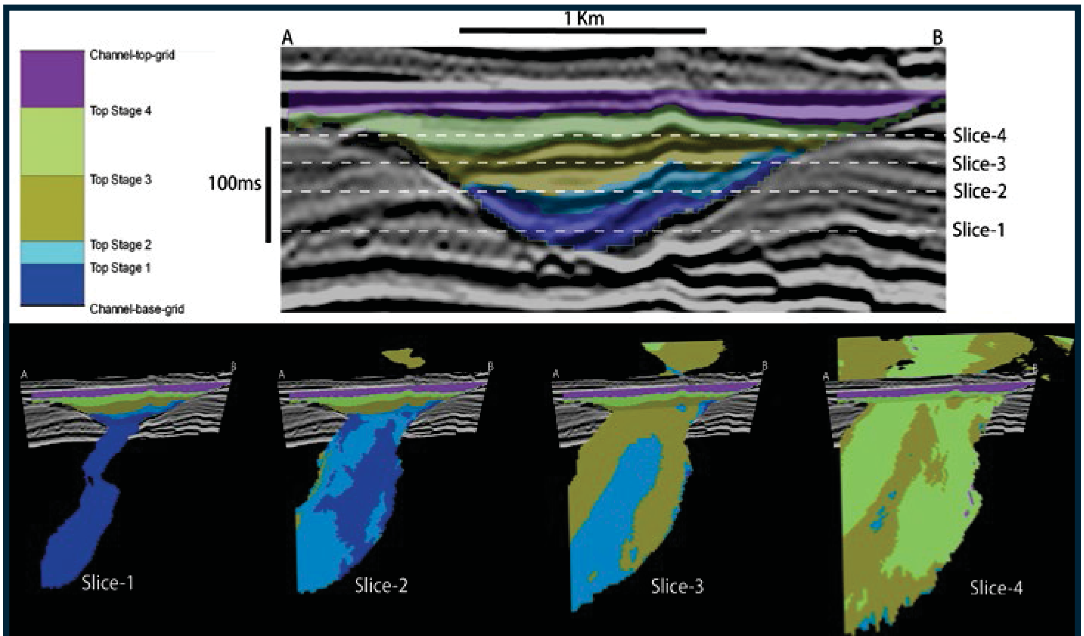

Figure 2 – A deepwater channel system of Australian Northwest Shelf is sub-divided into several channel stages attribute volume. Top: Color-coded channel stages are overlain on the seismic data. Bottom: Time-slicing through the channel stages in a flattened domain (channels top).

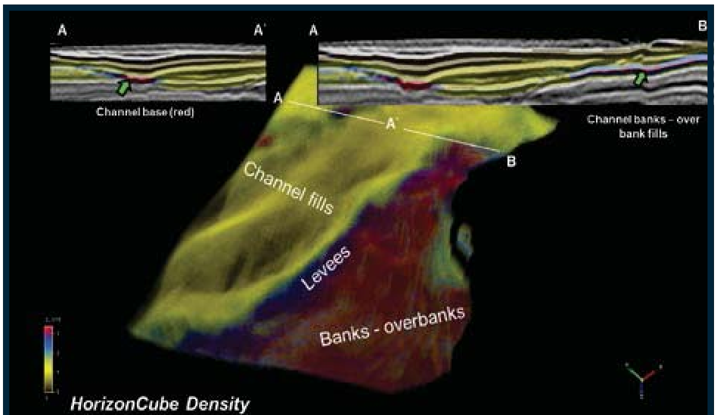

Figure 3 – Same channel systems are visualized using HorizonCube density attribute. Note that the locations of higher densities values mostly correspond to channel base, levees or over-bank regions.

New Family of Stratigraphic Attributes

For the continuous set of seismic horizons, a new family of attributes can be computed that visualize geologic features previously hidden.

Attributes include:

- **Isochron thickness** – This attribute highlights not only sedimentary bodies but also picks up local pinch-outs, condensed intervals and local unconformities.

- **Curvature** – This curvature attribute tends to be smoother than the conventional volume curvature attribute, computed using the seismic dip volume without mapping.

- **HorizonCube density** – Events can be counted within user-defined time windows, with high-density values corresponding to horizon convergence and low density values corresponding to the horizon divergence.

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The "HorizonCube density attribute" helps define the zones of pinch-outs, condensed sections and unconformities.

- **Arbitrary layers** – A dense set of seismic horizons can be separated into a set of arbitrary (stratigraphically uninterpreted) layers that divide the mapped seismic horizons into fix layers with a unique ID for each layer.

This plays an important role in quality control where visualizing hundreds of horizons can often be slow and laborious.

- **Derivatives** – Finally, first or second derivatives on a set of horizon events can be extended to perform a derivative on an isochron between a given ranges of events. These attributes measure subtle geometrical changes and discontinuities.

From a stratigraphic interpretation standpoint, the mapped seismic horizons in truncated form can be sub-divided into sequence stratigraphic units through the co-visualization of a structural domain and a Wheeler domain in conjunction with well data.

In both domains various data, such as wells and seismic, can be combined to interpret a set of sequence stratigraphic units, such as systems tracts and sequences.

Typical attributes that are extracted using this sequence stratigraphic

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framework include stratigraphic unit IDs (identification number) and isochrons. The IDs of interpreted stratigraphic units can either be unique (each systems tract unit is assigned a unique identification number) or common (each identical systems tract is assigned a common number).

An isochron attribute calculated the thickness of a stratigraphic unit. The unit of this attribute depends on the seismic survey type (TWT or in depth). This is a key attribute to understand how sedimentation filled a sedimentary basin as a function of geologic time.

The relative rate of preservation – the ratio between an isochron volume and a known geologic time-span for a particular unit – also can be calculated with the results being relative measurements of the rate of preservation per geological time unit.

Finally, an attribute can be generated that defines the difference between two isochron grids as a volume at a certain trace location.

Extracting Deepwater Channel Stages

During the Neogene period, Carnarvon Basin (Australian North West Shelf) comprised several deepwater meandering channelized systems. One of those systems is studied using the new stratigraphic unit ID attribute.

To our knowledge, this is the first study in which this attribute was used to define an unconventional set of stratigraphic units.

Convention nomenclatures are not adopted, as the interval may fall in one systems tract. Therefore, a further sub-division of channel system requires a new sequence model.

In this case, a "channel stages" sequence model is defined. It contains a set of N stratigraphic units defined as channel stages. Each unit is defined by its own unique ID.

Upper and lower boundaries of the channel system were manually mapped to form an initial framework to process the densely mapped set of seismic horizons. Within such a framework, a data-driven collection of densely mapped seismic horizons was created.

These were then sub-divided into a channel stages model that contained a user-defined set of color-coded stages. The criteria of sub-dividing a channel system into its stages are based on observations of features such as crosscutting relationships, timing and geomorphologic patterns.

Five channel stages can be seen in figure 2. The same interval also can be studied using the density attribute (figure 3), which clearly shows channel base, levees and banks of channel systems.

Workflows such as these support building better stratigraphic models to predict reservoir quality sands and to perform reservoir characterization.

Dense sets of seismic horizons help in defining new stratigraphic attributes – and these attributes help in understanding stratigraphy and geomorphology, and can be used as a means of performing stratigraphic interpretation on seismic data. E

(Editor's note: AAPG member Farrukh Qayyum, Nanne Hemstra and Paul de Groot all are with dGB Earth Sciences, Enschede, Netherlands.)