Seismic geomorphology: imaging elements of depositional systems from shelf to deep basin using 3D seismic data: implications for exploration and development

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Abstract: 3D seismic data can play a vital role in hydrocarbon exploration and development especially with regard to mitigating risk associated with presence of reservoir, source, and seal facies. Such data can afford direct imaging of depositional elements, which can then be analyzed using seismic stratigraphy and seismic geomorphology to yield predictions of lithologic distribution, insights to compartmentalization, and identification of stratigraphic trapping possibilities. Benefits can be direct, whereby depositional elements at exploration depths can be identified and interpreted, or they can be indirect, whereby shallow-buried depositional systems can be clearly imaged and provide analogues to deeper exploration or development targets. Examples of imaged depositional elements from both shallow and deep sections are presented.

Seismic data have long been used for lithologic prediction. Initially, such interpretations were based on the analysis of 2D seismic reflection profiles (Vail *et al.* 1977). The approach that was used involved first the identification of reflection terminations (e.g. onlap, downlap, toplap, erosional truncation) and the recognition of stratigraphic discontinuities such as unconformities. Second, the reflection geometries between discontinuity surfaces were described (e.g., oblique or sigmoidal progradation). Finally, the amplitude, continuity and frequency of reflections were described and mapped. In sum, these observations yielded insights with regard to the type of depositional systems present. This approach was referred to as seismic stratigraphy (Vail *et al.* 1977).

With the development of 3D seismic acquisition techniques, the opportunity to image geological features in map view opened up new approaches to geological prediction (e.g. Weimer & Davis 1996). Various reflection attributes such as amplitude, dip magnitude, dip azimuth, time/depth structure and curvature, to name a few, can be observed to yield direct images of depositionally and structurally significant features. In addition, analysis of seismic intervals can lend further insight to such features. The study of depositional systems using 3D-seismic derived images has been referred to as *seismic geomorphology* (Posamentier 2000). This represents a significant step change in how seismic interpreters evaluate 3D seismic data. In general, depositional environments had commonly been inferred on the basis of cross-section derived stratigraphic architecture and subsequent mapping of seismic facies leading to lithologic predictions. With the advent of seismic geomorphology, discrete, detailed depositional subenvironments and depositional elements could be interpreted directly from map view images leading to much more accurate understanding of lithologic distribution patterns and enhanced prediction of the distribution of reservoir, source and seal facies.

The following discussion will be divided into two parts, the first section illustrating examples of seismic images of depositional elements at exploration depths, and the second illustrating images of depositional elements at shallow depths.

Depositional elements at exploration depths

Cretaceous channels—Alberta, Canada

Figure 1 illustrates two views of a major channel crosscut by two lesser channels. Figure 1A is a *horizon slice* or *flattened time slice*, whereby a reflection 32 ms above was interpreted and used as a reference horizon for the purpose of slicing through the 3D seismic volume. Figure 1B is a reflection amplitude map of reflections immediately below the reflection associated with the channel. Each images the channels in a different way, with different details brought out by the two display styles. Both show linear features within the large channel, which can be interpreted as possible point bar deposits. Both show a crosscutting and therefore younger channel in the middle of the illustration. However Figure 1A shows another smaller channel crosscutting the larger channel towards the bottom of the illustration, not apparent in Figure 1B.

The integration of seismic geomorphology and seismic stratigraphy is illustrated in Figure 2. Inclined reflections within the interpreted channel fill can be observed on the reflection profile oriented normal to the long axis of the large channel (Fig. 2B). These reflections can be interpreted to represent lateral accretion surfaces associated with point bar deposition within the channel (Figs 2C and D). The isopach map indicates the presence of a thicker channel fill on the southwestern side of the channel (Figs 2A and D). The seismic profile reveals that the thicker part of the channel does not correspond to a deeper channel thalweg, but rather is associated with a 'bump' across part of the channel. This 'bump' is interpreted to be associated with a substrate that is less compactible than the other part of the channel fill (Fig. 2C). This least compactible section would suggest the presence of lateral accretion sets that would be most sand-rich, sand being less compactible than silt or shale (Fig. 2D).

Planning of horizontal well bore trajectories should take into account the presence of internal stratigraphic architecture comprising varying lithologies (Fig. 3). In this instance, orientation of horizontal well bores parallel to the lateral accretion deposits would allow for improved reservoir management. Lithologic variations associated with bedding parallel boreholes would be lower than those associated with bedding normal boreholes. Consequently, drilling parallel to bedding planes might better protect against gas or water breakthrough. Alternatively, if gas or water breakthrough is not a concern, then a preferred strategy might be to drill across bedding planes so as to access and drain multiple compartments with a single borehole.

Several crosscutting Cretaceous-aged channels are illustrated in Figure 4. This image represents a map of the negative polarity total amplitudes within a 16 ms window that contains at

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