

Mass transport complex imaging with P-Cable ultrahigh-resolution 3-dimensional seismic

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Summary

Accurate imaging of shallow mass transport complexes (MTCs) is often necessary for the planning and completion of offshore development activities in a timely and safe manner (Shipp, Nott, and Newlin 2004). In recent years there have been significant advances in ultrahigh-resolution 3-dimensional (UHR3D) seismic methodologies. Of specific relevance is the P-Cable receiver system (Berndt and Planke 2007; Planke et al. 2009), which, when combined with a high-resolution source, provides excellent illumination of MTCs within the upper 2 seconds two-way travel time (TWT) below seafloor. The level of resolution and continuity achieved with UHR3D seismic allows for the production of highly intuitive interpretive products that promote efficient communication between geoscientists and engineers. Here, we present relevant examples of MTCs imaged in the Gulf of Mexico with the P-Cable technology.

Introduction

Surface and subsurface MTCs are common to the continental slope of the Gulf of Mexico and the adjacent basin floor (Bouma, Roberts, and Coleman 1990; Posamentier 2003; Sawyer et al. 2009; Tripsanas et al. 2008; Young et al. 2003). Many of the near-surface MTCs can be associated with the glacial sealevel lowstands of the late Pleistocene based on relative and absolute stratigraphic age control derived from stable and radiogenic isotopes and also biostratigraphic first and last occurrences (Sawyer et al. 2009; Young et al. 2003). Beyond the Gulf of Mexico, mass transport processes are also common to, among other areas, the steeply sloped margins of volcanic islands (Crutchley et al. 2013). Here, we focus on subsurface mass transport complexes from the Gulf of Mexico, which have proven to be a serious impediment to safe and efficient subsea development when situated within 80 meters of the seafloor (Shipp, Nott, and Newlin 2004). Specifically, the installation of elements such as jetted conductors and suction piles can be complicated due to the presence of relatively consolidated MTCs (Shipp, Nott, and Newlin 2004). Therefore, accurately delineating the 3-dimensional (3D) nature of these deposits is of significant relevance. To this end, we present two examples of mass transport deposits imaged with the P-Cable UHR3D seismic system and the visualization products that can be produced from these data. Such data provide very well resolved continuous information between the shallow subsurface and the seafloor, which promotes swift and effective interpretation and also efficient communication between geoscientists and engineers.

Method

The data presented here were collected with a P-Cable receiver system comprised of 18 x 100 meter long solid streamers with a group spacing of 6.25 meters and a nominal cross-line streamer spacing of 12.5 meters. This configuration, totaling 288 receiver groups, yielded four-fold coverage at a shot spacing of 12.5 meters with a natural bin size of 3.125 x 6.25 meters. The data were collected at a 0.25 millisecond sampling interval and later subsampled to a 0.5 millisecond interval during processing. A single 210 in³ GI gun fired in harmonic mode (105 x 105 in³) provided the seismic energy. Positioning was accomplished via a suite of in-water DGPS (differential Global Positioning System) receivers and 3-axis magnetic compasses of which data were assimilated into a proprietary algorithm providing real-time shot, receiver and common mid-point positions (CMP) and real-time, online binning (Hardy, Hise, and Majzlik 2011; Majzlik, Hise, and Hardy 2011; Majzlik et al. 2012).

These data are from the preliminarily available, fast-track, data set. The data set has undergone navigation merge, basic wavelet processing, noise elimination, static corrections, post-stack time migration, and some basic post migration processing. These data have not undergone deghosting or any other advanced processing techniques. Therefore, the examples presented are a truly conservative representation of the quality of data acquired and the level of processing.

The interpretation products presented here were created with an off-the-shelf interpretation suite, and represent a wide range of deliverables. Some of these products represent a relatively large amount of interpretation time, such as interpreted time horizons and the associated amplitude extractions (tens of hours), and others, such as oblique-cut attribute volume surfaces, represent relatively minimal interpretation time (minutes to hours), but with, nonetheless, useful results. In the case of both examples presented below, the data products are aimed at clearly illustrating the nature of the MTCs in an intuitive manner, which is made possible by the high-resolution nature of the data.

Examples

Figure 1 is an example of a multifaceted subsurface MTC that, based on general sedimentation rates and depth of burial, was dominantly active during the late Pleistocene (Bouma, Roberts, and Coleman 1990). Figure 1A shows

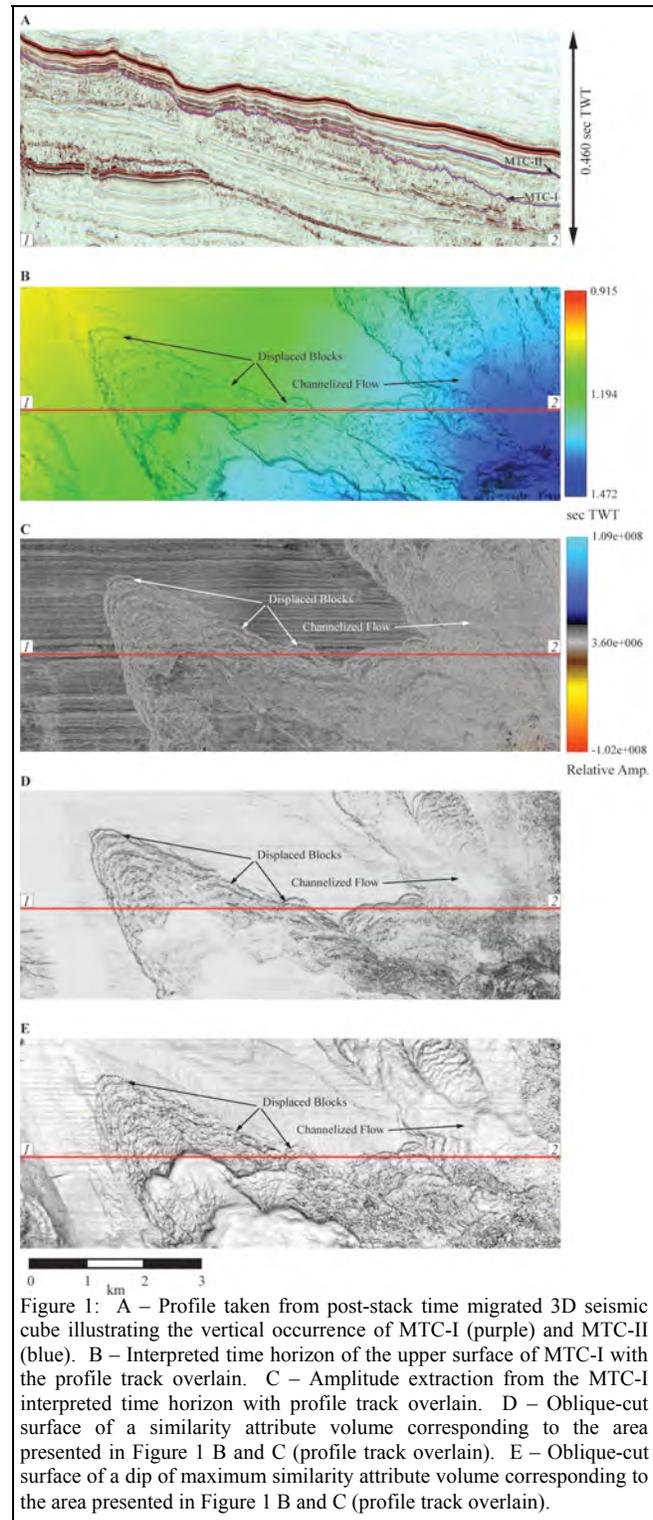
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the MTC in profile, with the interpreted upper surface of the MTC overlain (purple line – MTC-I). There has been some subsequent activity with this MTC, of which the interpreted upper surface is overlain in blue (MTC-II). Figure 1B represents the interpreted upper surface of MTC-I in 3D with the color scale illustrating TWT in seconds. Figure 2C is the amplitude extraction from this surface (color scale represents relative amplitude). These elements represent quite a few hours of interpretation time as this horizon was picked over a large area, and given the small bin size, hundreds of lines (inline, crossline and arbitrary diagonal) were semi-manually picked (peak fill) in order to successfully complete the pick with automation (3D hunt). The result is stunning and provides a very clear delineation of the mass transport complex, and also insights about the mechanisms of failure/movement, including displaced blocks and channelized flow (Tripsanas et al. 2008). Figure 2D is an oblique-cut of a corresponding similarity volume. Likewise, Figure 2E is an oblique-cut from a dip of maximum similarity volume. The oblique cuts were made such that the plane of the cut dipped at the same angle as the dip of the paleo-seafloor. Here, we did have the benefit of having interpreted the upper surface of MTC-I, but even if this had not been the case, a little trial and error with the cut dipping at roughly the dip of the current seafloor would have yielded a similar result. Excluding the time necessary to generate the attribute volumes, the investment in time necessary to image the MTC-I with the oblique-cut attribute method was minimal – less than an hour of trial and error with cuts and color scales.

Figure 2A shows the interpreted upper surface of a MTC in relation to the seismic volume. This MTC lies at about 0.040 seconds TWT below the seafloor. Figure 2B illustrates an overlay of the interpreted seafloor horizon (in transparency) over the interpreted upper surface of the MTC. Beyond the level of detail in the delineation of the MTC and seafloor, this figure provides an intuitive illustration of subsurface influence over seafloor geomorphology. We are able to visually comprehend that those features translated from the MTC may not represent active processes at the seafloor, but are indicative of possible complications for drilling and anchoring activities.

Conclusions

UHR3D seismic provides excellent illumination of shallow MTCs with a level of resolution and continuity that cannot be achieved with high-resolution 2-dimensional or reprocessed exploration scale 3D seismic data. This level of resolution and continuity facilitates the production of very detailed, intuitive interpretive products such as interpreted time horizons and amplitude extractions. In addition to this, UHR3D seismic allows for the production



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of high-quality attribute volumes that, in addition to providing valuable supplementary information, allow for rapid, interactive visualization of mass transport deposits when a more efficient interpretation is required.

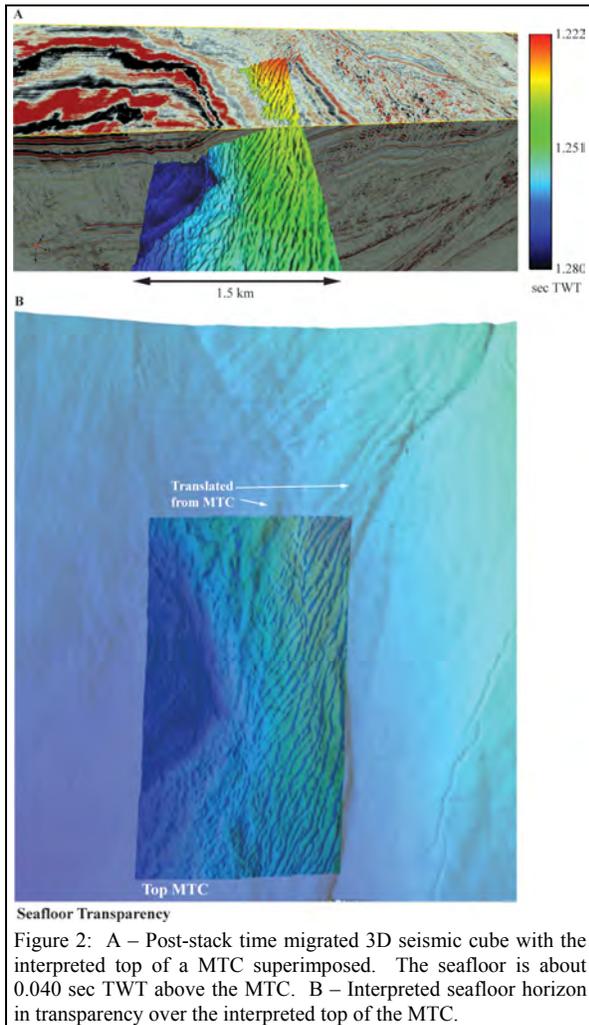


Figure 2: A – Post-stack time migrated 3D seismic cube with the interpreted top of a MTC superimposed. The seafloor is about 0.040 sec TWT above the MTC. B – Interpreted seafloor horizon in transparency over the interpreted top of the MTC.

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