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Significance of Amplitude Variations in Shaley Mass-transport Deposits - A Petrophysical-geophysical Correlation

T.M. Alves* (Cardiff University), K. Kurtev (Newcastle University), G. Moore (University of Hawaii) & M. Strasser (ETH - Zurich)

SUMMARY

For this work were used three high-quality 3D seismic volumes from SE Japan and SE Brazil, together with borehole data from the Nankai Trough. We show that, on 3D seismic data, seismic texture is defined as a reflection amplitude pattern that is characterised by the magnitude and variation of neighbouring data in a seismic volume (Chopra and Marfurt, 2007). We show the importance of seismic amplitude variations to assess the seal competence and reservoir potential of MTDs.

Introduction

Distinct degrees of stratal disaggregation, structural and petrophysical variations in mass-transport deposist (MTDs) have implications to the seal competence and reservoir potential of such strata (Nardin et al., 1979). Variations structural and petrophysical characters of MTDs promote the migration and escape of fluids to the surface (Masson et al., 2006), mainly through regions with lower net-to-gross ratios, significant internal deformation, or through faults and fractures (Bull et al., 2008).

On 3D seismic data, MTDs are often shown as intervals of distinct seismic amplitudes and facies when compared with confining strata. Most of these amplitude variations relate to the provenance (i.e. source strata) and degree of downslope transport of MTDs. As a result, MTDs can be composed of highly deformed sediments with no original depositional structures or, instead, a mix of highly and slightly deformed sediments, with great part of the original bedding still preserved in the form of remnant and rafted strata (Alves et al., 2010a,b). In addition, porosity and permeability are reduced in MTDs because of the high degree of deformation, variable lithologies, and variable porosity and permeability of strata comprising those (Moscardelli et al., 2006). Adding to their variable competence as seal units, Edwards (2000) and Ogiesoba and Hammes (2012) recognized reservoir potential in MTDs in the Gulf of Mexico. To recognize and describe MTDs is thus crucial to optimal well planning and hydrocarbon production.

For this work were used three high-quality 3D seismic volumes from SE Japan and SE Brazil, together with borehole data from the Nankai Trough. We show that, on 3D seismic data, seismic texture is defined as a reflection amplitude pattern that is characterised by the magnitude and variation of neighbouring data in a seismic volume (Chopra and Marfurt, 2007). We show the importance of seismic amplitude variations to assess the seal competence and reservoir potential of MTDs.

Method and/or Theory

Interpreted seismic volumes were chosen for comprising high-resolution data in two regions where there is stratigraphic control on the interpreted successions. The SE Japan volume is located in a region extensively drilled in multiple IODP Expeditions, in which clay and silt alternate with coarser turbidites and volcaniclastic intervals (Expedition 333 Scientists, 2012). Vertical seismic resolution approaches 6 metres in the SE Japan volume based on the dominant wavelength of ~24 m observed on synthetic logs and seismic profiles. The 3D seismic volume has an inline spacing of 12.5 m, a crossline spacing of 18.75 m, for a sampling rate of 5 ms. Data processing included pre-stack multiple removal and data conditioning (e.g., amplitude recovery, time-variant filtering, and predictive deconvolution) followed by 3D pre-stack depth migration (Moore et al., 2007; 2009).

Seismic resolution for the interval of interest approaches 10 metres in SE Brazil, based on the dominant frequency of the interpreted seismic volume (40 Hz) and on an estimated velocity of 1700 m/s based on data from DSDP Site 516 (Barker et al., 1983). The SE Brazil volume has a bin spacing of 12.5 m, a 2 ms vertical sampling window, and was acquired with a 6 x 5,700 m array of streamers. Data processing included resampling, spherical divergence corrections and zero-phase conversions undertaken prior to stacking, 3D pre-stack time migration using the Stolt algorithm and one-pass 3D migration.

We propose MTDs to be preferably imaged using root-mean square (RMS) amplitude maps. The maps provide measurements of the root-mean square amplitude of a seismic wave reflected at normal incidence on an interface (Brown, 1999). Peak amplitudes of reflected seismic waves, positive or negative, are root-squared into positive values of amplitude thus emphasising large reflection events over low-amplitude background strata. Secondary seismic attributes such as number-of-zero-crossings, dip or chaos can help understand variations in the degree of disaggregation and structural organisation (fabric) of MTDs (Fig. 1).

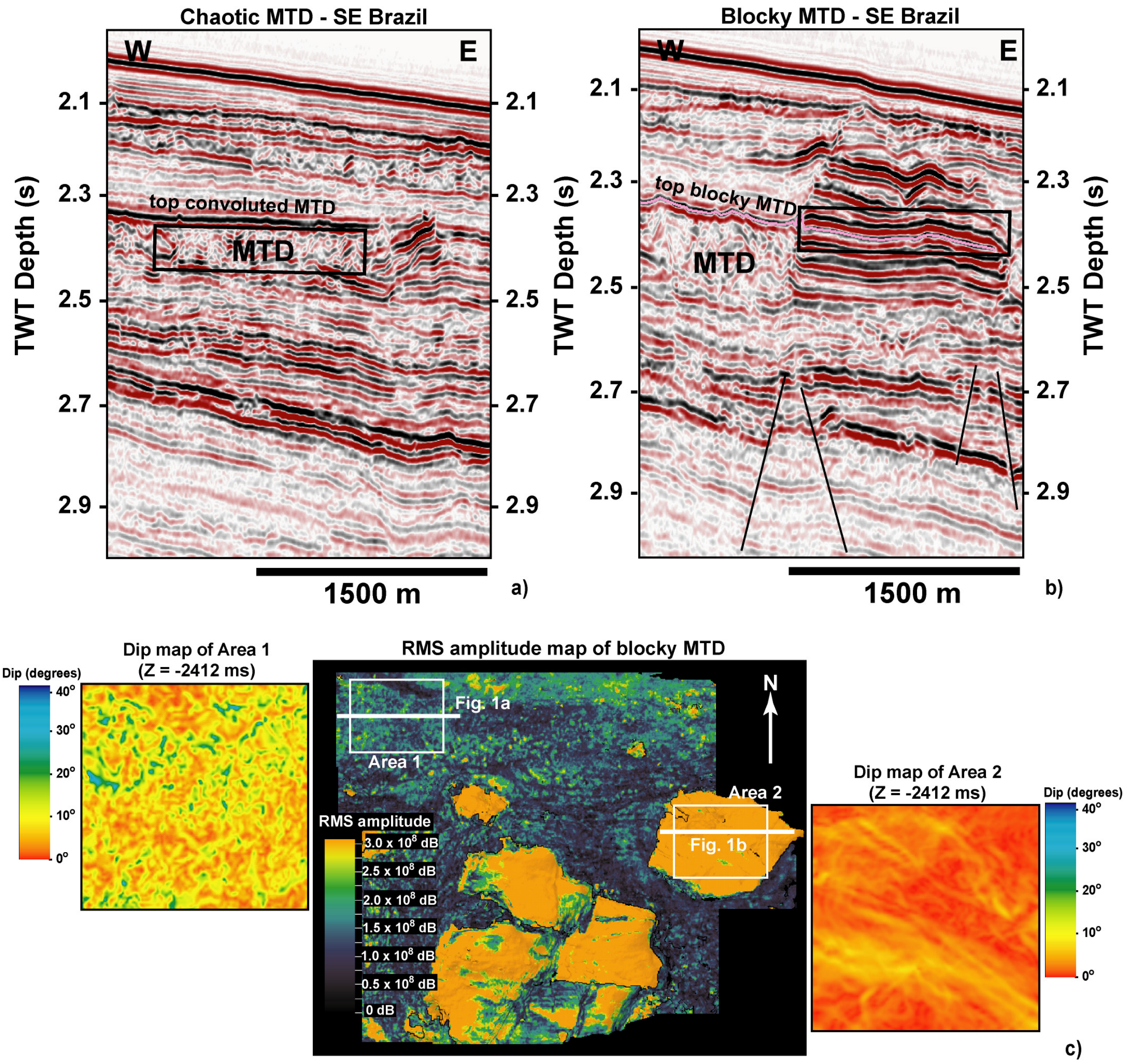

Figure 1 *Examples of the use of seismic amplitude to discriminate between MTDs with distinct internal characters. (a) Seismic profile depicting the location of a 3D volume of a chaotic, deformed MTD. (b) Seismic profile depicting the location of the 3D volume crossing a remnant block. (c) RMS amplitude map and associated dip maps of the MTD considered in the case-study. The figure shows the importance of amplitude variations and reflection character as criteria to distinguish debris flows from remnant strata and rafted blocks.*

Examples

The first example in this work is given by MTDs from IODP Expedition 333, which drilled at Site C0018A (Nankai Trough) a series of intervals evidencing individual MTDs (MTD 6, Strasser et al., 2012). In this work, we address two MTDs (MTD 5 and MTD 6) cored at site C0018A.

Strata in the thicker MTD 5 and MTD 6 comprise homogeneous silty clay, minor amounts of volcaniclastic material, together with chaotic strata and debrites. In contrast, below MTD 6 were drilled strata shown on 3D seismic profiles as high-amplitude continuous reflections. These continuous strata comprise well-stratified sandy turbidites, some volcaniclastic, interbedded with shales and silts. Peak-strength values and bulk density vary substantially in the MTD 5 and MTD 6. This character suggests seismic waves to be reflected out of relatively undisturbed, hardened strata in the two MTDs. Amplitude values in MTD 5 are high and evenly distributed, resulting from the presence of relatively high-amplitude reflections in the interpreted interval. Some of these high-amplitude reflections are possibly related with the presence of free gas and gas hydrates in the sediment (Kinoshita et al., 2012). In comparison, MTD 6 plots as strata with relatively high disaggregation and low seismic amplitudes. Deformation caused by folding and faulting results in a prominent fabric in parts of MTD 6. Layered strata below MTD 6 (mainly turbidites) show relatively high amplitude and no internal disaggregation, i.e. high lateral continuity.

From a blocky MTD in SE Brazil were extracted two 100x100 lines and 100 ms thick seismic volumes in two different areas. Area 1 comprises a region of moderate-amplitude, chaotic strata deposited between remnant blocks. Area 2 coincides with a remnant block showing sub-parallel strata. No major faults are observed in the remnant block in Area 2, which is likely to comprise alternate limestones and shales (Caravelas member, Brush et al., 2004; Fiduk et al., 2004). Area 1 shows a wide distribution of amplitude values, but two ranges of amplitudes recorded in the selected area. High-amplitude strata reflect small rafted blocks. Strikingly, high-angle rafted and faulted strata in Area 1 show a marked linear fabric on seismic data, a character replicating that of highly faulted or highly dipping strata within or outside MTDs. Strata in Area 2 show very low amplitude values, reflecting the sub-parallel nature of strata in the remnant blocks, i.e. not deformed during seafloor failure.

Conclusions

We present amplitude data from seismic data as crucial to understand the internal character of mass-transport deposits, their seal competence and reservoir potential. The data presented in this paper emphasizes three properties in MTDs with expression on seismic attribute data:

- Stratal disaggregation and degree of heterogeneity of strata in MTDs.
- Syn- or post-depositional fabric as, for instance, on basal shear surfaces of MTDs.
- Stratal connectivity, with high-amplitude reflections usually correlated with lower net-to-gross ratios. Relatively higher V_p and peak-strength values are recorded in deposits with high amplitude.

The three parameters above can be assessed on seismic data and plotted against borehole petrophysical properties. Based on this work, strata with moderate amplitude values or a marked fabric (e.g. dilational faults, thrusts or steeply-dipping strata) present the larger seal risk in MTDs.

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