Seismic geomorphology and stratigraphy of marine depositional systems controlled by tectonics (South Caribbean) and implications for hydrocarbon exploration

Esteban Alfaro, Michael Holz, Centro de Pesquisa em Geofísica e Geologia CPGG-Universidade Federal da Bahia

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Abstract

Sedimentary history of southern Caribbean has been affected by multiple tectonic events. Shallow marine deposition was controlled by a rift phase during Mesozoic to Paleocene. During post-Paleocene to recent, highly variable sedimentation was strongly controlled by episodic post-rift tectonic inversion. Seismic geomorphology and stratigraphy in 2D and 3D seismic data provide an excellent opportunity to reveal the distribution of marine depositional elements and insight into lithology. Interpretation of depositional elements were highlighted by typical seismic patterns (amplitude, continuity and frequency) and by seismic attributes such as complex-trace and coherence. There were proposed stratigraphic traps including pinch-outs, diverse reservoirs and seals related to gravity-driven deposits. Gravity-driven deposits consist of lobate and confined slumps and debrites. Tectono-stratigraphical characterization from a geomorphological perspective allows to suggest new reservoirs, seals and traps and to decrease risk of petroleum systems.

Introduction

Gravity-driven processes such as slides, slumps, debris flows and turbidity currents, are important agents for transporting sediments downslope into deep-marine environments (Shanmugam, 2006). Submarine landslides are an important mechanism in shaping and moving vast quantities of sediment down continental slope on both active and passive margins (Goldfinger et al. 2000; McAdoo et al. 2000) and at all latitudes, from glacial to equatorial regions (Laberg et al. 2000; McAdoo et al. 2000). These processes have been classified according to: nature of moving material, nature of movement, sediment concentration, fluid rheology and flow state. Normally, mass-transport complexes and associated deposits comprises 10-27 % of continental slope strata (Mienert et al. 2003; Hünerbach et al. 2004). In some settings, however, up to 70% of the entire slope and deepwater stratigraphic column is composed of these deposits (Maslin et al. 2004; Newton et al. 2004). The causes of such intense gravity-driven sedimentation at the continental slope include relative base level changes and syn-sedimentary tectonics causing clay diapirism which results in intra-basinal growth anticlines and thrust ramps. Diverse authors have proposed potential sandy reservoirs and structural traps of hydrocarbon in southern Caribbean (e.g. Barrero et al. 2007; Rey and Rubiano, 2009), however, there are not high-quality information about geometry and lithology of potential reservoir and seals neither potential stratigraphic traps. This paper treats about new exploration opportunities in southern Caribbean. Diverse potential stratigraphic traps, reservoirs and seals are revealed by stratigraphic and geomorphologic seismic methodology. Coherence seismic attribute has been used in many marine and continental basins around the world. In this case, coherence has been used on a slope which has been related to high structural growing and mud diapirism. Observations and interpretations highlighted by conventional amplitude and coherence, in a 3D high quality seismic data, are exposed in this paper.

Study Area

The study area is controlled by the interaction between the Caribbean, South American, Nazca and Cocos plates (Figure 1) (Cediel et al. 2003; Flinch, 2003; Gómez et al. 2007).

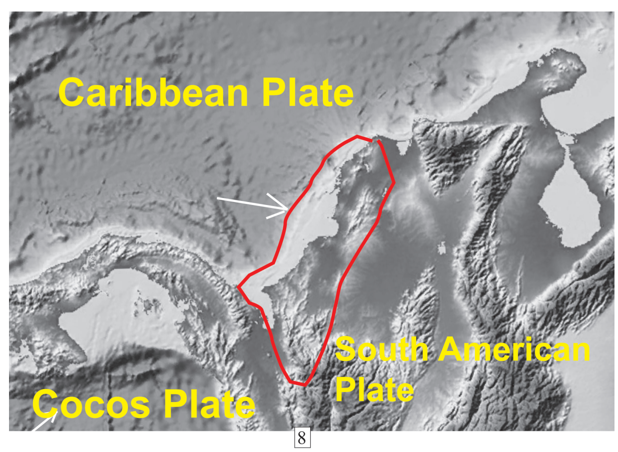

Figure 1: *Map of northwestern Colombian Caribbean margin showing the location of the study area. This area includes the Sinú-San Jacinto and Sinú Offshore basins*

Methodology

The interpretation methodology is based on seismic geomorphologic and stratigraphic procedures through standard seismic interpretation workflows. There was used seismic attributes like as amplitude, coherence and complex-trace.

Results

Five Mesozoic to Early Cenozoic syn-rift sequences and two post-rift seismic sequences related to passive margin settings, deposited from Eocene to recent, were observed in the Sinú-San Jacinto Basin. Syn-rift sequences are affected by horsts and grabens (Figure 2). The post-rift sequences show aggradational to progradational patterns, lobate basin floor fans and channel-levees deposited during Miocene (Figure 3, Figure 4).

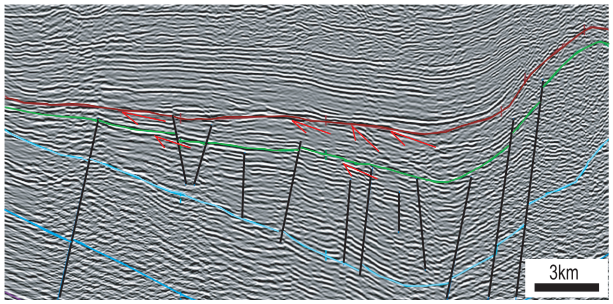

Figure 2: *Syn-rift sequences interpreted from observation of termination of reflectors. Observe pinch-outs and erosional surfaces related to the final phase of rifting.*

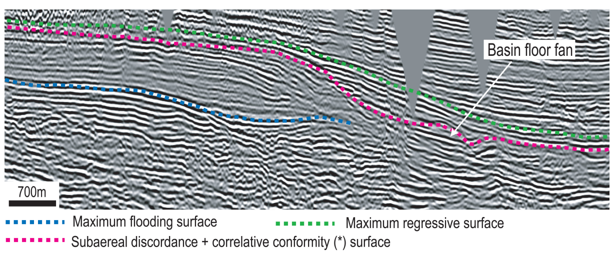

Figure 3: *Basin floor fan related to falling base level. (∗)Correlative conformity (sensu Hunt and Tucker, 1992).*

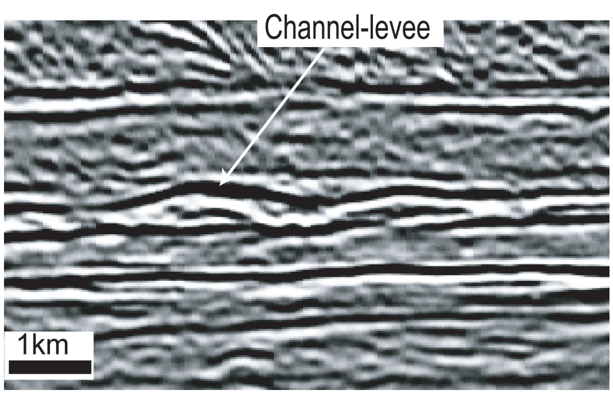

Figure 4: *Channel-leveed. Seismic facies consists in high amplitude and high continuity reflectors*

Rift structures and inversion tectonic controlled large carbonate banks and reefs (Figure 5). These carbonates show high amplitude, high continuity and low frequency seismic facies. Lobate "mixed slump-turbidites-debrites" and slumps deposits affected by mud diapirism were recognized (Figure 6; Figure 7; Figure 8).

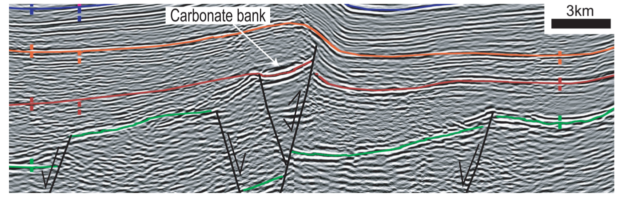

Figure 5: *Carbonate banks and reefs controlled by tectonic inversion of pre-existing extensive structures.*

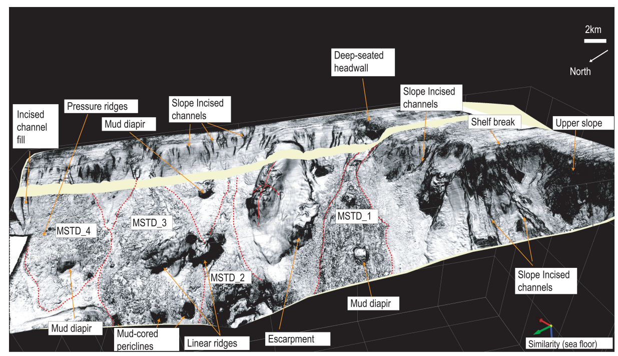

Figure 6: *Similarity attribute in sea floor showing geomorphical features related to slope system. Four lobate gravity-driven deposits are recognized. These deposits consist in interbedded slumps, turbidites and debrites or "mixed slumps-turbidites-debrites (MSTD)".*

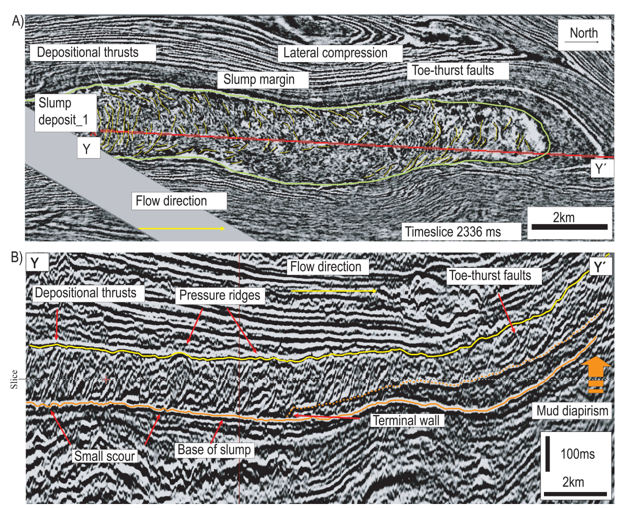

Figure 7: *A) Timeslice showing geomorphical features related to slumping. B) Seismic profile YY' along timeslice. Slump deposits showing depositional thrusts related to gravity processes. High-angle slope are associated to mud diapirism and faulting.*

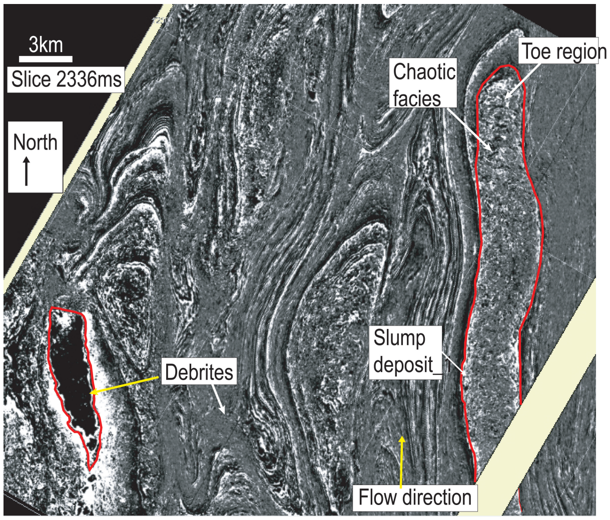

Figure 8: *Complex-trace attribute in timeslice 2336ms showing seismic features related to slumps and debrites*

Conclusions

1. Gravity-driven deposits like as slumps and debrites can be potential seals of hydrocarbon
2. Turbidites, channel-levees, carbonate banks and reefs should to be important reservoirs in this basin.
3. Pinch-outs and erosional surfaces related to final stages of rifting are excellent stratigraphic traps.
4. Seismic geomorphological and stratigraphical procedure in southern Caribbean was used as an excellent tool to identified and to characterize carbonate banks/reefs, lobate turbidites, incised channels, channel-levees, debrites and slumps. These depositional elements have important implications in hydrocarbon exploration.

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