[GC]Delineating the Geomorphological Character of Mass Transport Deposits: Examples from Upper Leonard Formation, Midland Basin*

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General Statement

With the advent of 3-D seismic technology and its remarkable spatial resolving power, mass transport deposits are better defined in terms of their full areal extent and their morphologic features in areas affected by slope failure. Though mass movements have been extensively studied within the Permian Basin, little work has been published on the nature of these MTDs and their related geomorphological expression on seismic.

The goal of this study is to understand sediment flow and delineate the anatomy of the MTD that was deposited 275 million years ago in the Midland Basin. This feature was deposited in the Upper Leonard interval which overlies the Upper Spraberry Formation.

During the time of deposition, sea level fluctuations controlled sediment input into the basin by flooding or exposing the platform. Cyclic Leonardian platform deposits started prograding toward the basin in the form of massive, clinoformal carbonates on the slope which, in turn, graded into flat-lying calcareous and siliciclastic intervals. Basin-wide maps of the Upper Spraberry Formation (seabed for this MTD) show that the principal sediment source lay to the northwest, north and northeast and the MTD was deposited in water depths of 600 to 1,000 feet.

Which Attributes are Useful?

In order to understand and map the full aerial extent of these features, one has to rely on seismic attributes. There are several attributes that can be used to map discontinuous features, however geometric attributes are the most useful methodology for studying MTDs.

Coherence is the first attribute that comes to mind for interpretation of structural/stratigraphic anomalies. In this study, we used Sobel filter, an attribute similar to coherence and discussed in Sobel Filtering Brings Edges into Sharp Focus, Search and Discovery Article #41511, which scans the data horizontally and vertically and detects the break in reflector configuration or lateral changes in amplitude values and waveform shape to map discontinuities.

Figure 1 shows a stratal slice extracted from a coherence volume and depicts discontinuous linear grooves observed within the MTD, which are essentially thrust faults. Since the grooves are oriented in the overall north direction, it is interpreted that the sediments must be coming in from the north (thrust faults align perpendicular to the sediment flow). This is confirmed by the Upper Spraberry structure map that shows probable entry points for the sediments into the basin. The attribute further delineates the presence of lateral wall and the sinusoidal path (interpreted as MTD grooves) the sediments take before settling down.

Figure 2 shows a northwest-southeast trending seismic cross section and gives an insight into the internal architecture of the MTD. Toward the compressional regime of the MTD, the seismic reflectors are chaotic and shows the sediments slumping on top of each other with a series of imbricate thrust faults. It is also evident that the MTD experienced sliding, as the seismic shows continuous reflectors before the compressional event with little to no internal deformation. The wavy relief observed (indicated by yellow arrow) in the sliding portion shows the compressive nature of these flows with localized faulting and detachment folds.

To truly delineate every aspect of this feature, another attribute we rely on is structural curvature. This attribute measures the curvedness of the bending and folding of seismic reflectors by taking the derivative of the dip in the inline and crossline direction. The attribute is further divided into k1 and k2 curvature highlighting the anticlinal and synclinal geometries when looking at features in a 3-D domain.

Gravity Spreading

An anomaly picked by the curvature attributes was used to pick up the presence of discontinuous localized events before the compressional event (Figure 3). These peculiar features trend orthogonal to the overall sediment flow and represents a sedimentary flow. The phenomenon causing this effect is referred to as “gravity spreading.”

Gravity spreading is the vertical collapse and spreading of a wedge under its own weight. For the MTD in our study area, at some point the mass transport body got distorted under its own weight and the sediments started spreading out under the influence of gravity. Another anomaly picked by this attribute was an en-echelon drag fold associated with the wrench fault of the Andrews shear zone. This deeper fault is interpreted to have acted as a constraint on the internal kinematics of the MTD and how the sediments were getting deposited.

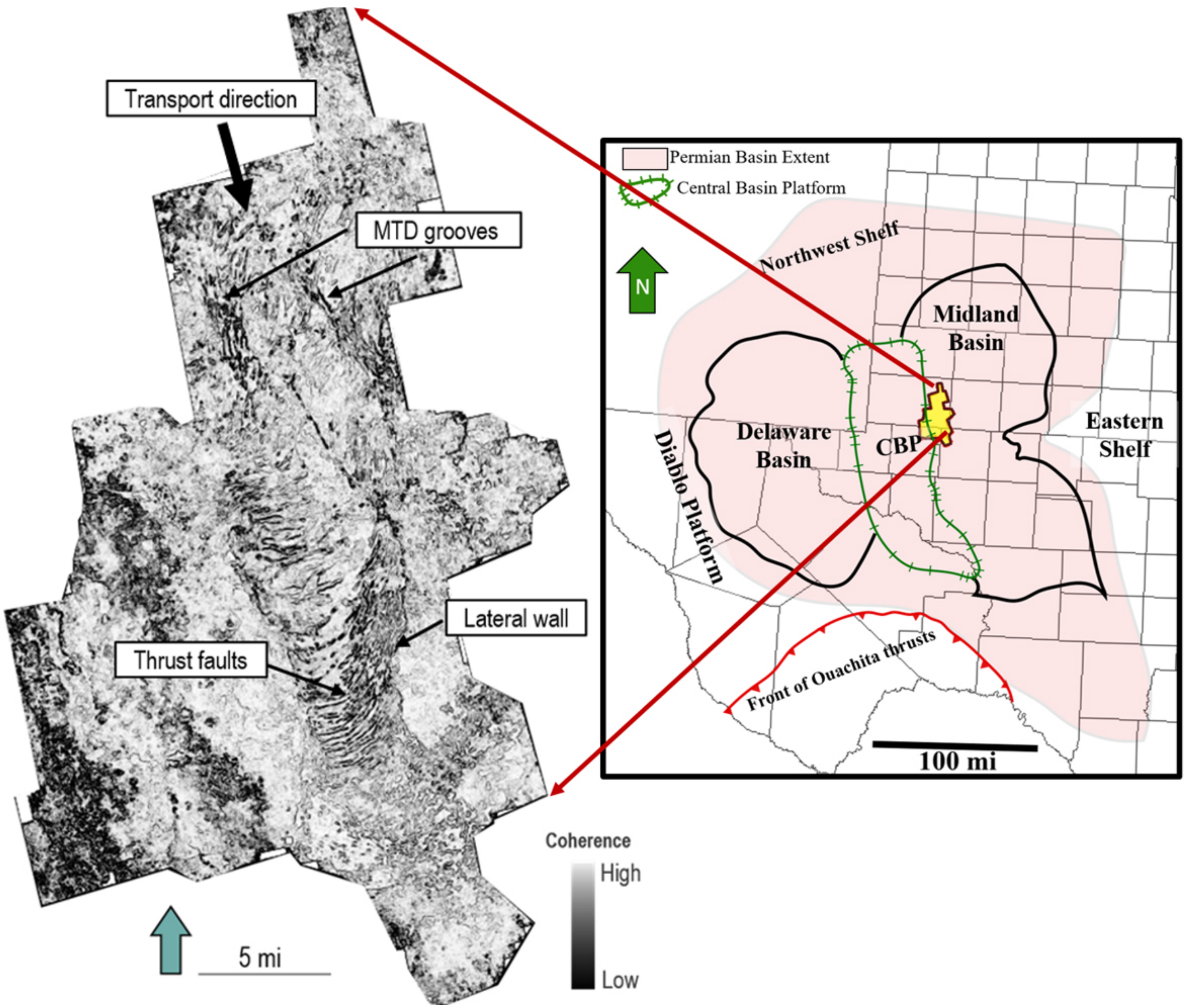

Figure 1. Stratal slice from the coherence attribute volume showing thrust faults (dipping north-northwest), lateral wall and overall sediment direction. The picture in the right is from Matt Scipione's MS thesis (2019) from University of Texas Permian Basin.

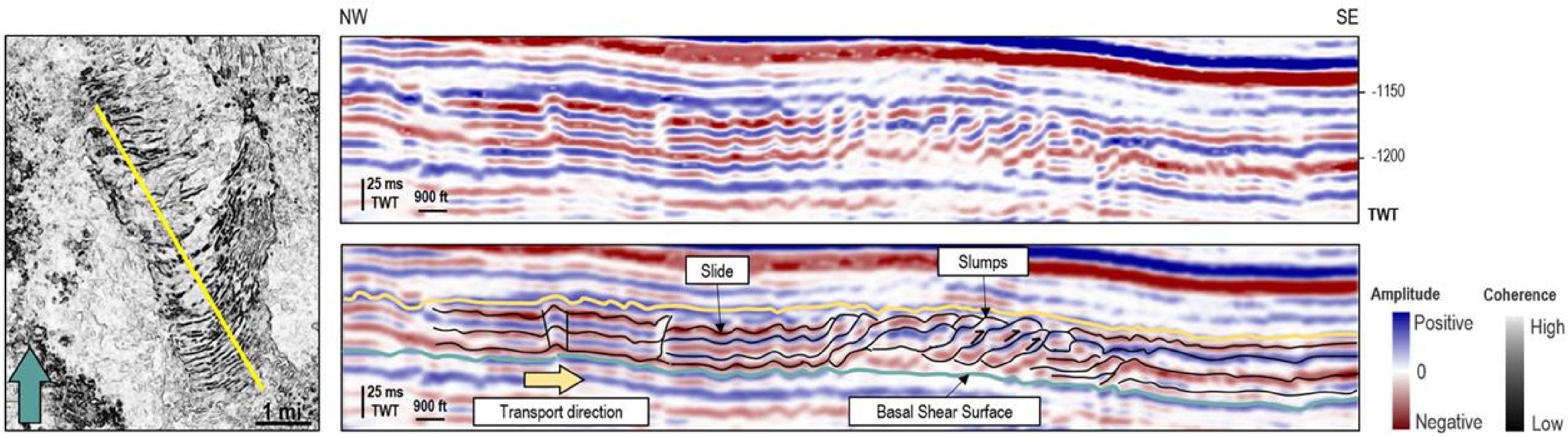

Figure 2. Northwest-southeast seismic cross section showing internal reflector configuration of the MTD and interpreted line diagram. Data courtesy of Fasken Oil and Ranch.

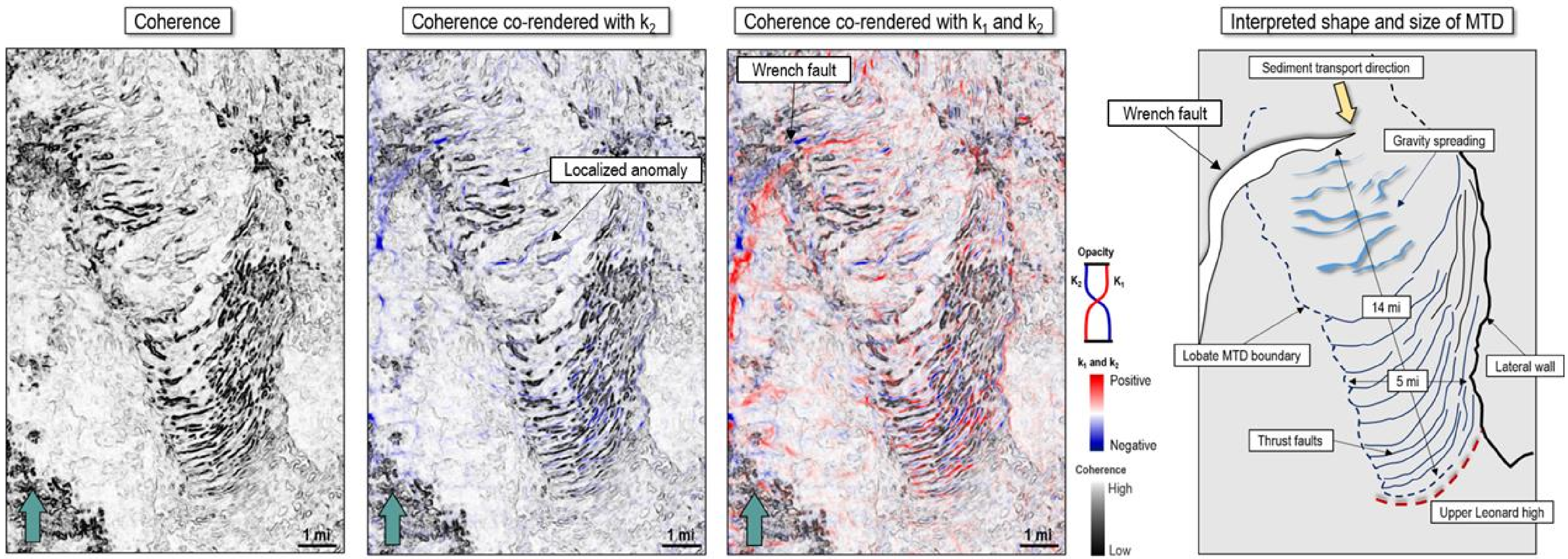

Figure 3. Overall interpretation of the MTD observed in the Upper Leonard of the Midland Basin. Kinematic evidence provided by the Upper Spraberry structure suggests the MTD flow direction was from the North toward bathyal depths as the sediments follow the peak and saddle morphology of the Horseshoe Atoll. The interpreted lobate shape of the MTD is due to the shearing of the sediments as they are restricted by the presence of the lateral wall. The slumping comes to a stop where the flow encounters an Upper Leonard high toward the compressional regime and as the structure starts climbing up toward the west on the Central Basin Platform. Data courtesy of Fasken Oil and Ranch.