Mass Transport Deposit (MTD) or Complex Channel System?  
A case study of the 3D Nimitz Seismic Survey, Taranaki Basin, New Zealand

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Mass Transport Deposit (MTD) or Complex Channel System? A case study of the 3D Nimitz Seismic Survey, Taranaki Basin, New Zealand

**Geological Feature:** Braided Channel System

**Seismic Appearance:** Splayed structurally controlled feature, with internally abundant, continuously lineated patterns on horizon slice

**Alternative Interpretations:** Erosional scour

**Features with similar appearance:** Mass Transport Deposit

**Formation:** Whenuakura

**Age:** Pleistocene – Recent

**Location:** Offshore Taranaki Basin, North Island, New Zealand

**Seismic data:** Nimitz 3D Seismic Survey. Obtained by Origin Energy Ltd and reprocessed by authors

**Contributor:** Roberto Clairmont, Heather Bedle, School of Geosciences, University of Oklahoma

**SUMMARY**

The Taranaki Basin is well known for studies examining the seismic stratigraphy, depositional and erosional features, and tectonic frameworks linked to the New Zealand (NZ) continent. This particular study examines a “Funny Looking Thing” (FLT) which we associate to be consistent with that of a braided channelized system. We observe this feature within the 3D Nimitz Survey (See Figure 1), located in the Northern Taranaki Basin (NTB) –off the western continental coast of North Island, NZ. The FLT occurs within Quaternary deposits of the Whenuakura Formation which are interpreted to reflect shelfal topset sediments (O’Leary et al., 2010). It is underlain by the Giant Foresets Formation (GFF) of Pliocene to Pleistocene age, which are described as large-scale progradational and aggradational continental successions that migrated west to northwest in
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basinward direction (Anell and Midtkandal, 2017; Clairmont et al., 2020; Hansen and Kamp, 2002; Shumaker et al., 2017) (Figure 2). It comprises a shelf-to-slope succession of claystone to siltstone with argillaceous sandstone intervals defining an overall coarsening upward succession (O’Leary et al., 2010). The FLT within the Whenuakura Formation is characterized by chaotic facies in cross section, which shares characteristics with potential mass wasting events (Figure 3a). However, further analysis using seismic attributes improved the spatial and stratigraphic architecture of the FLT, which favored a complex channelized system interpretation over a mass transport deposit complex.

SEISMIC DATA

The 3D Nimitz Survey was acquired using the ship, Pacific Titan, owned by Swire Pacific Offshore, and operated by Compagnie Générale de Géophysique (CGG). It covers an area of approximately 432 km² with a recording length of 6500 ms. The sampling rate is recorded at 2ms and crossline and inline interval dimensions have a measurement of 12.5 meters and 25 meters respectively. With a dominant frequency of ~ 45Hz measured within the area of interest and an average velocity of 1710 m/s between the top of the log at 454.6 meters and a Mean Sea Level datum (O’Leary et al., 2010), the vertical resolution for this shallow area is ca. 10 m.

APPEARANCE IN SEISMIC DATA

Seismic characteristics of MTDs (Mass Transport Deposits)

Mass Transport Deposits (MTDs) are common geological components found globally in the stratigraphic record of ancient and modern deep marine settings. They are gravity-induced events comprising of the downslope transportation and redeposition of remobilized sediments.
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(Moscardelli et al., 2006; Dugan and Stigall, 2010). They can be triggered by rapid sea level fall, seismicity, gas hydrate destabilization and high sedimentation rates (Moscardelli et al., 2006; Moscardelli and Wood, 2008; Dugan and Stigall, 2010; Rusconi, 2017). Distinct seismic characteristics associated with mass transport deposits/complexes, help in their identification within seismic data. Frey-Martinez (2010) examines four geological features important for identifying MTDs (i.e. the; basal shear surface, internal architecture, headscarp and toe region).

The basal shear surface is an erosional plane along which sediment traction decreases, and movement of mass downslope is identified in seismic cross section via truncation of parallel/subparallel reflectors (Bull and Cartwright, 2010; Frey-Martinez, 2010). The internal architecture of MTDs are generally characterized by chaotic/disturbed seismic facies with a wide range of seismic amplitude responses from low-to-high (Moscardelli et al., 2006). The head escarpment is the highest section of the slope (likely the shelf-break region) where the erosional event initiates, experiencing extensional forces that generate listric faulting (Frey-Martinez, 2010). The toe region represents the lower-slope extent of the MTD, where sediment accumulation creates thickening of the deposits in the stratigraphic section compared to the feature’s proximal region, and can be identified in seismic cross section by minor imbricate thrusts and folds (Frey-Martinez, 2010). Compressional thrust faulting within the MTD can also be identified by low coherence and linear discontinuous grooving, that trend perpendicular to flow direction (Bhatnagar et al., 2019). Due to the lateral extent of the seismic volume, limiting full coverage of the FLT, we utilize a couple of these common geological elements to aid in associated MTD interpretation.

Seismic characteristics of complex channelized systems
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Many studies utilize seismic interpretation methods to explore ancient and modern deep-marine channelized systems (Wescott and Boucher, 2000; Kolla et al., 2007; Janocko et al., 2013; Berlin, 2014) to identify the complexities in the processes that shape their depositional styles and the observed architectural elements. Along cross sections, these systems can be described by a list of seismic elements including u and v shaped facies of valley incision into the underlying strata, the occurrence of a high amplitude erosional base (Kolla et al., 2007) and a chaotic channel infill seismic signature (Berlin, 2014).

In cross-section, the ~3km wide FLT shows a pattern of internally deformed, partially chaotic seismic facies with low-mid-high seismic amplitudes, and lateral truncation via the base of the FLT, of the underlying parallel strata (Figure 3). V/U shaped seismic facies describing channel incision can be interpreted within the FLT, correlating with similar seismic facies identified below the FLT (Figure 3a). From time slices, it is evident that the FLT consists of very low positive to low negative seismic amplitude responses, which have splayed curvilinear-like architectures (Figure 3b). Comparison to cross-sections shows these curvilinear-like features reflect the channel incisions and have widths ranging from 100-170m. Similar channel-like features outside the FLT boundary are observed a little to the southwest and can be compared to for further analyses (Figure 3b).

SEISMIC ATTRIBUTES
Further characteristics are obtained using seismic attributes, e.g. seismic attributes: structural curvature and variance. The curvature attribute, a 2D second-order derivation of inline and crossline structural components, can aid in identifying channel geometry. The structural positive curvature \( k_1 \) reflects dome shaped features, whilst the negative curvature \( k_2 \) reflects valley/bowl-shaped features (See Figure 4) (Chopra and Marfurt, 2007). The schematic gives a clear representation of how \( k_1 \) and \( k_2 \) curvature attributes are co-located with the lateral geometrical changes across the channel’s axis (Figure 4b). Structural positive curvature clearly corresponds to the ‘dome-shaped’ banks/levees on either side of channel, whilst the negative structural curvature corresponds with the ‘valley-shaped’ channel incision (Figure 4a). The variance attribute, measures the unconformity in neighboring signal traces, and as such can identify abrupt changes across edges (Randen et al., 2001). As such, it can assist in identifying sudden discontinuities in the seismic response.

Evidence for mass transport deposit

The next step in our analyses, involves the interpretation of unambiguous channel features (Figure 4) and an MTD (Figure 5) within deeper stratigraphic units observed by Clairmont at al. (2020). The deeper identified MTD shows a very chaotic internal seismic facies, that laterally truncate parallel reflectors (Figure 5a). The erosional basal-shear surface, separates the overlain chaotic facies with the underlain continuous undisturbed seismic facies. Small-scale thrust faults in addition to few normal faults are visible, indicating the compressional forces associated with the downslope translation of the sediment mass. The coherent blocky sediment features likely correlate with the observed minor thrust and normal faulting (Figure 5b). Additionally, time
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slices (TS – 1368ms) of both the variance and co-rendered structural curvature attributes, further support an overall non-coherent chaotic internal character (Figures 5b and 5c), of the ca.14km wide, enclosed body. The more coherent blocky features identified along the variance attribute times-slice can represent more rigid, displaced boulder-sized rock. Clarmont et al. (2020) briefly evaluates the mechanisms that likely contributed to the occurrence and emplacement of this exact MTD, its chaotic internal character and also provides an idea of its longitudinal extent along surface horizons in a shelf-to-basin-ward direction. Curvilinear-like features, typical for the FLT, are not observed this bounded MTD as evident from both variance and structural curvature attributes (Figures 5b and 5c) whereas the internal character of the FLT does not show patterns of discontinuity as observed in the MTD (Figures 5, 6). However, the FLT shows along cross-sectional strike, a pattern of internal, partially chaotic seismic facies with low-mid-high seismic amplitudes, lateral-truncation of the underlying parallel strata and what we infer may reflect a basal-shear surface or an erosional surface.

Evidence for complex channelized system

Co-rendering of the positive and negative structural curvature attributes of the unambiguous deeper channel system, reveals the lateral changes in shape across the axis of the channel geometry with widths of the confined channel geometries ranging between 80-200 meters (Figure 4a). Similar characteristics are observed within the FLT (Figure 6a), although it is difficult to discern the continuity of the positive curvature responses along edges given the complexity of the system. Furthermore, the variance attribute may indicate some apparent chaotic facies, however, we observe that the curvilinear patterns have similar characteristics of
the channel-like features to the southwest, with high variance responses along the edges (Figure 6b). Interpretations reflecting a channelized system can therefore suggest that the base of the system is an erosional surface.

A COMPLEX CHANNELIZED SYSTEM

In conclusion, our observations reveal a partially weak chaotic internal seismic response (Figure 3a and 3b), the absence of fault structures (i.e lack of/no compressional/extensional forces), and that the curvilinear features incise into the underlying strata (Figures 3a and 3b) and share more characteristics with the deeper channel system, than the MTD. The distinct curvilinear features of the FLT do not coincide with the geological elements of observed MTD’s (Frey-Martinez, 2010; Bhatnagar et al., 2019; Clairmont et al., 2020) and show a pattern of partially meandering channel type features, growing toward the direction of the modern day NZ coast. We suggest that the observed FLT is a complex channelized system. It is also likely that the bottom limit of the FLT is an erosional base similar to interpretations by Kolla et al. (2007) associated with these systems. Additionally, the amplitude responses of the FLT can differ from other complex channel systems interpreted with seismic reflection data (eg. Kolla et al., 2007), based on its relatively shallow depth. The weak seismic signatures associated with its base and its internal character likely corresponds to limited burial, and hence poor compaction of the strata.

Furthermore, deposition of the sediments following the GFF commenced in local Castlecliffian stage (~ 1.63 Mya) and continued to present day, in which the boundary between the GFF and the Whenuakura formation is interpreted as being time-transgressive, with no single continuous event (O’Leary et al., 2010). Although the Quaternary marks the onset of glaciation and associated low-stands, rising sea levels during interglacial periods and associated transgressive
systems tract can explain the time-transgressive nature of this boundary. Given that the likely
direction of the growth of the channel system complex was toward the modern day coast and its
sudden termination, based on 3D visualization of the seismic data, this may reflect its drowning
as sea levels were rising following the last glacial maximum (Miller et al., 2005). This suggests
that the complex channel system formed in a subaerial paleo-environment during a glacial low-
stand with high fluvial gradients resulting in a braided river pattern. We infer from the seismic
geomorphological character that resembles that of a modern day subaerial braided-channel
system (eg. Figure 6 inset: The Brahmaputra River, originating in Tibet).

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REFERENCES

Anell, Ingrid, and Ivar Midtkandal. 2017, The Quantifiable Clinothem - Types, Shapes and
Geometric Relationships in the Plio-Pleistocene Giant Foresets Formation, Taranaki Basin,
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Berlin, Taylor Landry. 2014, Channel-Levee Complexes and Sediment Flux of the Upper Indus Fan, LSU Master's Theses. 61.


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212 https://doi.org/10.1007/978-90-481-3071-9


220 401.

221 Randen, Trygve, Stein Inge Pedersen, and Lars Sønneland. 2001, Automatic Extraction of Fault Surfaces from Three-dimensional Seismic Data. In SEG Technical Program Expanded...
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74x70mm (300 x 300 DPI)
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54x59mm (300 x 300 DPI)
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DATA AND MATERIALS AVAILABILITY

Data associated with this research are available and can be accessed via the following URL: Note: A digital object identifier (DOI) linking to the data in a general or discipline-specific data repository is strongly preferred.