Overbank sediment waves in the southern Taranaki Basin, New Zealand

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Abstract

In the southern Taranaki Basin, a thick stratigraphic sequence of late Miocene age is well imaged by modern 3D seismic data. Within this sediment package, the evolution of multiple deepwater channel systems are preserved and interpreted. Anomalous features located between channel complexes are identified in both map-view and vertical sections. Extracting selected seismic attributes along interpreted horizons and using in context geologic knowledge suggests these anomalous features are overbank sediment waves resulting from overbank sedimentation. Alternate interpretations are also presented, such as slump scarps and progradational clinoforms. The evidence aims at improving our identification of these deepwater depositional elements.

Geological feature: Overbank sediment waves in the southern Taranaki Basin, New Zealand

Seismic appearance: Shingled, undulating, downlapping reflectors

Alternative interpretations: Prograding clinoforms; slump scarps

Features with similar appearance: Prograding clinoforms

Formation: Mount Messenger Formation, Taranaki Basin

Age: Late Miocene

Location: Taranaki Basin, New Zealand

Seismic data: Hector-3D

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Analysis tools: Schlumberger's Petrel software was used for seismic interpretation and visualization; Attribute-Assisted Seismic Processing & Interpretation (AASPI) was utilized for computation of seismic attributes.

Summary

This region of the southern Taranaki Basin contains a remarkably complete stratigraphic record of large-scale progradation that occurred in the mid-Miocene through the present day. During this time, falls in relative sea level combined with hinterland uplift resulted in an increase in sediment transport to a sediment-starved Taranaki Basin. This led to the deposition of the southern equivalents of the Mount Messenger Formation (MMF). The Mount Messenger depositional system is characterized by channel complexes located on the base of the slope to the lower slope, with predominately transported fine-grained sands and silt (Rotzien et al., 2014). These multistoried, fine-grained deepwater channels transported eroded sediment from the newly uplifted South Island toward the Taranaki Basin in a southeast–northwest trend (Holt and Stern, 1994; King and Thrasher, 1996; Rotzien et al., 2018; Kroeger et al., 2019). We analyzed the Hector-3D survey, located due north of the South Island in the southern Taranaki Basin (Figure 1a). The Kiwa-1 well was tied to the seismic data, and formation tops were updated. Revised biostratigraphy was incorporated for age dating (Strong and Wilson, 2002). The study interval is within the latest Miocene, and paleobathymetry data indicate that the study interval was at bathyal conditions near the base of a slope (Figure 1c) (Strong and Wilson, 2002). Two horizons were interpreted: Horizon B corresponds to the top of the MMF. Horizon A was the most coherent reflector in the lower MMF (Figure 1d). To image how the system evolves through time, nine proportionally spaced stratal slices were generated (Figure 1d). Calculated volume attributes were subsequently extracted along horizons A and B and the nine stratal slices.

Because the environment of deposition is near the base of slope, flow confinement is reduced by minimal levee development due to the lack of sediment availability, which can result in unconfined sediment transport between channel complexes. Flow stripping preferentially removes the less dense, finer grained sediment from the top of the turbidity flow and forms these sediment waves in the overbank region between channel

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complexes (Posamentier, 2003). Curvilinear discontinuities are observed throughout the study interval on horizon A, and they are present through stratal slice 3 (SS3) (Figure 2). These anomalies in the interchannel region are indicative of overbank sediment waves. Sediment waves are present in the interpreted base of the study interval, the purple horizon A, and they are visualized through SS3 (Figure 1d). These are indicative of unconfined sediment transport, likely associated with overbank sedimentation.

Expression in seismic data

The sediment waves are present throughout the studied interval in the interchannel regions when

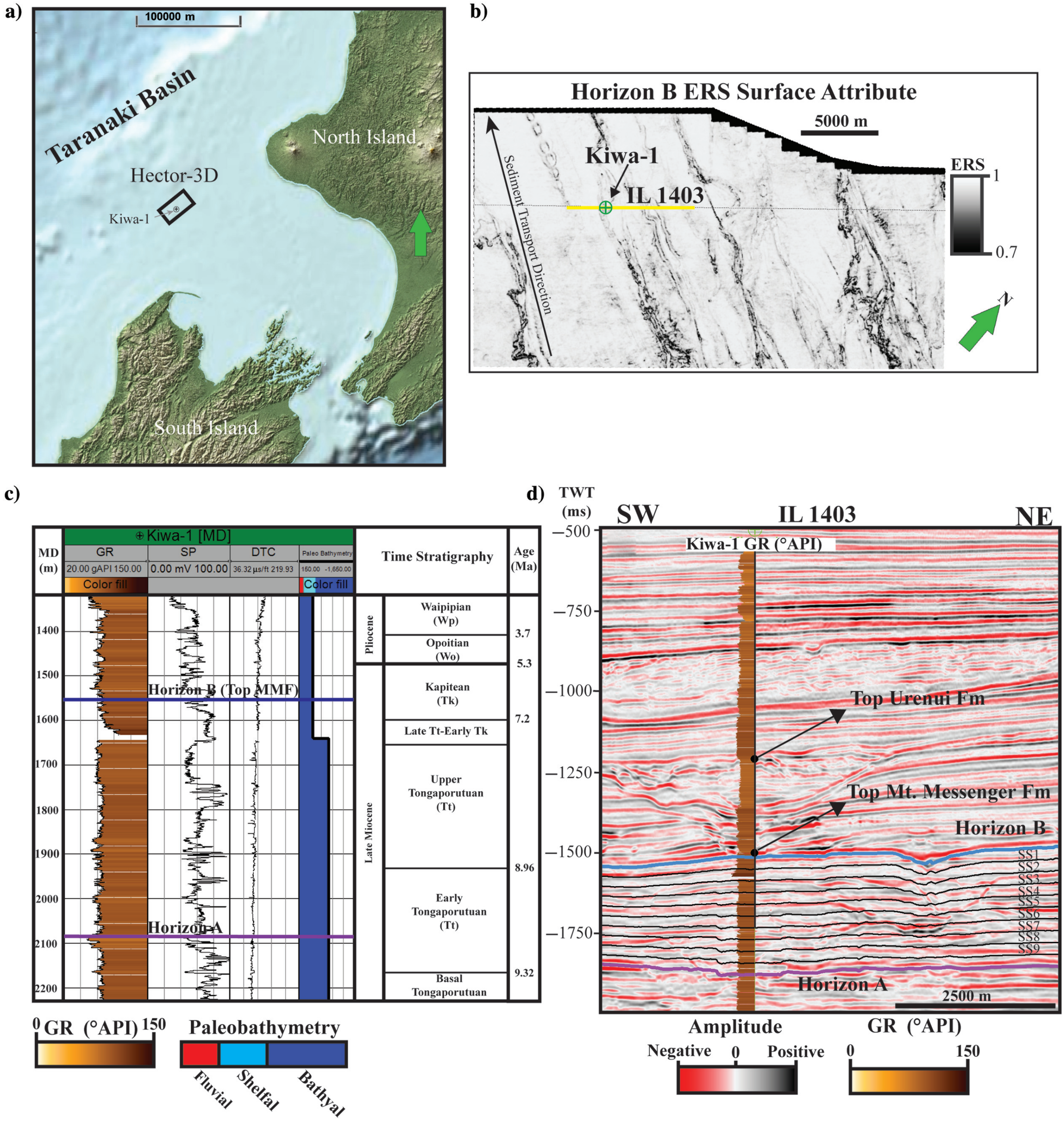


Figure 1. (a) Regional map displaying the study area location. (b) Horizon B ERS surface attribute showing the location of the Kiwa-1 well and inline 1403 in yellow. The sediment transport direction is to the northwest. (c) Well-log suite from the Kiwa-1 well with the corresponding time stratigraphy. (d) Vertical seismic display of IL 1403 showing the formation tops, interpreted horizons, and generated stratal slices.

viewed in map view. To illuminate these features, a suite of volume attributes was generated and extracted along the interpreted horizons and stratal slices: relative acoustic impedance, spectral decomposition, and energy ratio similarity (ERS), a coherency attribute (Figure 2). The relative acoustic impedance is extracted along horizon A and is corendered with ERS (Figure 2a). This attribute was selected because when viewed in the vertical section, the slump scarp reflectors have a somewhat weak, but distinct, amplitude contrast with the overlying and underlying reflectors indicated by the gray arrows in Figure 3b. Although the relative acoustic impedance provides no quantitative measurements, it still captures the relative trend of the boundary changes between the sediment waves. Alternating bands of negative values (red) to neutral values (green) define the sediment waves in the map view (Figure 2a). By corendering the ERS attribute, the channel edges are sharpened and the sediment waves are well-defined. The spectral decomposition was computed to enhance the visualization of the slump scarps as the amplitude data are decomposed into their spectral components (Partyka et al., 1999). Individual frequency cubes were generated and blended using a red-green-blue (RGB) blending scheme, and then they were flattened on horizon B (Figure 2b). The sediment waves have varying responses in the frequency domain and by blending their low-, medium-, and high-frequency responses, the sediment waves are better visualized. The sediment waves show up as bright to dim curvilinear anomalies oriented orthogonal to the direction of sediment transport. They are characterized by mild to strong responses by the 35 and 65 Hz components (green and blue). Coherency-based attributes, inlcuding ERS, excel at highlighting subtle discontinuities that are not easily seen in amplitude (Mafurt et al, 1998). ERS visualizes the slump scarps very well because the shingled reflectors cause discontinuities in the surface (Figure 2c). Horizon A displays a decrease in the sediment wave occurence downdip. This is likely due to a combination of the decreasing amount of sediment available and a decrease in depositional energy as the sediment transport distance increases. Using the three attributes above, sediment waves are mapped across horizon A (Figure 2d). It is important to note that these anamolies do not cross channel complexes, suggesting that they were either present before or during formation of the channel complexes.

Sediment waves are also widespread throughout SS3 (Figure 3a). When viewed in cross section, the sediment waves are characterized by an undulating top reflector with shingled, downlapping internal reflectors indicated by the gray arrows. Sediment waves also originate from channel complexes, and they decrease in thickness away from the channels. Flattening the seismic data on horizon B removes postdepositional tilting and provides better lateral relationships in cross section (Figure 4b). The sediment waves have similar geometries to prograding clinoforms, but the internal shingles within the sediment waves suggest that these formed through accretion, rather than progradation.

Alternate interpretations

Possible alternate interpretations include prograding clinoforms and slump scarps. Differentiating between overbank sediment waves and clinoforms can be very difficult because they have similar overall geometries (Figure 4b and 4c). This is an example of how the dep-

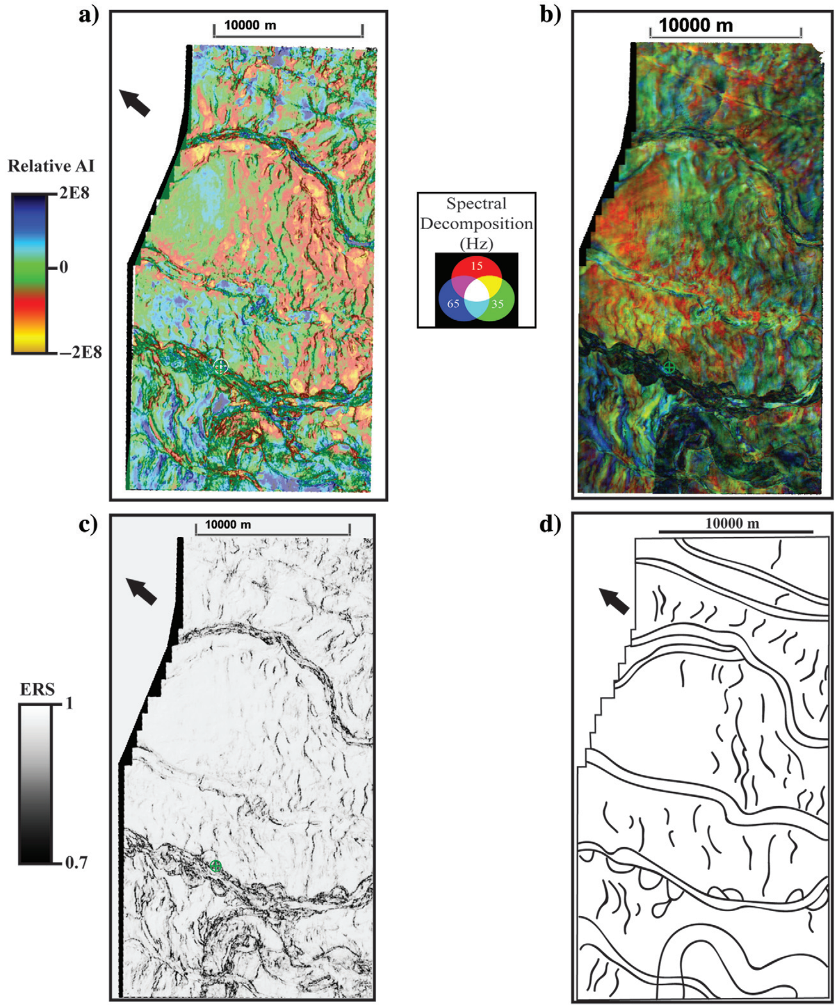


Figure 2. Volume attributes extracted along horizon A. The sediment transport is from right to left. (a) Relative acoustic impedance, (b) RGB spectral decomposition blend, (c) ERS, and (d) sketch interpreting some of the major channel features.

Figure 3. (a) Spectral decomposition blend extracted along SS3. Note the widespread occurrence of sediment waves. (b) Arbitrary seismic amplitude display located by the yellow line in (a). The sediment waves are characterized by shingled, downlapping reflectors originating from a channel at the right of the image.

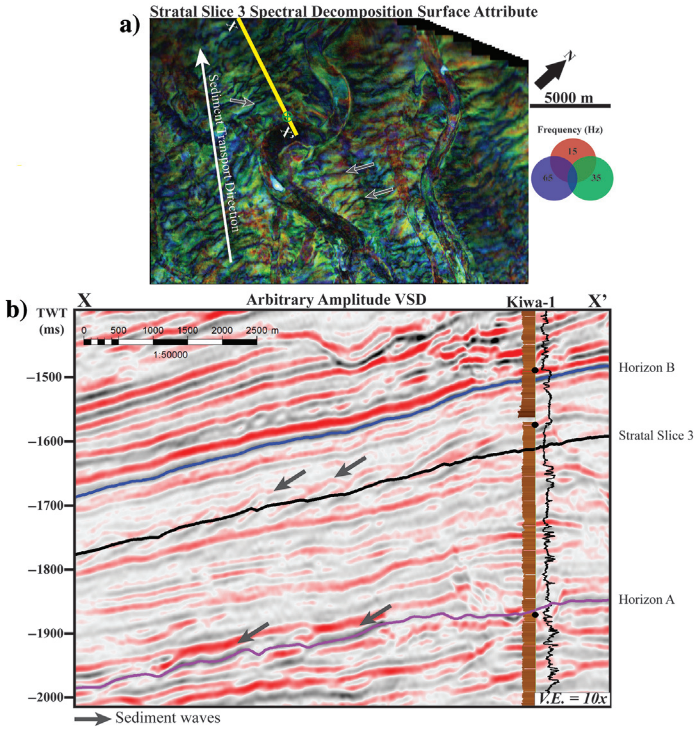
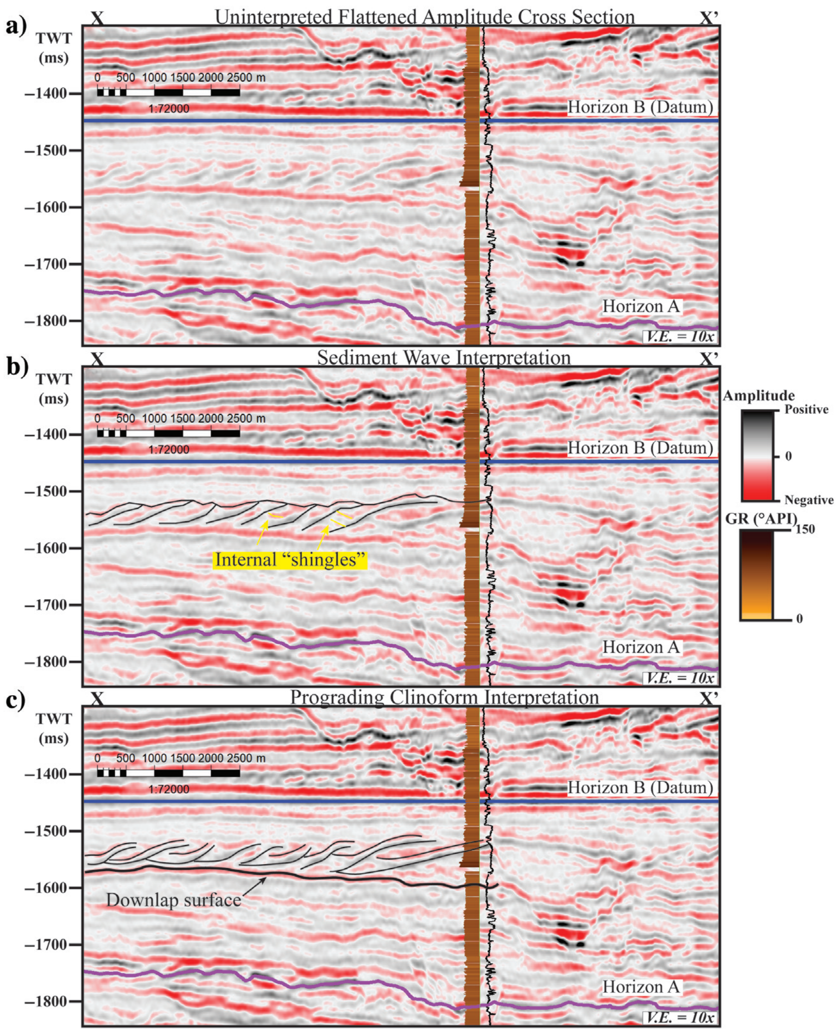


Figure 4. (a) Uninterpreted flattened amplitude cross section. (b) Sediment wave interpretations. The undulating reflector on the top is interpreted as the top of the waves, with inclined downlapping internal reflectors with minor internal shingles present. (c) Prograding clinoform interpretation. Inclined reflectors progressively build downdip and downlap onto the underlying boundary.



ositional model that the interpreter has in mind can influence the interpretation that will be made because not accounting for the nearby channels could result in interpreting the feature as clinoforms. In addition, as the paleo water depth is estimated to 1600 m, clinoform development is unlikely to occur in such an environment. The gamma ray log within the study interval in the Kiwa-1 well also lacks the traditional coarsening-upward parasequences of progradational clinoforms (Figure 1c). Slump scarps are also another plausible interpretation because slump scarps are a common feature in lower slope/base of slope deepwater settings. However, if these were to be anomalies related to slope failure, it would be indicative of a widely unstable slope with large-scale mass transport deposits (MTDs) nearby. However, no evidence of MTDs are observed within the Hector-3D survey or in the surrounding seismic data. The quantity and spacing of the anomalies further argues against the MTD interpretation because slump scarps are typically more isolated.

Acknowledgments

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Data and materials availability

Data associated with this research are available and can be obtained by contacting the corresponding author.

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