

Late Pliocene to Recent Seismic Stratigraphy of the Northland Basin, New Zealand*

Stephen Johnston¹, Lorna Strachan¹, and John Cassidy¹

Search and Discovery Article #50327 (2010)

Posted September 30, 2010

* Adapted from an oral presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, USA, April 11-14, 2010

¹Geology Programme, School of Environment, University of Auckland, Auckland, New Zealand. (stephen.johnston@auckland.ac.nz)

Abstract

The Northland Basin, New Zealand is a sedimentary basin contiguous with the Taranaki Basin to the south, whose hydrocarbon potential is currently being explored. Two-dimensional seismic reflection data from the Northland Basin reveal the evolution of an extensive turbidite system and shows that shelf margin growth was significantly influenced by an offshore stratovolcano complex that formed in the Miocene. The shelf system comprises:

- a) A shelf margin delta
- b) Submarine channel systems
- c) A basin floor fan
- d) Mass transport deposits

During the Late Pliocene-Recent period, the shelf margin delta exhibited highstand progradation with minor aggradation type growth. While the overall growth pattern of the shelf margin delta is that of a highstand, reflection terminations and analysis of the shelf break has shown that the shelf margin delta to have evolved through a series of downstepping progradation, transgression and aggradational and progradational phases, implying sea level and sediment input variations. Periods of clinoform oversteepening occur to the south of the Northland Basin where the delta progrades over volcanic massifs.

The initiation of submarine channel incision and turbidite deposition in the Late Pliocene coincided with that of the shelf margin delta. However, to the north, a large volcanic massif has inhibited channel development and shelf margin growth. The northern channels

were abandoned by the Calabrian (c. 1.6 Ma), where seismic facies indicate low energy deposition. Submarine channels offshore of the Kaipara Harbour are ubiquitous throughout the Late Pliocene to recent, indicating a long-lived link between terrestrial and marine environments. A large basin floor fan related to these channels is observed to the north and south, onlapping the base of the Late Pliocene to recent sequence. Minor unconformities within the fan are tentatively linked to complexities of the shelf margin delta evolution. Mass transport deposits are observed only in a limited zone to the south of the Northland Basin, where they are sourced from the flanks of stratovolcanoes.

Isochron maps of an earlier Miocene to Late Pliocene sequence and the Late Pliocene-Recent sequence show a shift of preferential deposition from northwest to southeast, indicating a regional tilt and/or a change in ocean dynamics and sediment source during these time periods.

References

- Duvail, C., C. Gorini, J. Lofi, P. Le Strat, G. Clauzon, and A. Tadeu dos Reis, 2005, Correlation between onshore and offshore Pliocene-Quaternary systems tracts below the Roussillon Basin (eastern Pyrenees, France): *Marine and Petroleum Geology*, v. 22, p. 747-756.
- Gerber, T.P., L.F. Pratson, M.A. Wolinsky, R. Steel, J. Mohr, J.B. Swenson, and C. Paola, 2008, Clinoform progradation by turbidity currents: modeling and experiments: *Journal of Sedimentary Research*, v. 78, p. 220-238.
- King, P.R. and G.P. Thrasher, 1996, Cretaceous-Cenozoic geology and petroleum systems of the Taranaki Basin, New Zealand: New Zealand, Institute of Geological & Nuclear Sciences Monograph, Report No. 13, 243 p.
- Pirmez, C., L.F. Pratson, and M.S. Steckler, 1998, Clinoform development by advection-diffusion of suspended sediment: Modeling and comparison of natural systems: *Journal of Geophysical Research*, v. 103/B10, p. 141-157.
- Porebski, S.J. and J. Steel, 2006, Deltas and sea-level change: *Journal of Sedimentary Research*, v. 76/3-4, p. 390-403.
- Uruski, C.I., V. Stagpoole, M.J. Isaac, and N. McCormack, 2004, Seismic interpretation report – spectrum reprocessing Northland Basin, New Zealand: Ministry of Economic Development New Zealand, unpublished Petroleum Report PR3055.

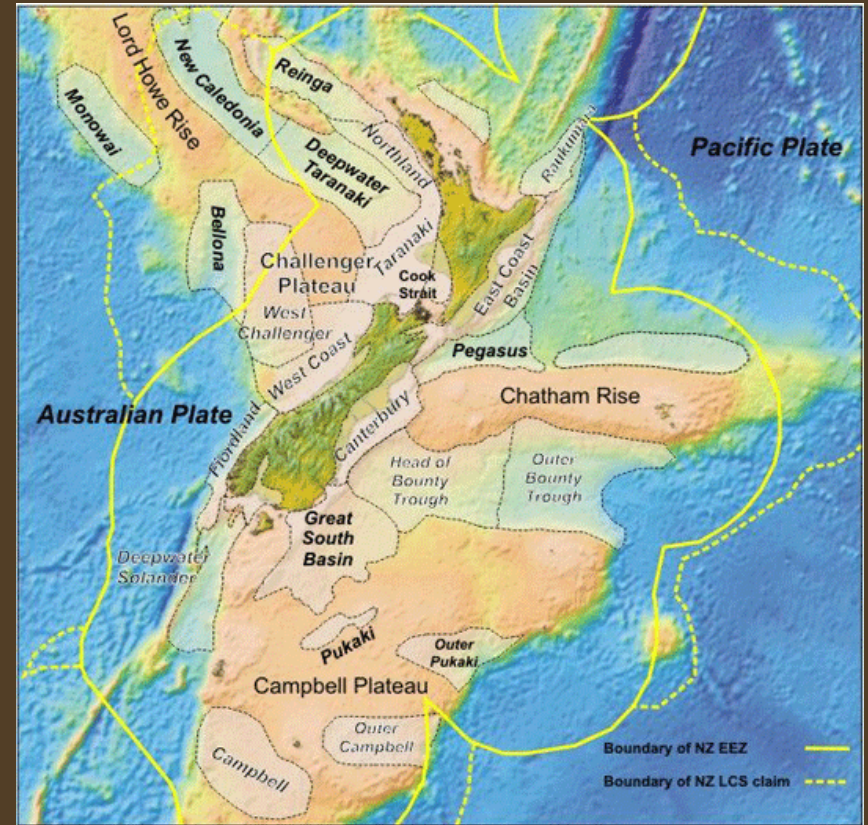
Late Pliocene to Recent Seismic stratigraphy of the Northland Basin, New Zealand

Stephen Johnston, Lorna
Strachan, John Cassidy



The Northland Basin

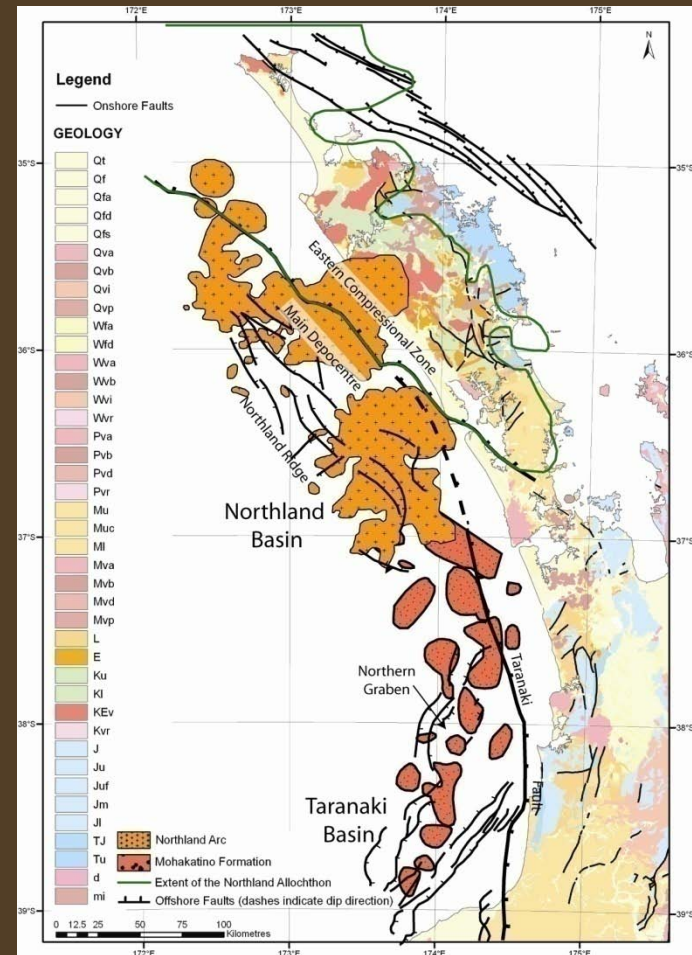
- Located off the west coast of the North Island
- Approx. 350 km length along strike, 100 km wide
- Up to 9 km sediment
- Contiguous with the Taranaki Basin to the south



Crown Minerals

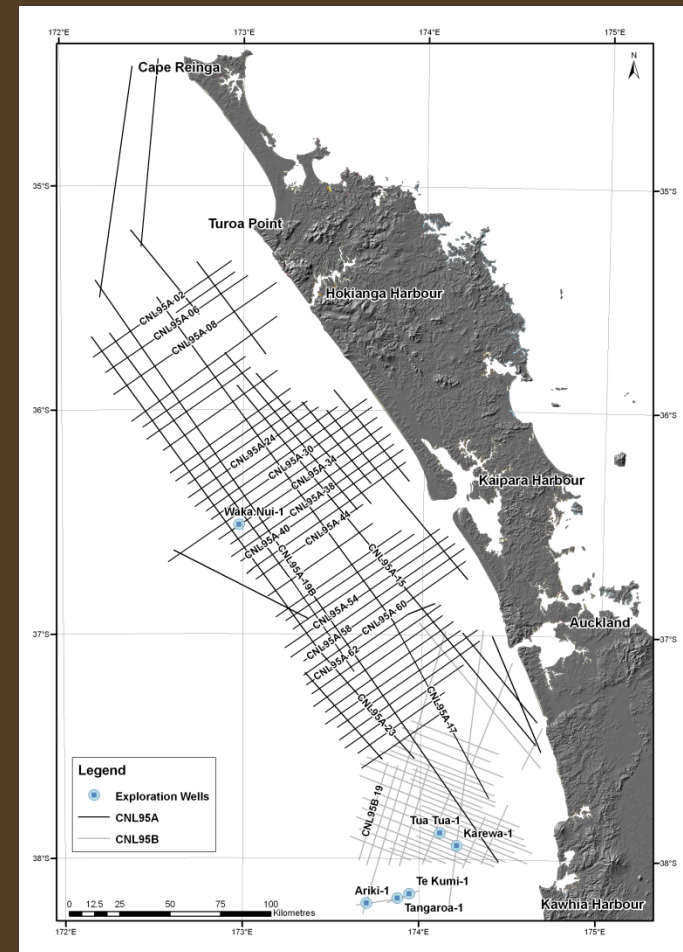
Regional geology

- Cretaceous to Late Paleocene rifting
- Late Oligocene to Middle Miocene: subduction zone present, volcanism
- Middle Miocene – Recent: passive margin phase



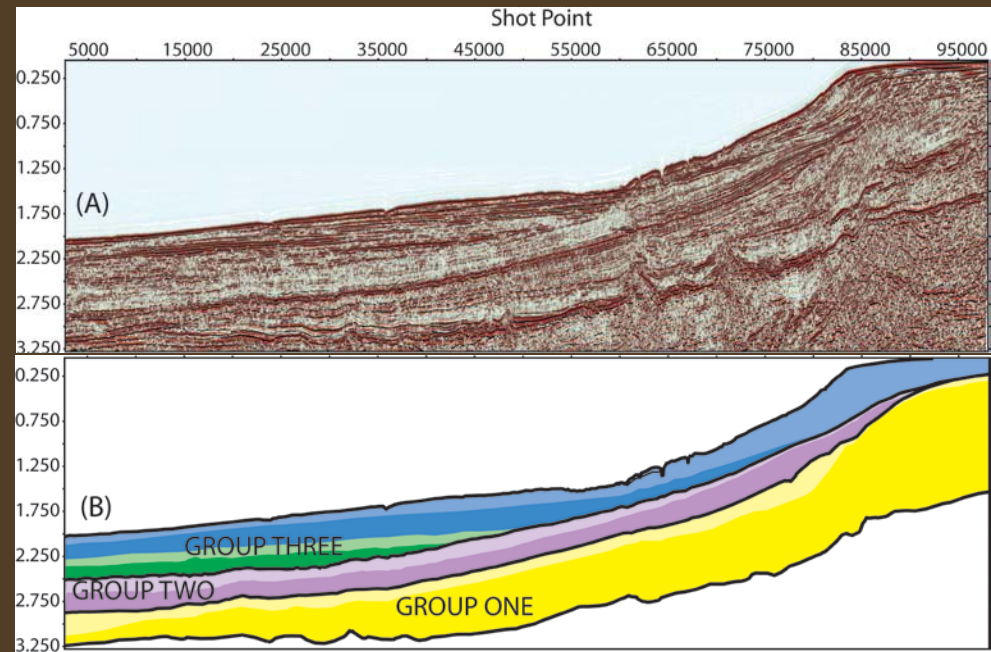
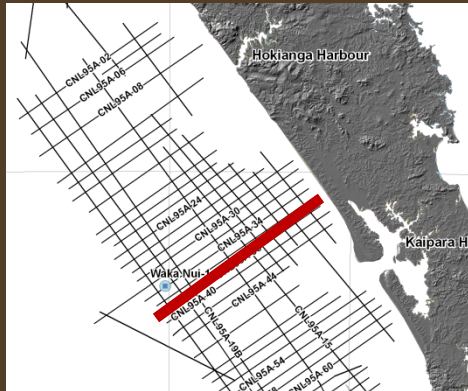
Available data

- Regional seismic coverage
 - 1982: Geco
 - 1995: Conoco
- Two offshore wells
 - Waka Nui-1, Karewa-1
 - No core, no geophysics and only Karewa-1 had useful dating

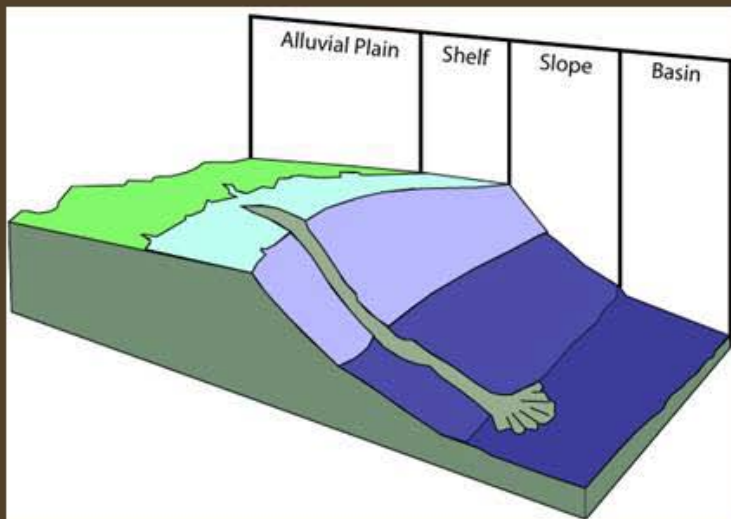


Late Pliocene to Recent Depositional period

- Lower surface is regional unconformity
 - Surface of onlap and concordance
- Upper surface:
 - Sea floor



Depositional elements

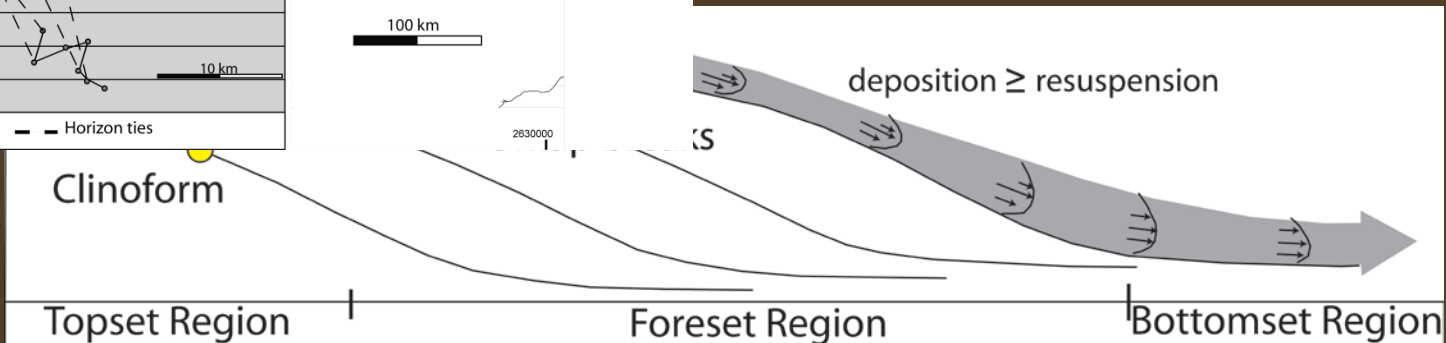
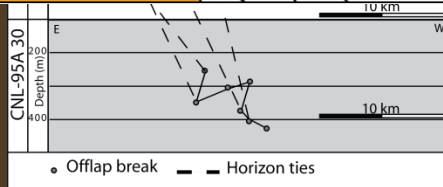
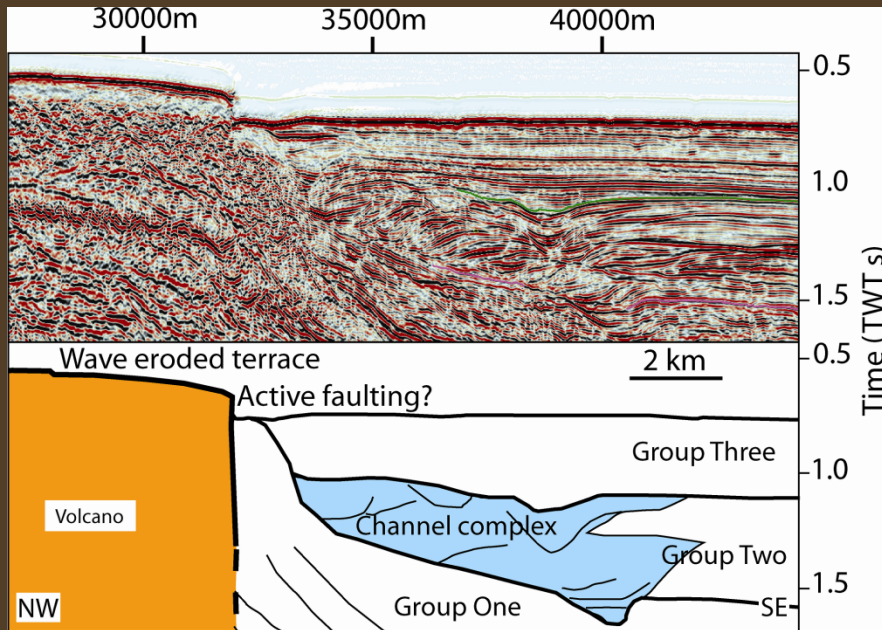


- Facies maps split into depositional elements
 - Shelf margin delta
 - Submarine channel
 - Base of slope fan/turbidites
 - Mass transport deposits

Notes by Presenter: Splitting of basin up into depositional/architectural elements – building blocks of the shallow to deep marine passive margin setting. This was done using the aforementioned seismic facies mapping; maps were created showing the distribution of seismic facies. Facies that were of like depositional setting were grouped together, i.e. Topset, foreset and (where applicable) bottomset facies were grouped into a shelf margin delta depositional element.

Shelf margin: offlap breaks

1. Sourced from the Kaipara Harbour
2. Shelf margin growth confined by volcanic massifs
3. Growth patterns identified by offlap break trajectories
4. Back stepping mound facies observed in shelf margin growth



Modified from Gerber et al. (2008)

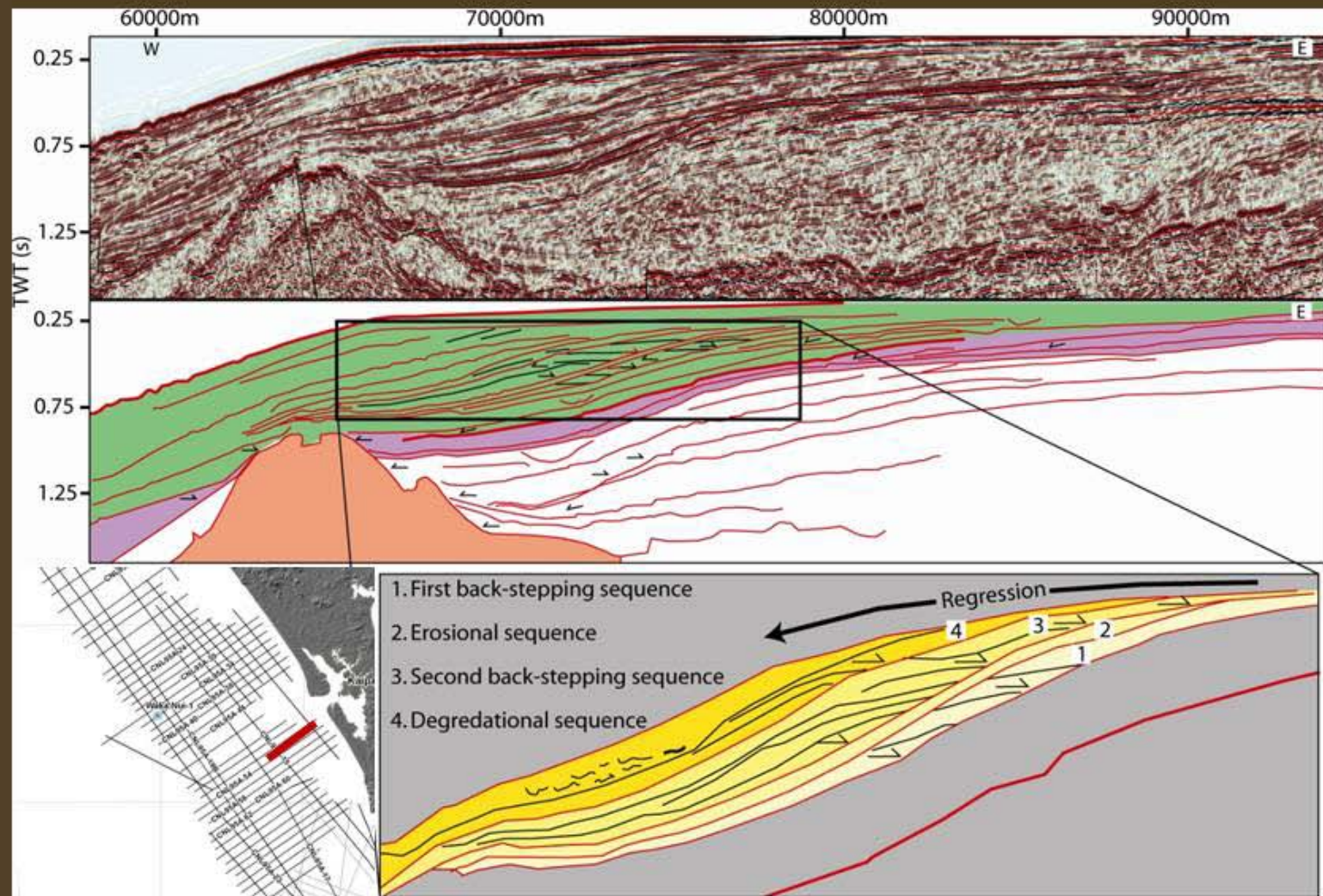
Notes by Presenter (for previous slide):

The growth of the shelf margin can be observed on only a few seismic lines, shown on this image here. Volcanic cones have passively affected the growth of the shelf during this time period, acting to redirect and confine turbidity currents and subsequent deposition. The growth of the shelf margin was deduced in a manner similar to Duvail et al., 2005, whereby offlap breaks are mapped along the margin. Offlap break trajectories reflect stratigraphic adjustment to a changing sediment accommodation to sediment supply (Porebski and Steel, 2006). The figure here shows offlap breaks, not all of which were able to be mapped along the margin, and subsequent growth patterns. Progradation is to the right on the graph, and it shows how different periods of progradation with downstep, progradation with landward stepping, pure aggradation or pure progradation occurred across the margin. The three main periods that can be observed throughout the time period and throughout the dataset are defined by the dotted lines, which are a period of progradation with aggradation, progradation with regression followed by another period of progradation with aggradation (though in all of these packages smaller order changes are observed).

Three 'higher order' phases are seen:

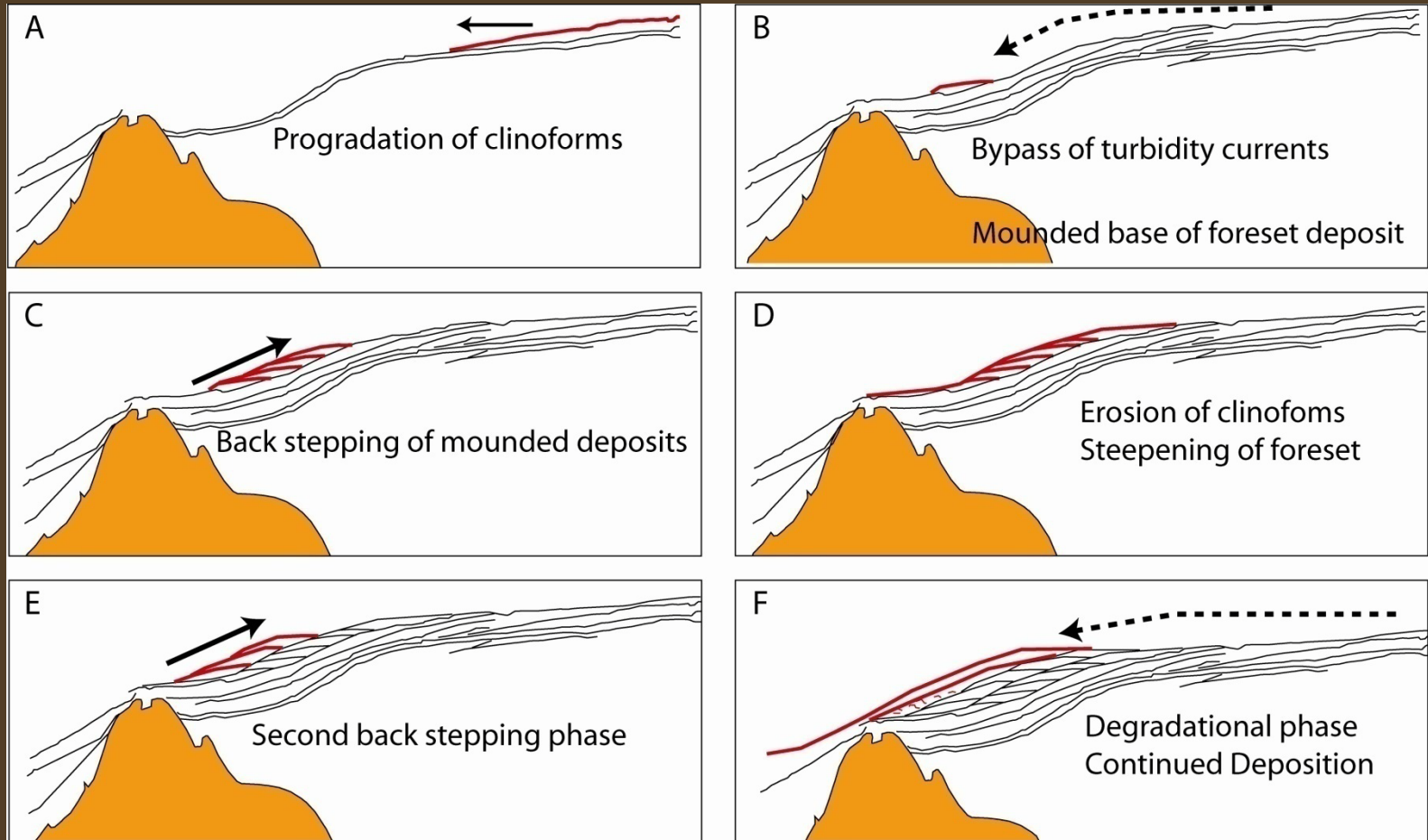
1. Progradation with aggradation
2. Progradation with downstepping
3. Progradation with aggradation

Shelf margin: CNL95a-58



Notes by Presenter: Inclined base towards the volcanic edifice seen in the seismic. Two backstepping mound features seen, indicating that the first mound front was of sufficient gradient to cause resulting backstepping.

Shelf margin: oversteepening



Notes by Presenter (for previous slide):

The model for usual deposition of sediment on the foresets of a delta, and thus the progradation of the foresets is one where:

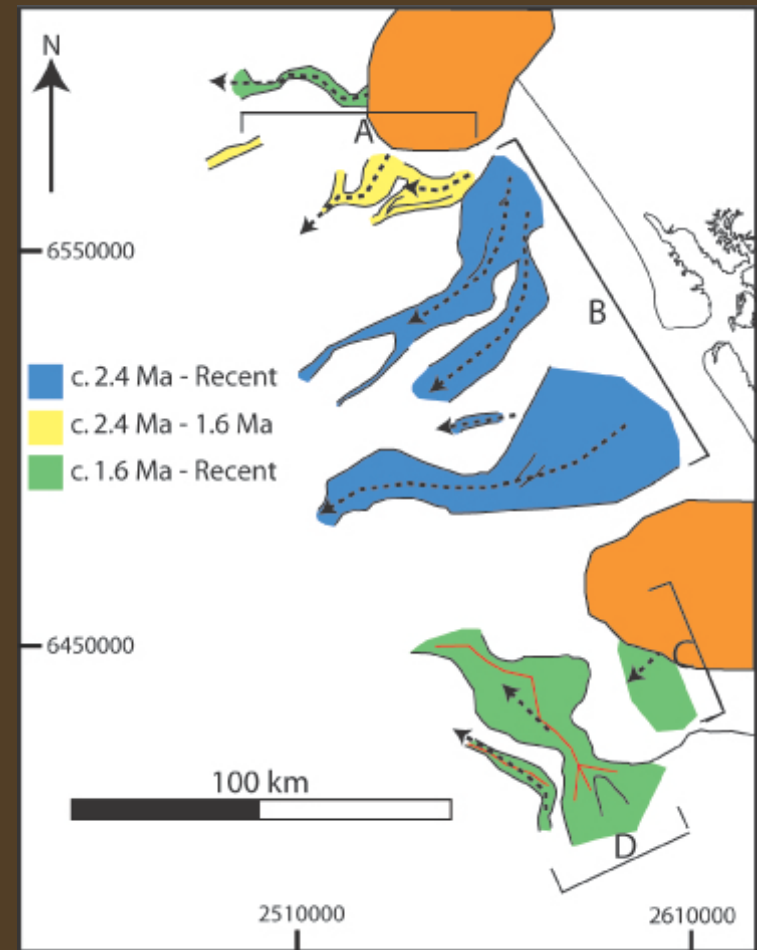
1. In shallow water shear stresses enacted on turbidity current by topsets (sea floor) are such that deposition is inhibited
2. As turbidity current moves into deeper water past the shelf/offlap break shear stresses are decreased, allowing deposition on the foresets, with decreasing sediment deposited on bottoms sets

Pirmez et al., 1998 also showed that as clinoforms prograde over an basinward inclined base that an increase in foreset angle would occur. Gerber et al., 2008 show that turbidity currents will bypass the foreset as the foreset angle becomes too steep and that rapid deposition will occur in lobes at the point of greatest decrease in slope. Subsequent flows will continue to bypass the slope and deposit on the previously deposited lobe. This will continue until the lobes have backstepped up the foreset to the topset.

This is what is seen in the seismic. The inclined base is due to volcanic massif that is being prograded over. 2.5° slope caused this.

Submarine channels

- Three regions of submarine channels
 - A. Early stage northern; straight
 - B. Ubiquitous central; sinuous, levees
 - C. Later stage southern; sinuous, levees, northward directed



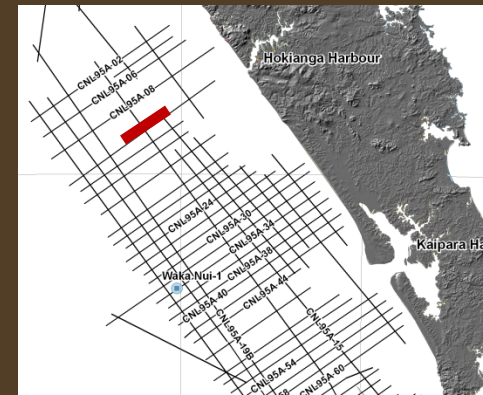
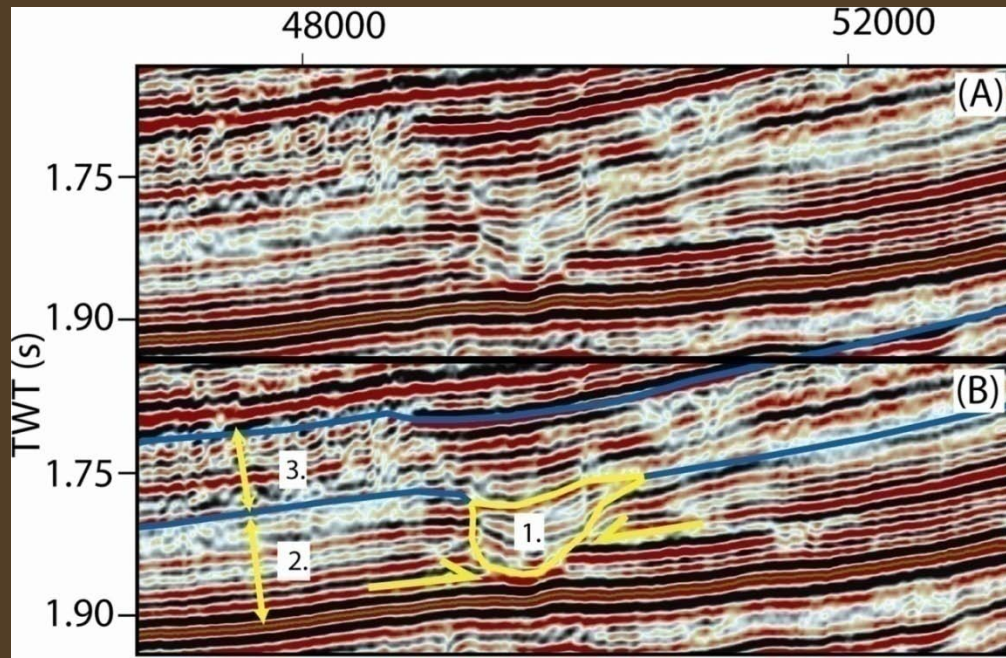
Notes by Presenter (for previous slide):

The distinctions between the channels highlight how sediment source and barriers to sediment flow affect deposit types. There are varieties of submarine channel systems during this time period of the Northland Basin. The main, shown in blue on the figure on the left, initiated at the start of this particular depositional sequence, and continues through to the present day. The seismic data shows that during this time period channel erosion hiatuses occurred, and in some cases channels ceased, while the system itself continued. To the north few channels are observed, which is inferred to be caused by the lack of any major harbours/river systems, as well as due to the Waipoua(?) volcanic system acting as a barrier to sediment flow. Seismic data shows that turbidites were directed around this body.

At c. 1.6 Ma a northern channel system ceased (A). The reflector defining the top of this period can be traced throughout the basinal region, representing a regional hiatus to channel incision. Following this hiatus channels to the centre of the basin resumed activity, with channels to the south initiating.

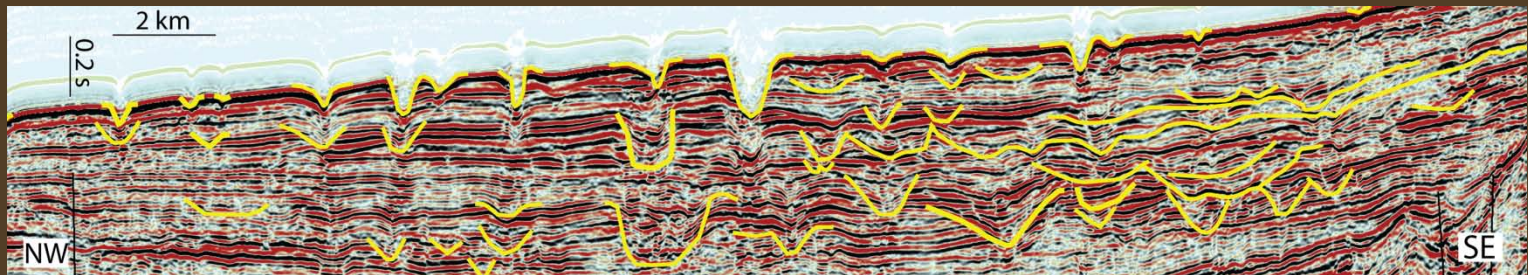
Submarine channels: Northern

- High amplitude, continuous facies during channel incision period
- Low-moderate amplitude, discontinuous facies post channel incision



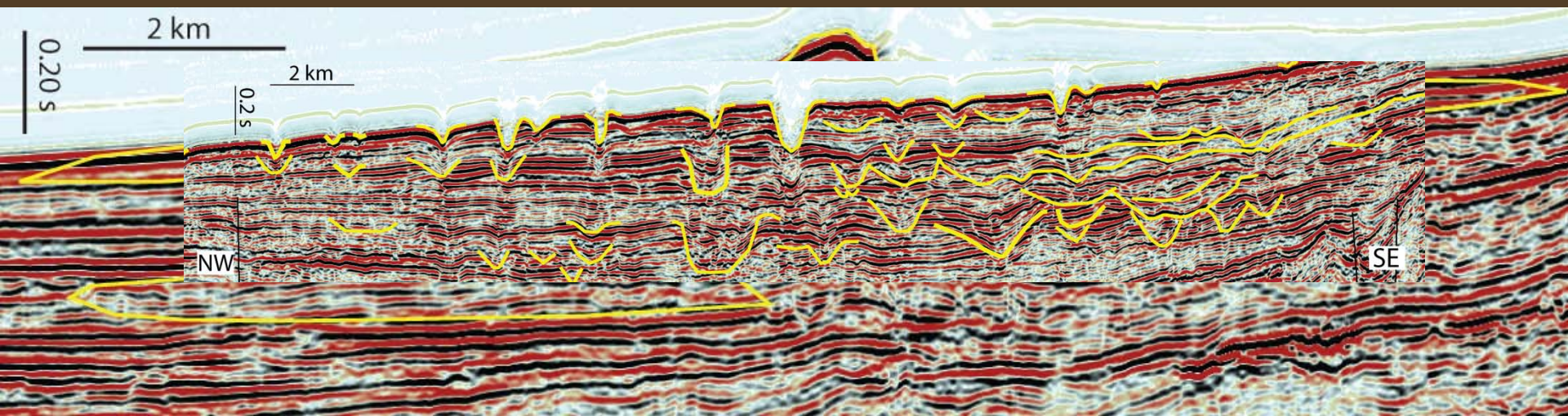
Submarine channels: Central

- Many channel incisions at initiation of depositional period (c. 2.4 Ma)
- Minor hiatus at c. 1.6 Ma
- Continuing through to recent time



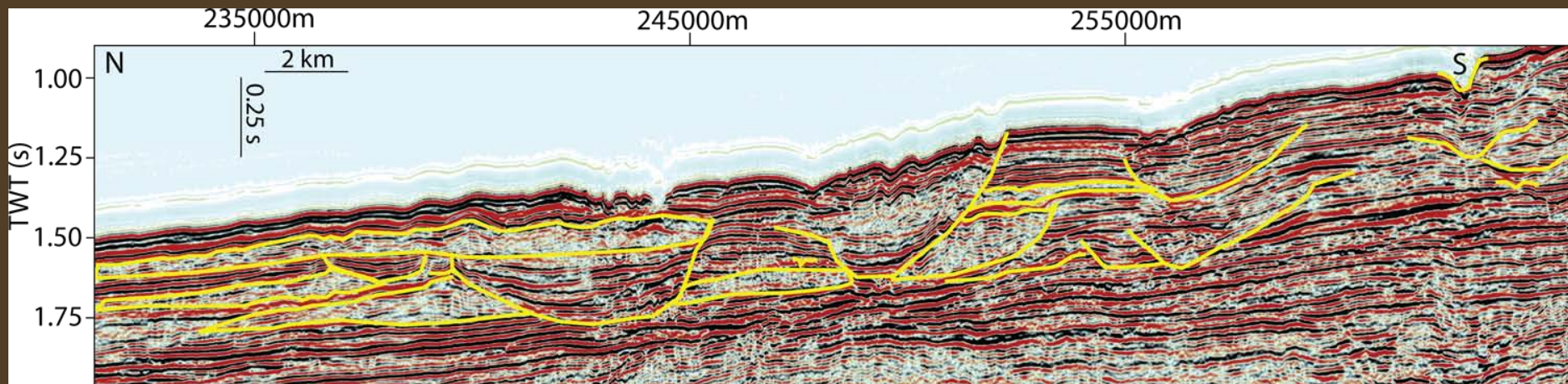
Submarine channels: Central

- Many channel incisions at initiation of depositional period (c. 2.4 Ma)
- Minor hiatus at c. 1.6 Ma
- Continuing through to recent time



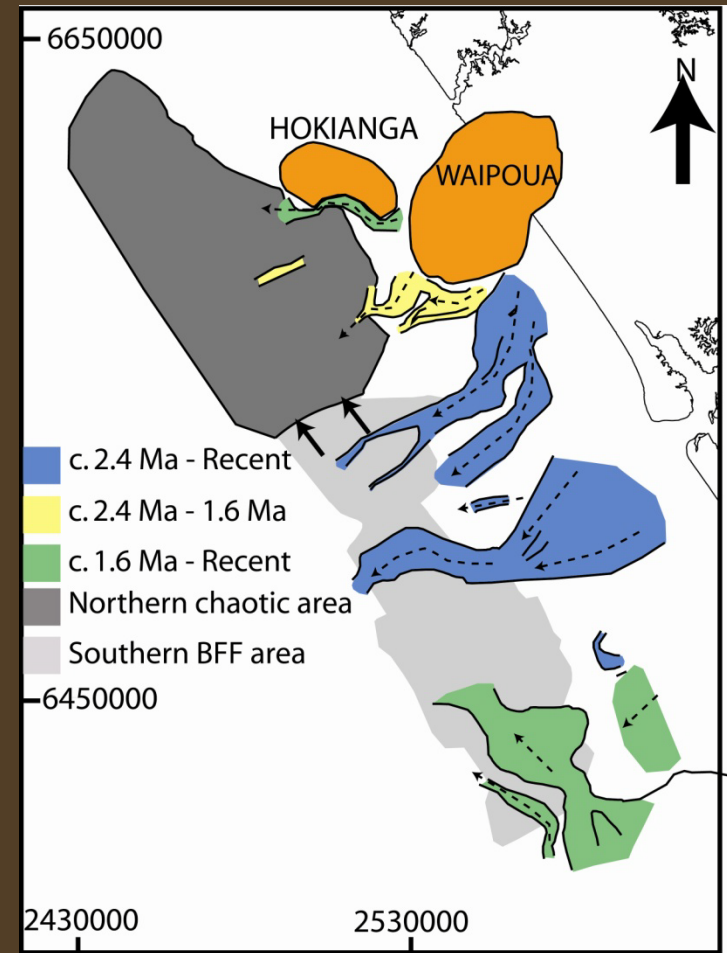
Submarine channels: southern

- Many channel incisions
- Late (c. 1.6 Ma) stage initiation
 - Progradation northward of central west coast shelf into Northland Basin



Basin floor fans/turbidites

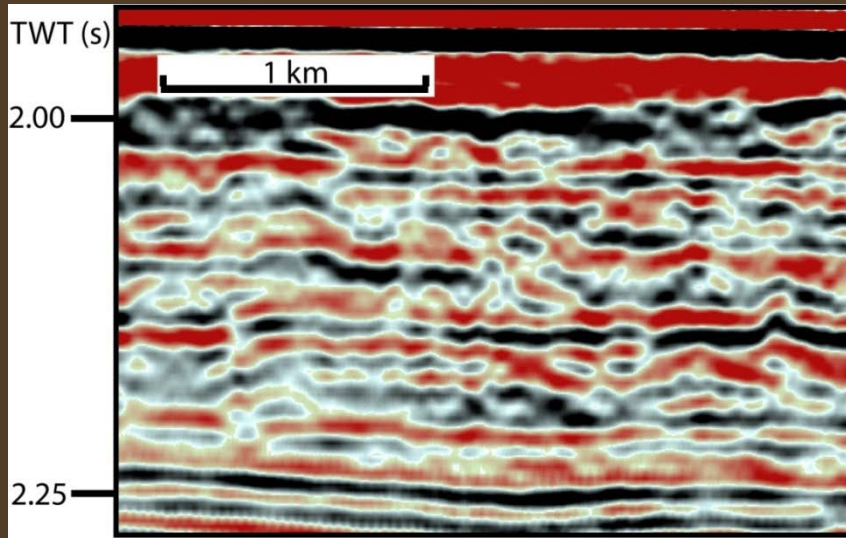
1. Northern zone
 - Low energy facies
2. Central zone
 - Large basin floor fan
3. Southern zone
 - Northward directed turbidite deposits



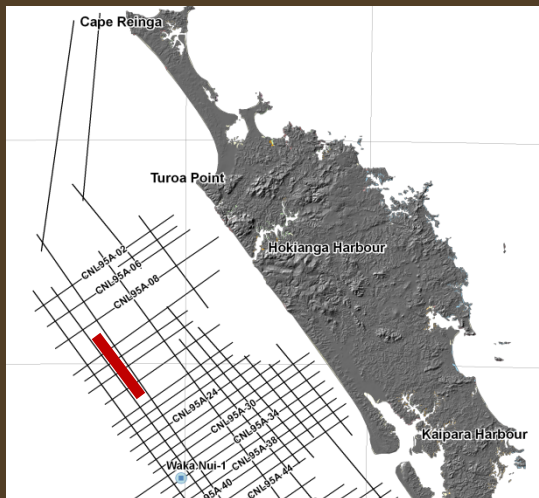
Notes by Presenter (for previous slide):

A large basin floor fan or series of basin floor fans extend across the central to south region of the Northland Basin. These fans, which are difficult to map individually with the sparse data sets, initiated after a hiatus marking the boundary of this depositional group. A major onshore/nearshore erosional period is assumed to have occurred causing a large amount of sediment to be shed offshore. The location of basin floor fans is directly related to position of submarine channels, with interpreted low energy facies being observed to the north of the basin directly related to the small amount of channels observed up there, as well as due volcanic massifs blocking the onshore region from the offshore. Basin floor/turbidite deposits are identified by onlapping

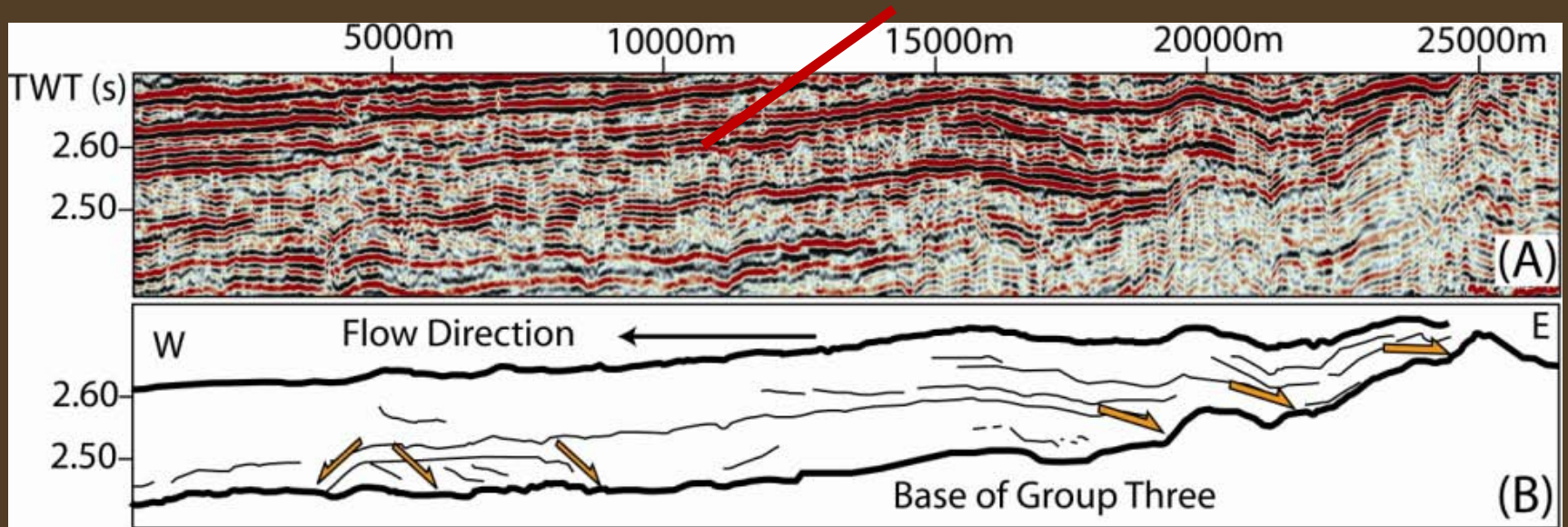
Low energy basin deposit



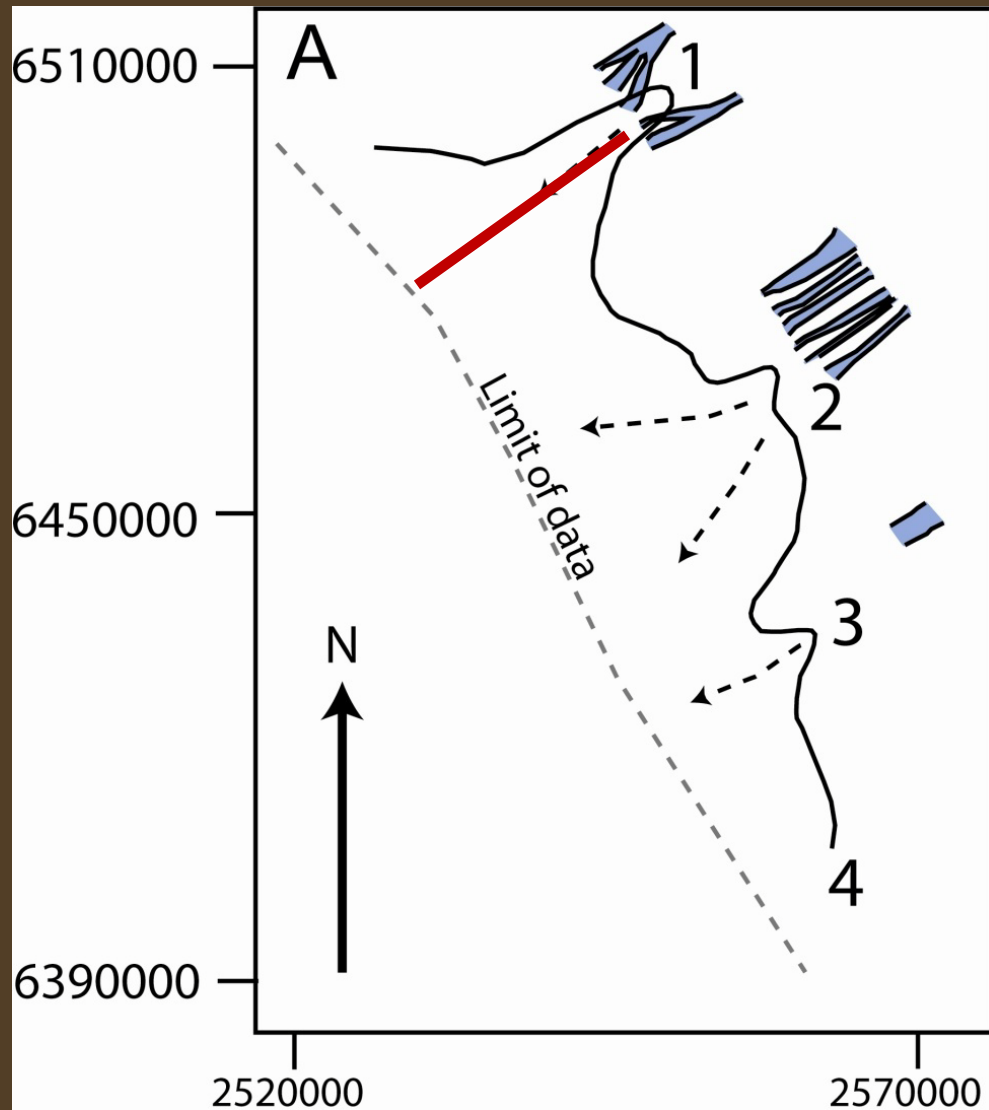
- Low to moderate amplitude
- Discontinuous
- Indicative of low energy depositional environment



Basin floor fans

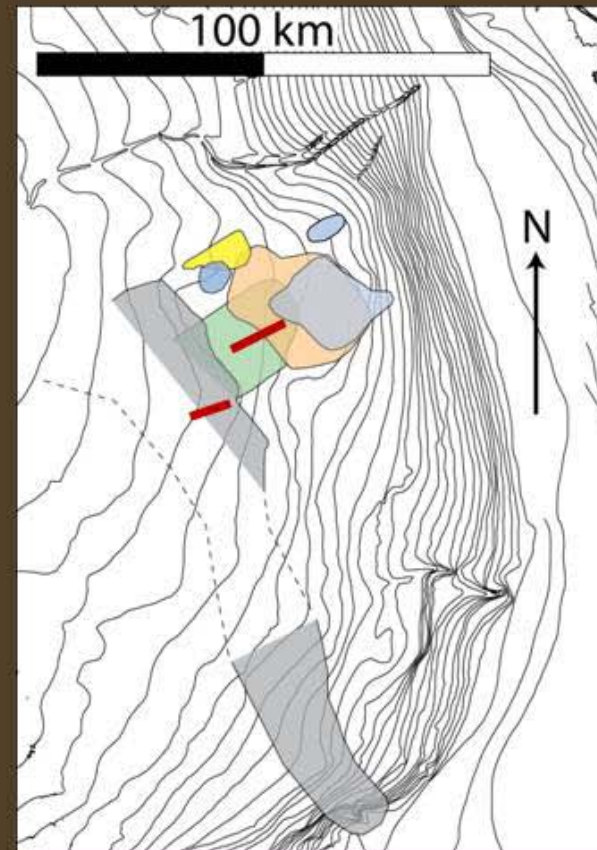


Basin floor fans



Mass transport deposits: distribution

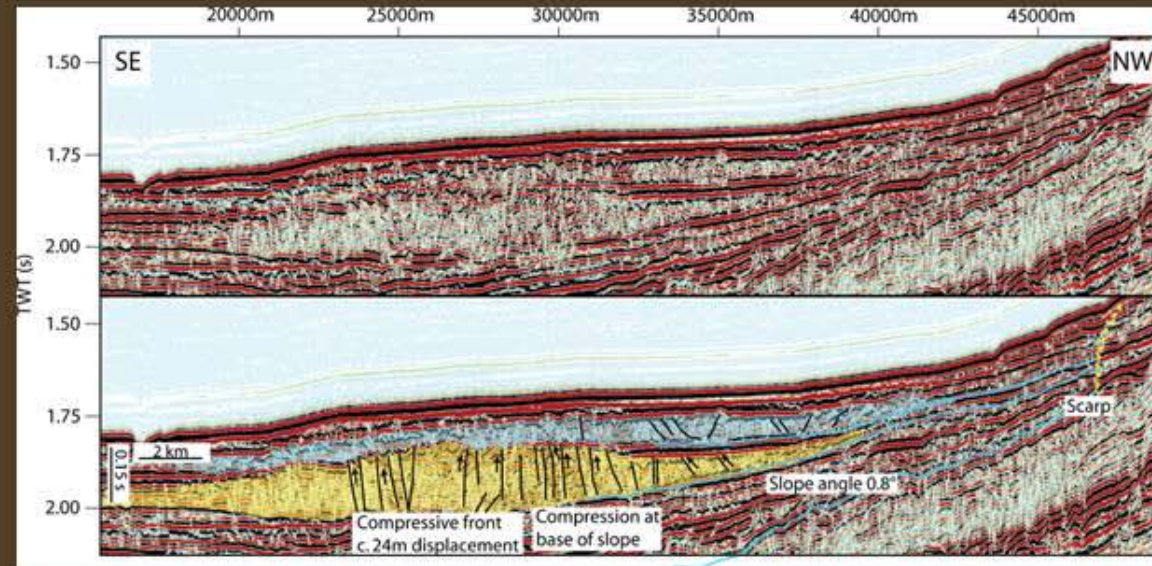
- Two types of mass wasting feature
 - Lobe shaped, sourced locally from steep slope
 - Erosive, tabular shaped, distance source



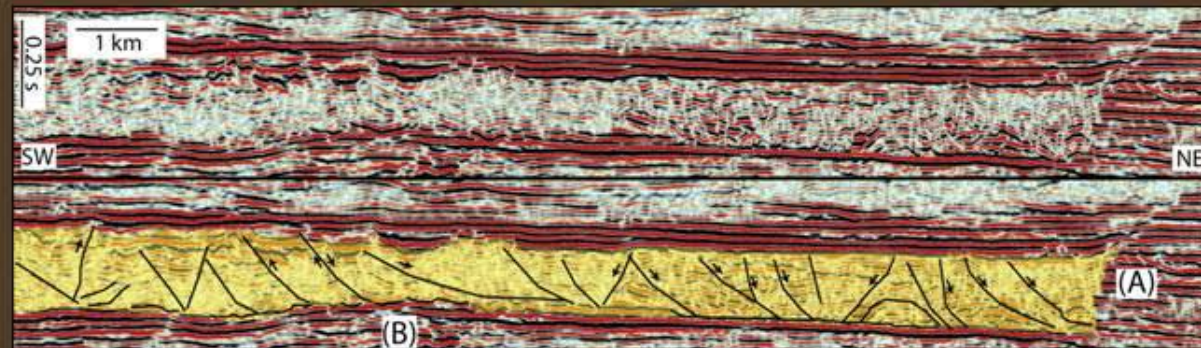
Notes by Presenter: Distribution of MTD's in the Late Pliocene to Recent section of the Northland Basin is primarily controlled by location of steepest slopes (bathymetry shown, but is very similar on base of sequence horizon map). With the exception of the grey, long MTD, all MTD's are lobe shaped and extend from the steepened slope of the Manakau Volcanic Massif. MTD's may present a danger to offshore infrastructure

Mass transport deposits

Lobe:



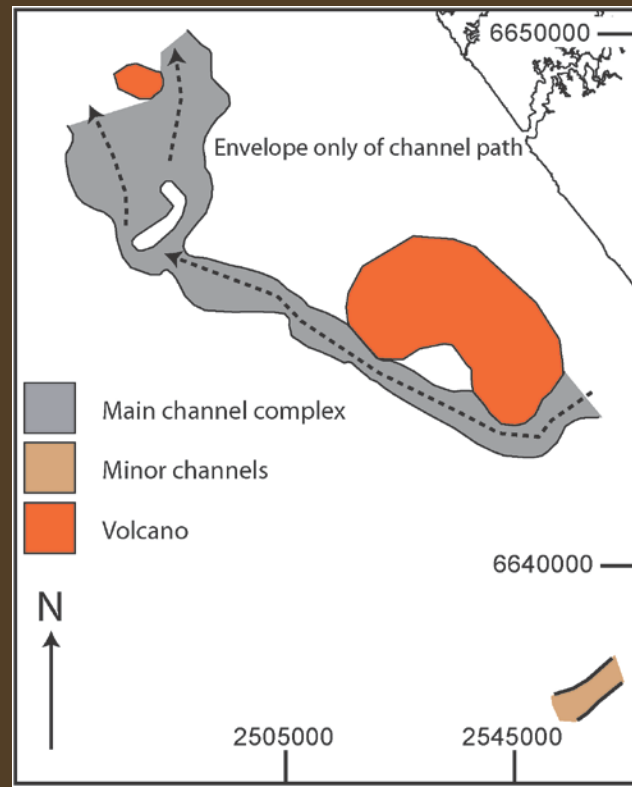
Tabular; erosive:



Notes by Presenter: Different styles of MTD are related to different processes.

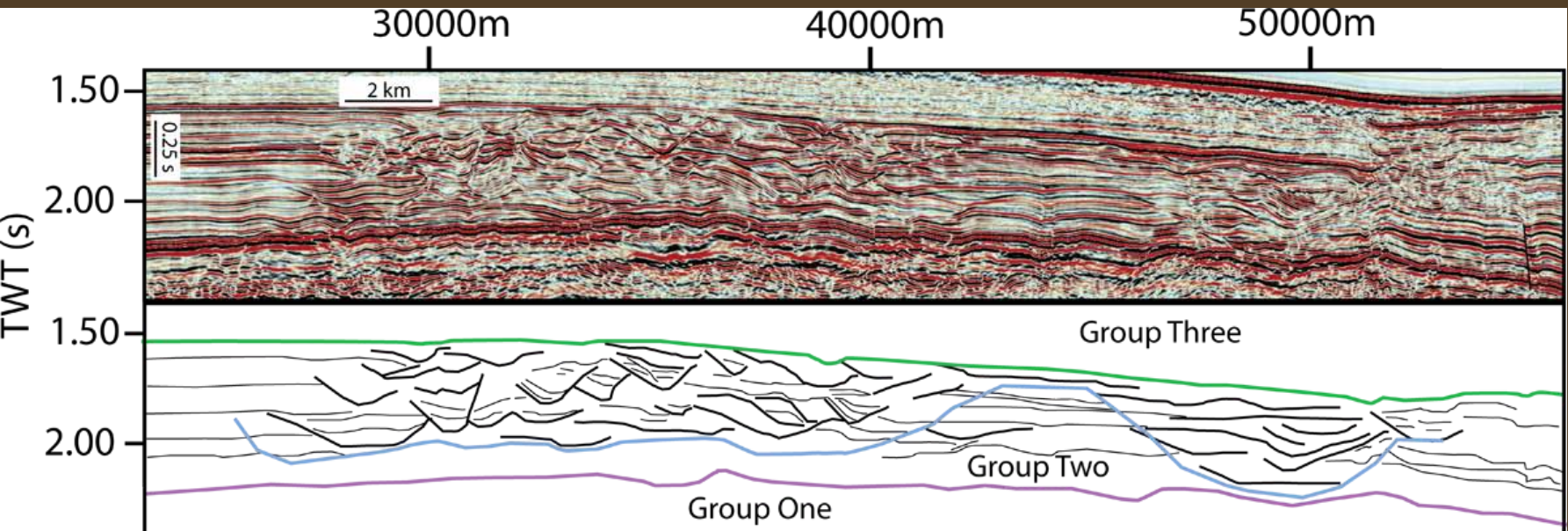
Base of sequence

1. Change in deposit types
2. Shift in position of preferential deposition
3. Change in regional ocean dynamics?



Base of sequence

1. Change in deposit types
2. Shift in position of preferential deposition
3. Change in regional ocean dynamics?



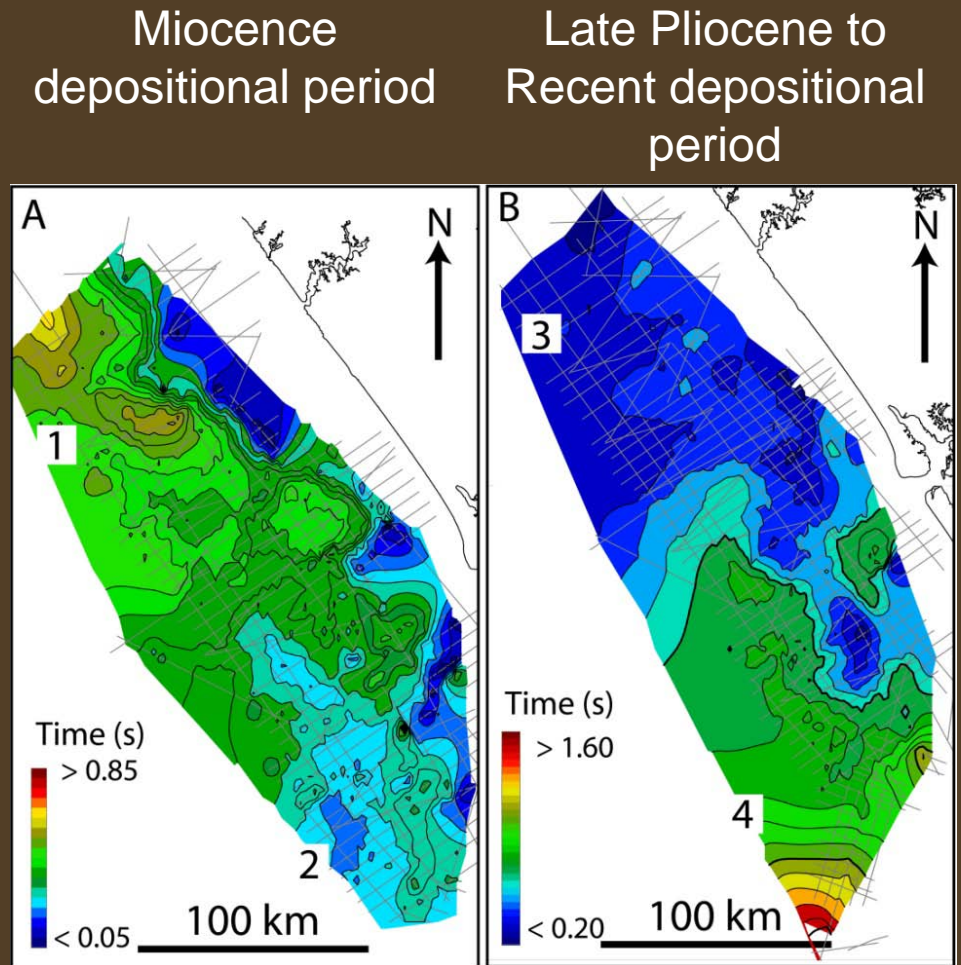
Notes by Presenter (for previous slide):

Late Pliocene sediments show onlapping and concordant reflection configurations with the base of this sequence. The base of sequence can be traced quite confidently throughout the basin as a high amplitude reflector, showing a change between low energy turbidite and contourite deposits (Mid Miocene to Late Pliocene) and submarine channel, levee, turbidites/low energy (to the south), low energy shelf/base of slope deposits (to the north). Shelf development during the Mid Miocene to Late Pliocene period was minimal, with minor aggradation/progradation if any at all. Slope/shelf sediments of this time period are observed to pinch out under Late Pliocene to Recent sediments in some locations. So we are going from a rather period where sediments are either very efficiently bypassing the shelf or not being supplied (possible mechanisms include a north westerly trending contourite system) to a period of shelf progradation (10 km) and aggradation (200 m), with many submarine channel systems forming, some being very long lived.

This abrupt change is thought to be caused by rapid fall in sea level (King and Thrasher, 1996), which is observed throughout the Northland Basin/Taranaki Basin region as a lithological change between the condensed Ariki Formation (marl) and the silt/sand/volc Rotokare Group (Late Pliocene to Recent). Therefore, this drop in sea level resulted in a large amount of sediment being shifted offshore through turbidity currents and in the cessation of a northward trending large contourite system.

Base of sequence

- Shift of preferential deposition location
 - from north (contourite deposits) to south (turbidite deposits)
- Cause:
 - Regional rotation?
 - Change in ocean dynamics?



Conclusion

- Sediment shifted offshore from Late Pliocene to Recent
 - Significant shelf margin progradation
 - Large submarine channel systems and subsequent turbidite deposits
- Extinct volcanic edifices preferentially confined sedimentation to offshore Kaipara Harbour and south relative to previous depositional periods

Acknowledgements

- John Cassidy and Lorna Strachan.
- Data and assistance provided by GNS and NIWA.
- George Gisbon, Riko Hashimoto for reviewing abstract.

References

- Duvail, C., Gorini, C., Lofi, J., Le Strat, P., Clauzon, G. and Tadeu dos Reis, A. 2005. Correlation between onshore and offshore Pliocene-Quaternary systems tracts below the Roussillon Basin (eastern Pyrenees, France). *Marine and Petroleum Geology*, Vol. 22, pp. 747-756. Pirmez et al., 1998
- Pirmez, C., Pratson, L.F. and Steckler, M.S. 1998. Clinoform development by advection-diffusion of suspended sediment: Modeling and comparison of natural systems. *Journal of Geophysical Research*, Vol. 103, No. B10, pp. 141-157.
- Gerber, T.P., Pratson, L.F., Wolinsky, M.A., Steel, R., Mohr, J., Swenson, J.B. and Paola, C. 2008. Clinoform progradation by turbidity currents: modeling and experiments. *Journal of Sedimentary Research*, Vol. 78, pp. 220-238.
- Uruski, C.I., Stagpoole, V., Isaac, M.J. and McCormack, N. 2004. Seismic Interpretation Report – Spectrum Reprocessing Northland Basin, New Zealand. Ministry of Economic Development New Zealand Unpublished Petroleum Report PR3055.