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A Sediment-flooded Subduction-to-Strike Slip System: Canyon, Channel and Basin Floor Turbidites of the Southern Hikurangi Trough, New Zealand

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Abstract

Knowledge of deep-water sediment transport and depositional processes in submarine canyon, channel, and basin floor fan systems on presently active convergent margins aid the interpretation of reservoir sequences in petroleum basins that developed in similar settings. In particular, modern analog environmental and sedimentation process data may enhance predictive capability in the interpretation of turbidite sandstone reservoirs imaged in seismic reflection data.

The deep water (>2500 m) southern Hikurangi Trough off eastern New Zealand is an example of a major canyon-channel sedimentary dispersal system on a tectonically active, obliquely convergent continental margin. The basin contains primarily clastic sedimentary rocks up to ~9 km thick, and is currently under exploration permit. This active basin offers an excellent case study in which improved understanding of Late Quaternary geomorphology, tectonic structure, sedimentary processes, and turbidite deposition may provide insights into the nature of buried channel and basin floor clastics (sand and gravel) which may represent excellent quality petroleum reservoirs. Today, there are numerous slope basins, and major submarine canyons, which supply sediment to the proximal reaches of the 2000 km-long, meandering, basin-floor Hikurangi Channel.

The southern Hikurangi Trough is a triangular shaped sedimentary basin constrained between the southern Hikurangi subduction margin and the submerged continental Chatham Rise (Figure 1). The basin straddles a transition from oblique subduction of the Pacific Plate beneath the east coast of North Island, New Zealand, to continental transpressional strike-slip deformation in the Marlborough and north Canterbury regions of South Island. The transition zone from subduction to transform results largely from an along-strike change in the crustal structure of the Pacific Plate, and increasing obliquity of relative motion between the Pacific and Australian plates. Structurally, the western flank of the basin is an accretionary margin that narrows from about 120 km width off northern Wairarapa to <60 km off Marlborough. The accretionary wedge off northern Wairarapa is a classic example of a low-taper subduction thrust system forming in response to high sedimentation supply, and relatively smooth subducting oceanic crust that is buffered by sediment cover. The late Cenozoic thrust wedge formed against an older Mesozoic accretionary backstop, and the continental slope is characterised by elongate margin-parallel sedimentary basins that are bounded by predominantly seaward-verging thrust faults and associated fault-propagation folds. In contrast, the Marlborough margin to the south is characterised by a narrower outer thrust wedge, which is locally propagating beneath the southern Hikurangi Channel, and major strike-slip

faults further inboard beneath the continental shelf. The Chatham Rise slope along the southern edge of the basin is underlain by a now-inactive accretionary wedge and rift basins of Mesozoic age, and has remained largely tectonically passive through the Late Cenozoic, apart from a region of low-strain extensional reactivation of south-dipping faults near the southern apex of the basin.

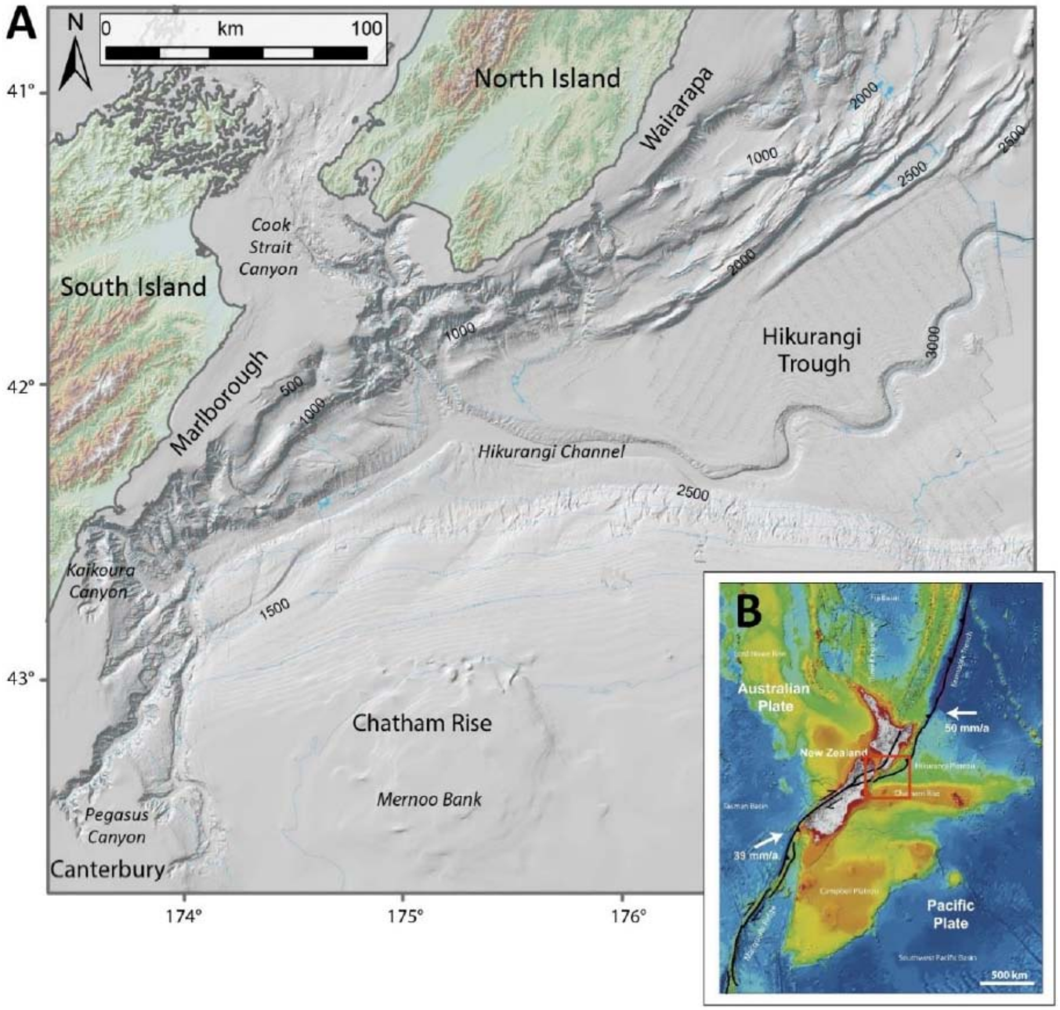

Figure 1. A. Morphology of the southern Hikurangi Trough, New Zealand: a tectonically and sedimentologically active basin containing thick, deep-water clastic sedimentary rocks. B. Inset map showing New Zealand, submerged plateau region of Zealandia, and general configuration of the Pacific – Australian plate boundary.

Reconnaissance 2D multichannel seismic reflection data of the PEG09 survey indicate that the southern Hikurangi Trough is underlain by up to 6 km of Late Cenozoic (Miocene to Recent) channel, levee and overbank basin floor turbidites in a trench-fill wedge that onlaps and buries thick (up to 3 km) subducting Cretaceous and Paleogene source rocks. The Late Cenozoic clastic fill developed in response to abundant sediment supplied from northern South Island and southern North Island, fed to the basin via submarine canyons. The clastic wedge developed in association with evolution of the axial Hikurangi Channel, and with progressive growth of the accretionary wedge along the western margin of the basin. The seismic data reveal buried channel paleo-environments beneath the present basin floor, as interpreted from seismic architecture supported by high-resolution seismic velocity analyses. Buried channels beneath the broad basin floor off Wairarapa have migrated progressively to the present day configuration of the modern Hikurangi Channel, which remains active. The channel location has remained seaward of the thrust front, and migration over the temporal interval of major Late Quaternary climate cycles (at least the last 1 Ma) has been driven by channel wall erosion at channel bends, rather than avulsion processes. In contrast, off Marlborough where the basin floor is narrow and confined, lower slope thrust propagation has driven long-term channel migration southeastward, and the present channel is now relatively linear and restricted to between the Marlborough and Chatham Rise slopes.

Some 50,000 km^2 of 25 m-resolution 30 kHz surface-ship multibeam bathymetric data provide high quality geomorphology coverage of the basin. Seafloor backscatter analysis, hi-resolution sub-bottom profiles, short (<4 m) sediment cores, and geomorphic interpretation show that presently 10 major submarine canyons have variably contributed Late Quaternary turbiditic gravel, sand, and mud to deep-water channel and basin floor environments. We infer that temporally varying roles of different canyons likely respond to cycles in global glacio-eustatic sea level (100 ka periodicity), terrestrial sediment supply, and along-shelf sediment transport. At least two major canyons (Kaikoura and Cook Strait) have remained very active throughout the Holocene high-stand of sea level, and appear to have supplied Holocene turbidites to the southern Hikurangi Trough. Cores from the southern Hikurangi Channel, its levees, and overbank basin floor reveal Holocene turbidites emplaced at an average recurrence interval in the order of 200-300 years. Other canyons have been largely or completely removed from active littoral sediment transport systems during the Holocene, but some, such as the major Pegasus and Pukaki canyons in the south, have supplied large volumes of mass-transported debris to the southern reaches of the basin off Marlborough. A variety of geomorphic bedforms and seafloor scour features, some associated with varying backscatter, are recognised in canyon, gully and channel systems, providing some constraints on turbidity current flow processes.

In order to better understand how this system functions, the possible nature of the turbidity currents, and where significant sand is being deposited, we have been undertaking numerical modelling of turbidity currents triggered in major canyons using MOVE software developed by Midland Valley, Glasgow. Our preliminary results, including deposits from multiple sources triggered simultaneously, indicate that large volume (~3-6 km3), low concentration flows are required to generate basin-wide deposits on the floor of the Hikurangi Trough. Modelling outputs such as deposit thickness and sand fraction ratio also provide insights into the heterogeneous distribution and quality of turbidite sand reservoir facies as a function of various grain size source, flow, and seafloor environmental parameters.