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Seafloor structural geomorphic evolution of the accretionary frontal wedge in response to seamount subduction, Poverty Indentation, New Zealand

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ABSTRACT

High quality swath bathymetry and seismic reflection data reveal that the steep forearc slope along the northern sector of the obliquely convergent Hikurangi subduction zone is characteristic of non-accretionary and tectonically eroding continental margins, with reduced sediment supply in the trench relative to further south, and the presence of subducting seamount relief on the Hikurangi Plateau. These seamounts influence the subduction process and the structurally-driven geomorphic development of the over-riding margin of the Australian Plate frontal wedge.

The origin of the Poverty Indentation, on the inboard trench slope, is attributed to multiple seamount impacts over the last c. 1 Myr period, accompanied by canyon incision, thrust fault propagation into the trench fill, and numerous large-scale gravitational collapse structures with multiple debris flow and avalanche deposits ranging in downslope length from a few hundred metres to more than 40 km. The indentation is directly offshore of the Waipaoa River which is currently estimated to have a high sediment yield into the marine system. The Poverty Canyon stretches 70 km from the continental shelf edge directly offshore from the Waipaoa to the trench floor, incising into the axis of the indentation. The sediment delivered to the margin from the Waipaoa catchment and elsewhere during sea-level high-stands, including the Holocene, has remained largely trapped in a large depocentre on the Poverty shelf, while during low-stand cycles, sediment bypassed the shelf to develop a prograding clinoform sequence out onto the upper slope. The formation of the indentation and the development of the upper branches of the Poverty Canyon system has led to the progressive removal of a substantial part of this prograding wedge by mass movements and gully incision. Sediment has also accumulated in the head of the Poverty Canyon and episodic mass flows contribute significantly to continued modification of the indentation by driving canyon incision and triggering instability in the adjacent slopes.

Prograding clinoforms lying seaward of active faults beneath the shelf, and overlying a buried inactive thrust system beneath the upper slope, reveal a history of deformation accompanied by the creation of accommodation space. The middle to lower Poverty Canyon represents a structural transition zone within the indentation coincident with the indentation axis. The lower to mid-slope south of the canyon conforms more closely to a classic accretionary slope deformation style with a series of east-facing thrust-propagated asymmetric anticlines, separated by early-stage slope basins. North of the canyon system, seamount impact has resulted in frontal tectonic erosion associated with the development of an over-steepened lower to mid-slope margin, fault reactivation and structural inversion and over-printing.

1. Introduction

Sedimentary sequences accumulating at continental margins may provide records of paleo-climates, sea-level change, tectonics/deformation, geomorphic evolution and anthropogenic effects (e.g. Orange, 1999; Carter et al., 2002; Greene et al., 2002). Subduction zones associated with thick trench-fill sequences and high sediment flux rates along continental margins commonly form wide and voluminous accretionary wedges in response to the interaction of the subducting plate with the over-riding plate (e.g. Dickinson and Seely, 1977; Dickinson and Seely, 1979).

Seamount subduction plays a significant role in the morpho-structural evolution of convergent margins (e.g. Fryer and Smoot, 1985; Lallemand and Le Pichon, 1987; Dubois et al., 1988; Yamazaki and Okamura, 1989; Lallemand et al., 1989; Maruyama and Liou, 1989; Konishi, 1989; Masson et al., 1990; Robertson, 1998; Mann et al., 1998; Dominguez et al., 1998b; Dominguez et al., 2000;

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Hühnerbach et al., 2005). Many studies have primarily focused on the localized effects of these collisions, such as inhibiting or modifying frontal accretion and producing re-entrants (e.g. Dominguez et al., 1998b; Hühnerbach et al., 2005), rather than their contribution to the temporal and spatial aspects of the evolution of the forearc slope as a whole.

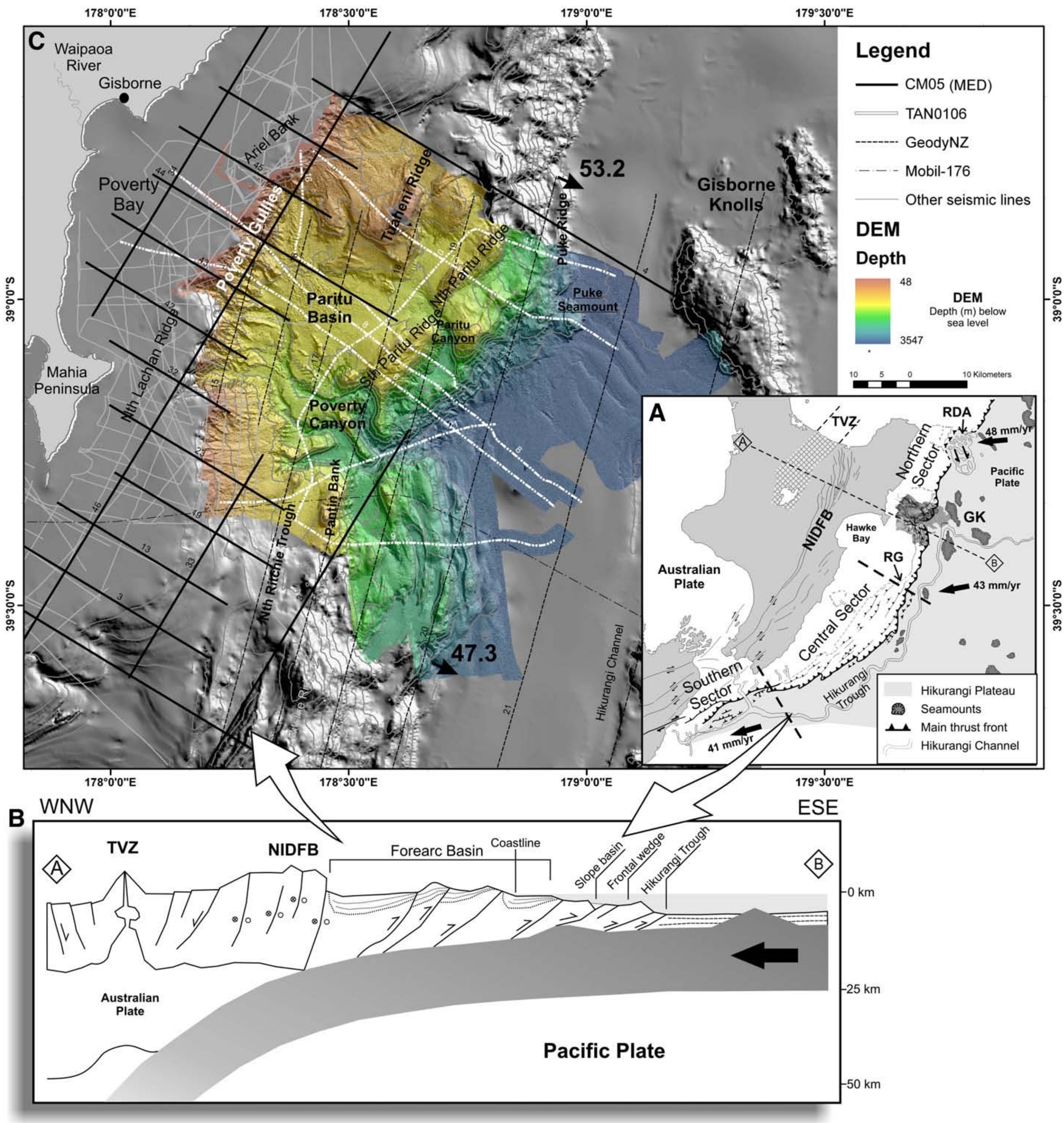

Fig. 1. A: Location map of the Hikurangi Margin and the Poverty Indentation, with the major seafloor geomorphic features labelled. The Hikurangi Margin is divided up into Southern, Central and Northern Sectors. The Poverty Bay Indentation is located north of the transition from the Central to the Northern Sector, located at the southern end of the Rock Garden (labelled RG) (see Barnes et al., in press). Plate motion vectors (relative to a fixed Australian Plate) are indicated by the heavy black arrows (from Beavan et al., 2002). Line A–B represents the approximate location for the representative cross-section detailed in Fig. 1B. New names introduced in this paper are underlined (modified from Lewis et al., 2004). GK = Gisborne Knolls, RDA = Ruatoria Debris Avalanche, NIDFB = North Island Dextral Fault Belt. TVZ = Taupo Volcanic Zone, with subduction related volcanics and back arc extension (after Walcott, 1978; Lewis, 1980; Cole and Lewis, 1981; Beanland and Haines, 1998). B: Schematic cross-section A–B, not to scale, through the northern Hikurangi Margin showing the relationship between the subducting Pacific Plate and the large-scale deformation features observed in the over-riding Australian Plate. NIDFB = North Island Dextral Fault Belt, TVZ = Taupo Volcanic Zone. C: Swath bathymetry generated digital elevation model (DEM) and seismic lines for the Poverty Indentation offshore from Poverty Bay, North Island, New Zealand. Bold black numbers indicate modelled convergence rates (mm/yr) and vectors between the Hikurangi Margin and the Pacific Plate (Wallace et al., 2004). Names of significant morphological features within and around the Poverty Bay Indentation are shown, with names introduced in this paper underlined. Bathymetry contours = 250 m. Grey area is a background hillshade from archived SIMRAD EM12 Dual multibeam data acquired by RV L'ATALANTE, and coastal echo-soundings.