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Holocene sedimentary activity in a non-terrestrially coupled submarine canyon: Cook Strait Canyon system, New Zealand

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ABSTRACT

The Cook Strait Canyon system, located between the North and South islands of New Zealand, is a large (1800 km^2), multi-branching, shelf-indenting canyon on an active subduction margin. The canyon comes within 1 km of the coast, but does not intercept fluvial or littoral sediment systems and is therefore defined as a non-terrestrially coupled system. Sediment transport associated with a strong tidal stream, and seafloor disturbance related to numerous high-activity faults, is known from previous studies. Little is known, however, about the rates of sedimentary activity in the canyon and the processes driving it. A substantial dataset of EM300 multibeam bathymetry, gravity cores, 3.5 kHz seismic reflection profiles, camera and video transects and current meter data have been collected across the region between 2002 and 2011. The canyon system therefore provides an excellent study area for understanding sediment transport in a non-coupled submarine canyon system. Analysis of the data reveals a two-staged sediment transport system where: (1) oceanographic (tidal) processes mobilise sediment from the continental shelf and transport it to depocentres in the upper–central canyons, and (2) tectonic (earthquake) processes remobilise sediment that is transported through the lower canyon to the deep ocean. Tidal boundary-layer currents within the canyon reach velocities up to 0.53 m/s and are capable of mobilising fine sand in the central reach of the upper canyons. The velocity is higher at the canyon rim and capable of mobilising coarse sand. Sediment depocentres resulting from this tidally forced sediment transport have a well formed geomorphology within the mid-upper canyon arms of Cook Strait and Nicholson Canyons. Pseudo-static stability modelling, supported by sediment core analysis, indicates that sediment accumulated in the upper canyons fails during seismic events approximately every 100 years. The 100 year return period ground shaking-level (peak ground acceleration, ignoring the effect of the water column above the seabed) at this site is estimated to be 0.23g. Fresh rock outcrops and bed-scour in the lower canyon floor indicate that remobilised material is transported to the deep ocean. The processes identified here are likely to be analogous to those occurring in many non-coupled shelf-indenting canyons on active margins globally, and provide a framework within which the biological response to geomorphic processes in submarine canyons can be assessed.

1. Introduction

The traditional model of submarine canyon evolution proposes active canyon formation during sea level low-stands and canyon inactivity during sea level high-stands (Emery and Uchupi, 1972; Vail et al., 1977). According to this model, the principal control on canyon activity is the coupling of the submarine canyon system to terrestrial sediment sources, by direct connection to either fluvial or littoral sediment transport. Apart from the significantly enhanced sediment supply, the more pronounced canyon development during sea level low-stands is also related to the higher proximity of the coastal sediment-supply system to the canyon heads.

Harris and Whiteway (2011) propose that only approximately 150 submarine canyons (2.6% of the global canyon population) are connected to terrestrial river systems today. This represents the proportion of river-connected canyons during the brief periods of high sea level, with the number expanding during global sea level fall. Thus, the large majority of submarine canyons worldwide are disconnected from direct terrestrial sediment supply and should be relict features. Recent studies of the upper reaches of submarine canyons (Canals et al., 2006) and deep-sea canyon fan

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systems (Covault and Graham, 2010), however, have shown that a number of sedimentary and oceanographic processes maintain geomorphic activity in non-terrestrially coupled submarine canyons during sea level high-stands. These processes include dense shelf water cascading (Canals et al., 2009; Puig et al., 2013), tides (Mulder et al., 2012), internal waves (de Stigter et al., 2011) and storm-related turbidity currents (Puig et al., 2004), among others.

In this study we demonstrate that the Cook Strait system, a non-terrestrially coupled submarine canyon system (i.e. it is not connected to any river or shallow littoral system), which incises a tectonically active margin offshore New Zealand, has been active during the Holocene. We analyse multibeam echosounder and seismic reflection data, gravity cores, video/photo transects and *in situ* oceanographic measurements acquired from the upper Cook Strait Canyon system to (i) determine the character, extent and timing of sedimentary activity across the submarine canyon system, (ii) identify the driving mechanisms responsible for such sedimentary activity and (iii) propose a conceptual model to explain sea level high-stand canyon activity. The results of this study contribute to our growing understanding of the myriad of processes that enable non-terrestrially coupled submarine canyons to maintain sedimentary activity in periods of sea level high stand. Quantifying these mechanisms, some of which occur at human timescales, is important because they influence important processes such as carbon transfer to the deep ocean, and inter-canyon biological habitat variability.

2. Regional setting

Cook Strait is a seaway connecting the Pacific Ocean and Tasman Sea between the North and South islands of New Zealand (Fig. 1). The “land gap” exists due to the long-term tectonic alignment of the Pacific and Australian tectonic plates. A land bridge is proposed to have formed to the north west of Cook Strait during glacial periods, and the opening and closing cycle of Cook Strait has persisted over many eustatic sea level cycles (Lewis et al., 1994). The large-scale geomorphology of the seaway reflects these long-term landscape-forming processes, while superimposed on this is the impact of modern active processes that postdate sea level rise (Lucieer and Lamarche, 2011; Mountjoy et al., 2009; Proctor and Carter, 1989). At the narrowest point between the North and South islands (“The Narrows”), the Cook Strait is 22 km wide. To both the north and the south east, the strait widens, although the seafloor displays significantly different morphologies on these two sides. To the north, the seafloor of the Tasman Sea is predominantly gently undulating and not deeper than 150 m across several hundreds of kilometres squared of area.

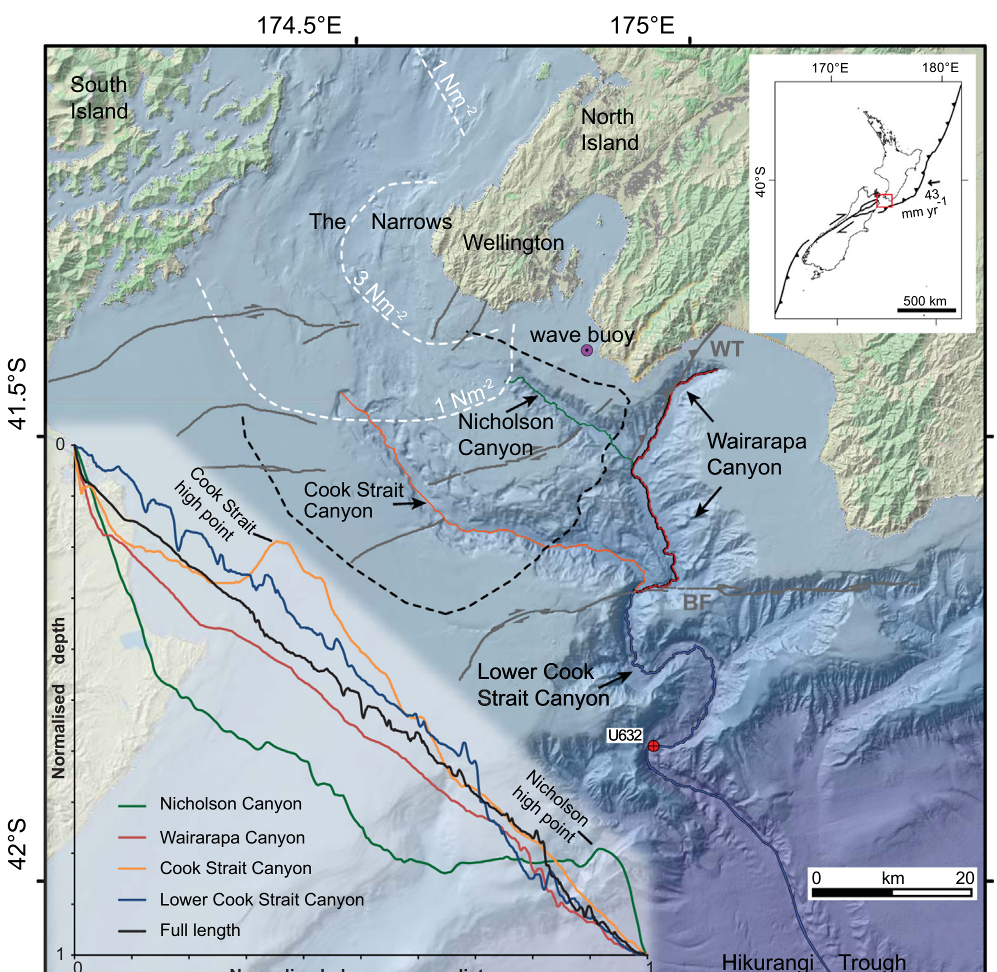

Fig. 1. Cook Strait Canyon physiography showing the main component canyons and their normalised long profiles. Contours of modelled tidal bed-shear stress (white dashed lines) from Proctor and Carter (1989). The extent of tidal influence on seafloor morphology (black dash lines) is from Mountjoy et al. (2009). Selected offshore active faults shown by grey lines, after Pondard and Barnes (2010). WT Wharekauhau Thrust, BF BooBoo Fault. Inset location map shows the main plate boundary tectonic structures and the relative plate motion vector on the pacific plate, after Beavan et al. (2002).