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Tectonic activity and the evolution of submarine canyons: The Cook Strait Canyon system, New Zealand

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Submarine canyons are Earth's most dramatic erosional features, comprising steep-walled valleys that originate in the continental shelf and slope. They play a key role in the evolution of continental margins by transferring sediments into deep water settings and are considered important biodiversity hotspots, pathways for nutrients and pollutants, and analogues of hydrocarbon reservoirs. Although comprising only one third of continental margins worldwide, active margins host more than half of global submarine canyons. We still lack of thorough understanding of the coupling between active tectonics and submarine canyon processes, which is necessary to improve the modelling of canyon evolution in active margins and derive tectonic information from canyon morphology.

The objectives of this study are to: (i) understand how tectonic activity influences submarine canyon morphology, processes, and evolution in an active margin, and (2) formulate a generalised model of canyon development in response to tectonic forcing based on morphometric parameters. We fulfil these objectives by analysing high resolution geophysical data and imagery from Cook Strait Canyon system, offshore New Zealand.

Using these data, we demonstrate that tectonic activity, in the form of major faults and structurally-generated tectonic ridges, leaves a clear topographic signature on submarine canyon location and morphology, in particular their dendritic and sinuous planform shapes, steep and linear longitudinal profiles, and cross-sectional asymmetry and width. We also report breaks/changes in canyon longitudinal slope gradient, relief and slope-area regression models at the intersection with faults.

Tectonic activity gives rise to two types of knickpoints in the Cook Strait Canyon. The first type consists of low slope gradient, rounded and diffusive knickpoints forming as a result of short wavelength folds or fault break outs and being restored to an equilibrium profile by upstream erosion and downstream deposition. The second, more widespread type of knickpoints have high slope gradients and angular profiles. These knickpoints have undergone upslope advective migration through slope failures on the canyon floor and localised quarrying and plucking by sedimentary flows. Knickpoint migration is driven by base level lowering due to regional margin uplift and deepening of lower Cook Strait Canyon, and is likely faster in larger canyons because of higher sedimentary flow throughput.

The formation and migration of knickpoints, the non-adherence to Playfair's Law, the linear longitudinal profiles and the lack of canyon-wide, inverse power-law slope-area relationships indicate that the Cook Strait Canyon is a system that is in a transient state, undergoing continuous adjustments to perturbations associated with tectonic displacement and changes in base level and sediment fluxes.

Based on the reported canyon morphological parameters and their response to tectonic activity, we propose a generalised model for canyon geomorphic evolution in tectonically-active continental margins.