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Large Canyon-Channel Complexes from South Island of New Zealand Show Contrasting Morphologies

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Abstract

Large submarine canyons are prominent geomorphic features that incise the continental margin. They provide conduits for dispersal of terrestrially derived material to the deep ocean, display complex morphology and provide insights into the processes that operate on the margin between continental shelf and deeper water, and the associated potential petroleum reservoir targets. The west coast South Island supports two large canyon-channel complexes fed by steep, short-reach rivers that carry 63 MT of suspended sediment (Hicks et al., 2011), ~30% of New Zealand's total riverine contribution to the sea. These complexes form important point sources of land-derived nutrients and bioactive material. In contrast, southeastern coast of the South Island has a concentration of nine major continental shelf bisecting nearshore canyons and many minor canyons along a 200km long section of the continental slope.

West Coast Canyons

The West Coast canyon complexes occur along a ~350 km long northeast trending coastal margin bisected by numerous short-reach rivers that drain the steep axial mountain range of the Southern Alps. The continental shelf varies in width from ~60 km wide in the north to <20 km wide in the south, and is dominated by fine sands to muds (Carter, 1980). Sediment supply to the continental shelf is high as a consequence of the rapid tectonic uplift of the Southern Alps, an extremely wet maritime climate and high rates of erosion within the catchments of the numerous, steep, short, rivers. Shelf transport is dominated by the northeasterly flowing Westland Current, which combined with predominantly southwesterly storm waves and winds, is sufficient to entrain shelf sediments with net transport to the northeast. The west coast continental shelf is supply dominated, blanketed by terrigenous muds, with rare relict sediments around some canyon heads (Radford, 2012).

Fifty thousand square kilometres of multibeam bathymetry was recently acquired at 25m-resolution, and shows four principal canyon–channel complexes make up the Hokitika/Cook canyon system, which extends at least 1000 km offshore and falls vertically >3000 m (Figure 1a). Here, channels are locally entrenched up to 1000 m into the continental slope. Two of these conduits have aggraded and built levees with sea-level rise, fed by river discharge and littoral drift where they cross the shelf and upper slope. The upper reaches of the complex are up to 28 km wide and comprise numerous v-shaped canyons feeding into multiple, sinuous and migrating channels. In contrast, the lower reaches of the channels are incised, erosional and narrow. The channel confluences are marked by hanging valleys, indicating that the Cook Channel is either the distributary system that has sustained the latest and/or at least the largest avulsive event. The Hokitika Channel terminates in a low relief fan with minor distributary channels at >4800m water depth.

Dependant on location, sediments within this channel-levee system range from well-sorted, mica-rich silts and sands to coarser turbidite deposits and last glacial gravels at the base of the erosional channel. Cores indicate that fine overbank deposits have been accumulating for at least the last 1.5 My with more deposition of fine muddy sediments occurring on levees bordering the upper reaches of the canyon systems and outer reaches of the Hokitika Channel, where channel incision is <400 m. The volume and grain size of terrigenous sediment increased during glacial lowstands, with the first occurrence within this canyon/channel complex of mica-rich silt turbidites evident in water depths >3800 m water depth as overbank deposits on levees, ~450 km down channel, when channel incision is <400 m.

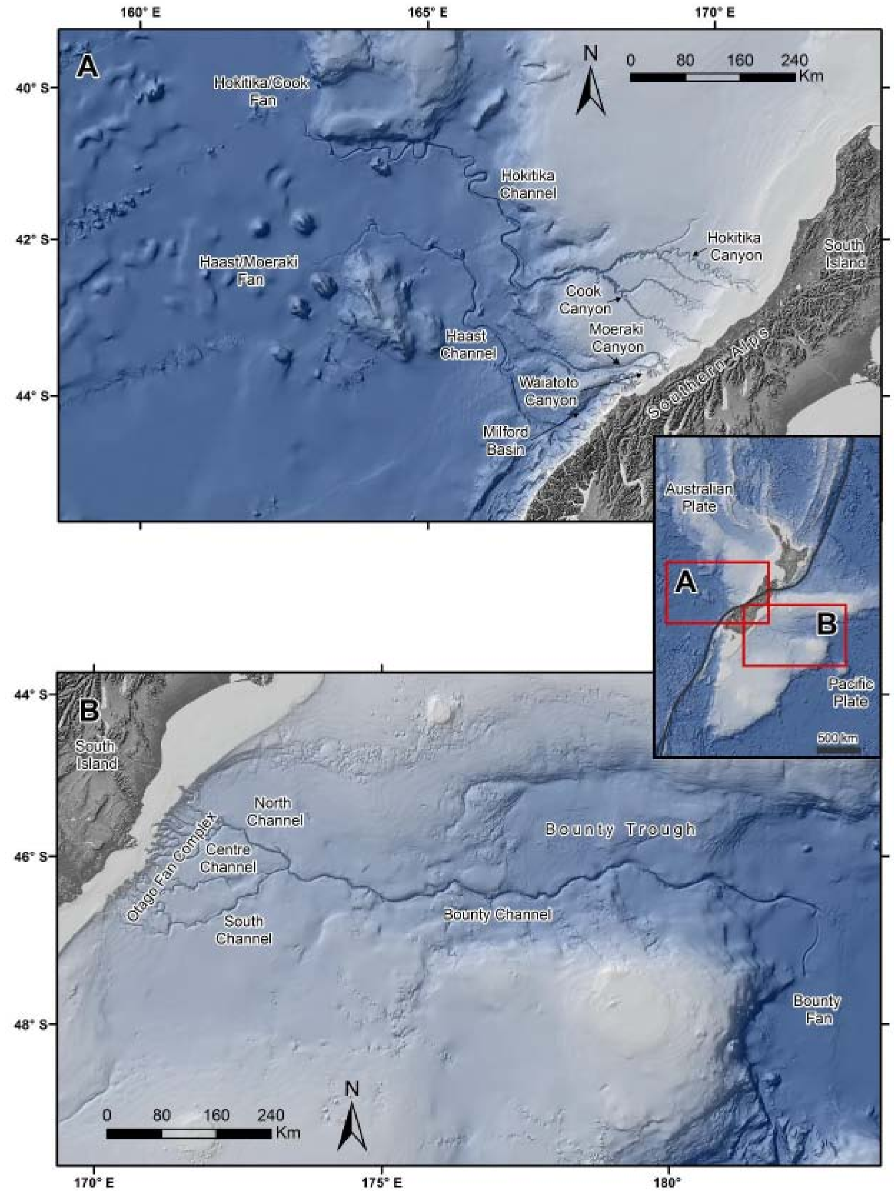

Figure 1. A. Morphology of the West Coast canyon/channel complexes, West Coast, South Island, New Zealand. B. Morphology of the Otago Fan Complex and Bounty Channel, East Coast, South Island New Zealand. Inset map shows New Zealand, the submerged plateau of Zealandia, and the Pacific-Australian plate boundary.

In contrast, the Moeraki/Waiatoto complex further south on the west coast South Island extends ~700 km offshore to >4000 m water depth, with a primary channel (Moeraki) that is flat-bottomed and steep-sided, incised 500-800 m into the slope, and considerably larger at 5 km-wide (Figure 1a). This primary channel is fed by three near-shore canyons, and sediments within the channel-levee complex are mainly coarse sands and gravels to well-sorted, mica-rich silts, respectively. Similarly, the Waiatoto canyon system is fed by at least four near-shore canyons at its head as well as by gravel-rich, glacial outwash fans at its shoreward flank. The Moeraki Canyon feeds into the Milford Basin and eventually the Haast Channel. The Moeraki/Waiatoto systems merge to form a single, entrenched, northwesterly trending channel that continues onto the abyssal plain eventually terminating in a low relief fan with minor distributary channels.

Regionally sediment accumulation rates increase five-fold between the northerly Hokitika/Cook system and Moeraki/Waiatoto to the south. High sedimentation also occurs in intra-canyon slope areas, whereas along the canyon axes slow sedimentation and persistent erosion occurs. Organic carbon data show that, contrary to expectations, higher amounts of more labile organic material are found at the intra-canyon continental slope sites, although additional sampling is required to fully characterise the system. Results from studies of seabed communities of canyon and slope environments (including Kaikoura Canyon, northeast coast of the South Island) indicate that habitat complexity and the availability of labile organic matter has a dramatic impact on abundance, diversity, and distribution of benthic invertebrate fauna within and among the canyons, and nearby slope areas.

Bounty Channel, East Coast, South Island

Earlier surveys of the east coast South Island Otago Fan complex and Bounty Channel have recently been supplemented by ~23,000 km^2 of multibeam bathymetric surveys. The Bounty Channel and Fan System is located within the Bounty Trough and comprises the Otago Fan Complex, which feeds the axial Bounty Channel, which in turn flows onto the abyssal depth Bounty Fan (Figure 1b). The Bounty Trough is a failed rift in the eastern New Zealand continental margin, incepted in the late Cretaceous and bounded to north by Chatham Rise and the south by the Campbell Plateau. The Bounty Channel and Fan System is an extremely long-lived sediment transport system, with the eastern margin of NZ being characterised since the Paleocene (55 My) by a marine channel (Carter and Carter, 1987; Carter et al., 1990).

Uplift along the axial Southern Alps governs the lithology and amount of riverine sediment supplied to the Otago shelf, but eustatic sea level is the primary control on whether available sediment enters the Bounty Channel and Fan system. Today sediment shed from the Southern Alps is largely trapped in glacially formed lakes, but around 1.2 MT is delivered to the coast today (Hicks et al., 2011) to form the modern shore-attached terrigenous sediment wedge. The Bounty Trough is characterised by predominantly pelagic sedimentation represented by a drape of foraminiferal-nannoplankton ooze over channels and levees alike. Today, levees on the Otago Fan Complex still receive terrigenous sediment presumably reworked from the adjacent continental shelf. During glacial periods, rivers discharged directly into canyon heads and were distributed throughout the Bounty Trough as hemipelagic and turbiditic sediment facies. Overspill along the entire length of the Bounty channels produced asymmetric levee growth (Carter and Carter, 1988), in contrast with evidence from the west coast system.

Nine major and many minor submarine canyons along a 200-km long section of the eastern South Island incise the continental slope to form the Otago Fan Complex. Here, canyons reach maximum depths of ~750 m some 5-15 km down slope from their head and coalesce into the

North, Centre and South channels, which ultimately merge to form the Bounty Channel, ~200 km seaward of the shelf edge. The canyons form a set of tributaries, rather than acting as distributaries. Channels are bordered by prominent levees that, on the steep Otago fans, are mainly narrow sandy ridges (Carter and Carter, 1988). Between the Otago Fan Complex and a distinct sill at 3250 m water depth is a 700 km long zone of gently sloping floor, the axial Bounty Trough, along which the Bounty Channel runs. For most of its length, the Bounty Channel maintains a uniform incision depth of 350-380m relative to the north wall and is flanked by broad, low relief, muddy levees.

New multibeam data reveals the geometry of the canyon heads of the Otago Fan Complex and the asymmetrical levees of the Bounty Channel and associated sediment wave fields, formed by channel overspill of coarse sand to silt turbidity currents during glacial periods. In addition, these new data highlight the recurving channel meanders, and higher sinuosity evident between ~1300–1500 m water depth. Cut-off or abandoned meanders also occur suggesting that when active the channel-levee system is evolving through time.

Morphological Indicators of Hydrocarbons

Pockmarks occur over large areas of the seafloor around the mid and lower continental slope of New Zealand and are at times coincident with the location of slope failures. These features are likely to be related to fluid expulsion at the seabed, possibly gas or ground water. It is possible that such fluid systems play a role in destabilising slopes. Pockmarks are associated with the Hokitika/Cook complex between 450–750 m water depth and are up to 150 m across and exhibit ~10 m relief. However, pockmarks associated with Bounty Channel occur between 500–850 m water depth, often in greater abundance on the northern levees, and are up to ~200 m across and have ~20 m relief.

Understanding sedimentary basins and the potential petroleum reservoir systems within them can be aided by these examples of the modern seabed that illustrate the geometry and origins of depositional elements analogous to actual and potential oil and gas reservoirs that originated at and beyond the shelf margin. However, it is possible modern analogues over sample the depositional elements relative to the large mass-flow deposits that comprise the larger proportion of deep-sea submarine fan systems.

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