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Review

Submarine channel flow processes and deposits: A process-product perspective

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ABSTRACT

Process-product studies have been central to the development of process sedimentology over the past few decades, with the ability to first measure flows, and then examine the resulting deposits, removing much of the ambiguity associated with previous interpretations. However, perhaps uniquely for large geomorphic systems on Earth, there are no field-scale process-product studies of submarine channels. In fact, there are remarkably few direct measurements even of the flow dynamics as a result of the difficulties of measuring these powerful, infrequent, and often inaccessible flows. Over the past decade, physical experimentation has provided the first process-product studies for model submarine channel systems, enabling us to link flow behaviour and sedimentation patterns. This has been supplemented by numerical simulations, particularly of submarine channel flow dynamics. Here for the first time, we synthesise these observations, in the context of our direct knowledge of submarine channels, to derive an overview of submarine channel flow dynamics, and process-orientated intra-channel architecture models for low and high latitude systems. In addition, we propose new models for the development and evolution of point bars and for inner bend sedimentary accumulations that can comprise point bars overlain by finer-grained oblique accretion deposits. The work reveals a rich range of flow behaviour and associated sedimentation patterns in submarine channels that are far more complex than in fluvial systems.

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1. Introduction

Submarine channels are prominent topographic features on seafloor continental slopes and basin plains and are formed by sediment-laden turbidity currents and other sediment-rich gravity currents (Fig. 1; Menard and Ludwick, 1951; Pickering et al., 1989; Mulder, 2011). Such channels are the underwater equivalent of river systems on land: rivers are the primary mechanism for sediment transport in the terrestrial sphere, neglecting the possible role of humans (Hooke, 1994; Milliman and Farnsworth, 2011), whereas submarine channels have the same role in the oceans, transporting sediment from the continental shelf into deep-water and across ocean floors (Wynn et al., 2007). The importance of sediment, as both suspended- and bedload, in both submarine channels and rivers has led to many analogies between the two (e.g., Klaucke and Hesse, 1996; Peakall et al., 2007), albeit as discussed herein there remain major differences in many aspects of their fluid dynamics and sedimentary deposits.

Submarine channels and their associated turbidity currents also share similarities with thermohaline-driven gravity currents that act to redistribute heat around the global oceans (e.g., Cenedese and Adduce, 2008, 2010; Fer et al., 2010; Wells et al., 2010). This analogy is closest at the major ocean gateways that link ocean basins where these thermohaline currents narrow and form prominent channels that are often associated with contourites (Akhmetzhanov et al., 2007; Legg et al., 2009; Sumner et al., 2014; Cossu et al., 2015). However, whilst thermohaline currents and turbidity currents are both types of gravity current, the presence of sediment rather than a solute phase leads to distinct differences in stratification in turbidity currents (Section 2.1) and this in turn affects other flow dynamics. Herein, we concentrate on submarine channel dynamics, utilising fluvial channels and oceanic gateways as analogues as appropriate.

Submarine channels are classified herein into six distinct geomorphological types (Fig. 1). (i) As the 'arteries and veins' of submarine fans, which are some of the largest sedimentary accumulations on Earth (Curray et al., 2002), and are typically connected at sea-level low-stand directly to river systems. (ii) As isolated deep-ocean channels that are not associated with prominent fans (e.g., Carter, 1988; Klaucke et al., 1998; Lewis and Pantin, 2002). Such channels form in the early stages of ocean–basin formation, are often strongly basement controlled, and can remain active for as long as subsidence at the terminus exceeds sediment deposition (Carter, 1988). They can produce some of the longest-lived geomorphological systems on Earth, typically millions of years and in some cases tens of millions of years (Carter and Carter, 1987, 1996; Carter, 1988). (iii) As axial channels in ocean trenches (e.g., Thornburg and Kulm, 1987; Shimamura, 1989; Pickering et al., 2013). (iv) As aggradational or erosive slope channels (e.g., Hackbarth and Shew, 1994; Maier et al., 2012). In the case of erosive slope channels, erosion scales with the flow depth, in marked contrast to submarine canyons (see below). (v) As non-margin ocean channels, in ocean basins far from terrestrially derived sources of sediment (Gardner, 2010). This channel type has only recently been recognised, with spectacular channels initiating high up on volcanic seamounts in a

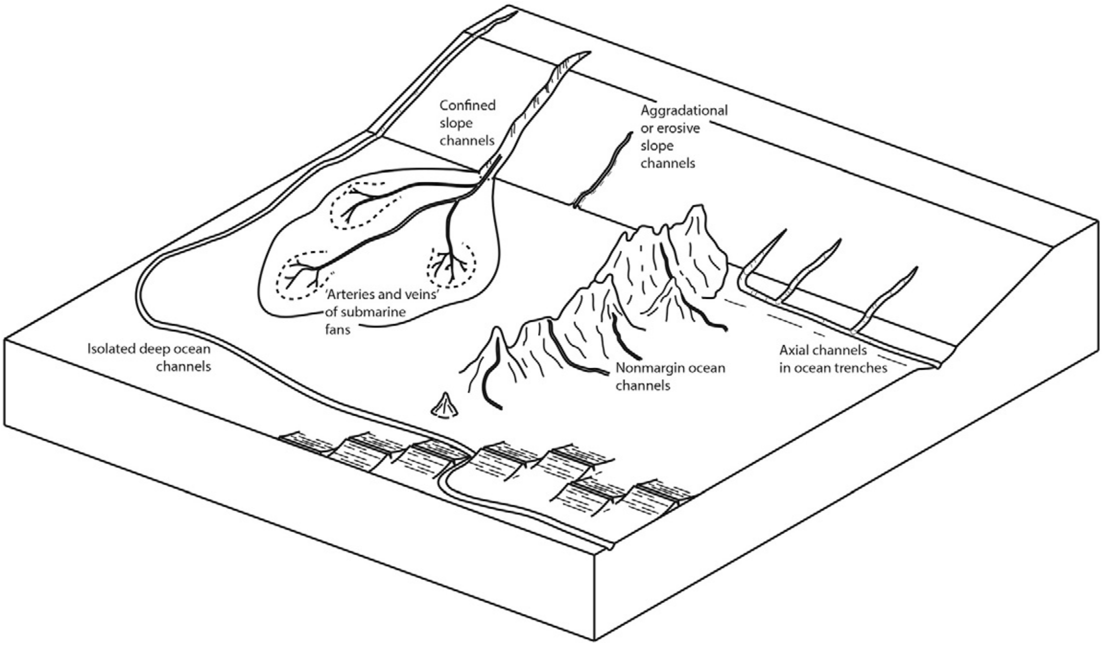

Fig. 1. Schematic view of the six major types of submarine channels: (1) the 'arteries and veins' of submarine fans; (2) isolated deep-ocean channels; (3) axial channels in ocean trenches; (4) aggradational or erosive slope channels; (5) non-margin ocean channels; and (6) confined slope channels. The figure shows channels at present-day sea levels; however at sea level lowstands the heads of many of these channels and canyons extend across the continental slope and connect directly to river systems. See text for further details of each type.