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Isotopic and elemental evidence for Scabland Flood sediments offshore Vancouver Island

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ABSTRACT

Geological records contain evidence for catastrophic ice-sheet processes such as megafloods and massive ice discharges. Such large-scale phenomena, associated with ice sheet collapse, rapid sea-level rise, and disruptions to ocean circulation, have never been directly observed, but are forecast as a consequence of global warming. Here we use potassium-argon (K/Ar) ages and neodymium (Nd) isotopes as provenance tools to show that cyclical megafloods from the Cordilleran Ice Sheet of western North America traveled through the Channeled Scabland of Washington and transported sediments to the continental slope of Vancouver Island during the last glacial, laying down a sequence of rhythmically bedded sediments in deep-sea core MD02-2496. This work addresses longstanding questions about the absolute timing of Scabland Floods, their cyclicity, and the fate of their sediments and freshwater in the marine realm. Our data suggest that, between ~19.3 and ~14.9 ka, Scabland Floods repeatedly generated far-traveled sediment-water plumes in the NE Pacific Ocean, requiring a hydrologically active ice sheet system capable of producing catastrophic megafloods for about 4500 years.

1. Introduction

Glacial megafloods, defined as flows $>10^6$ m^3/s, commonly occurred during Pleistocene glacial-interglacial transitions, when large, dynamic ice sheets impounded water behind temporary ice dams. In western North America, the eastern Cordilleran Ice Sheet (CIS) formed proglacial Lakes Missoula and Columbia as the Purcell Trench (Waitt, 1985) and the Okanogan (Atwater, 1986) lobes advanced, blocking drainage to the NE Pacific. Unstable subglacial reservoirs may also have existed (Lesemann and Brennand, 2009). Though it is recognized that resulting megafloods transformed the landscape with a vast network of mega-scale erosional and depositional features (e.g. Bretz, 1925), repeatedly injected freshwater into the ocean (Lopes and Mix, 2009), and generated long-traveled turbidity currents (Zuffa et al., 2000; Normark and Reid, 2003), the timing of flooding and the offshore path of the flood waters remain enigmatic (VanLaningham et al., 2008).

Marine sedimentary evidence has the potential to provide a well-dated record of CIS megaflooding and information about freshwater routing. Thus far, diatoms indicate that decreased sea-surface salinities occurred ~400 km from the Columbia River mouth (Lopes and Mix, 2009), yet direct isotopic evidence for the Scabland Floods has been limited to Astoria Fan turbidites (Prytulak et al., 2006), where radiocarbon dating opportunities are limited.

Here we use isotopic analyses of marine and terrestrial sediments to show that floods through the Channeled Scabland carried fine-grained sediments to the continental slope offshore Vancouver Island, where they are preserved in the well-dated core MD02-2496. The connection between the Vancouver Island marine sediments and the Scabland Floods is provided by K/Ar age and $^{143}Nd/^{144}Nd$ measurements. While old K/Ar ages (>250 Ma) and negative ε_{Nd} values (−8.5) in MD02-2496 are incompatible with proximal sediment sources, as demonstrated by geologic and

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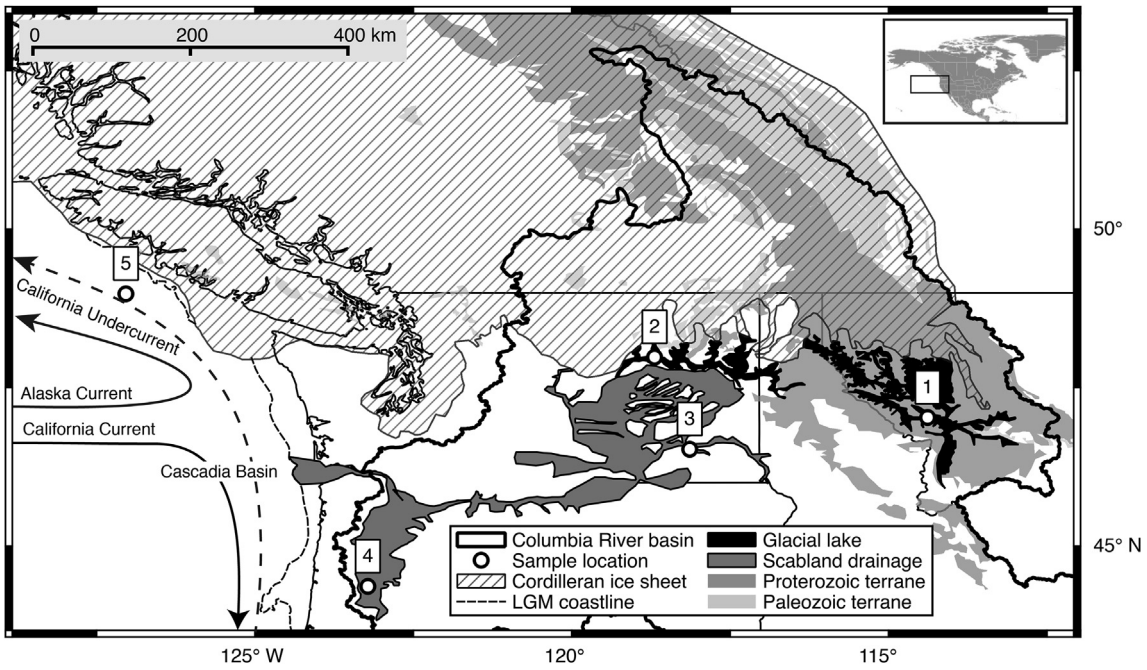

Fig. 1. Map of the study area showing the maximum extent of the Cordilleran Ice Sheet, the LGM coastline, glacial lakes Missoula and Columbia, the Scabland Flood drainage, schematic surface (solid lines) and subsurface (dotted line) currents, and sample locations. Locations are (1) Ninemile section of glacial Lake Missoula, (2) French John's section of glacial Lake Columbia, (3) Tucannon River valley, (4) Irish Bend section of the Willamette Valley, and (5) MD02-2496 Map adapted from Hendy (2009).

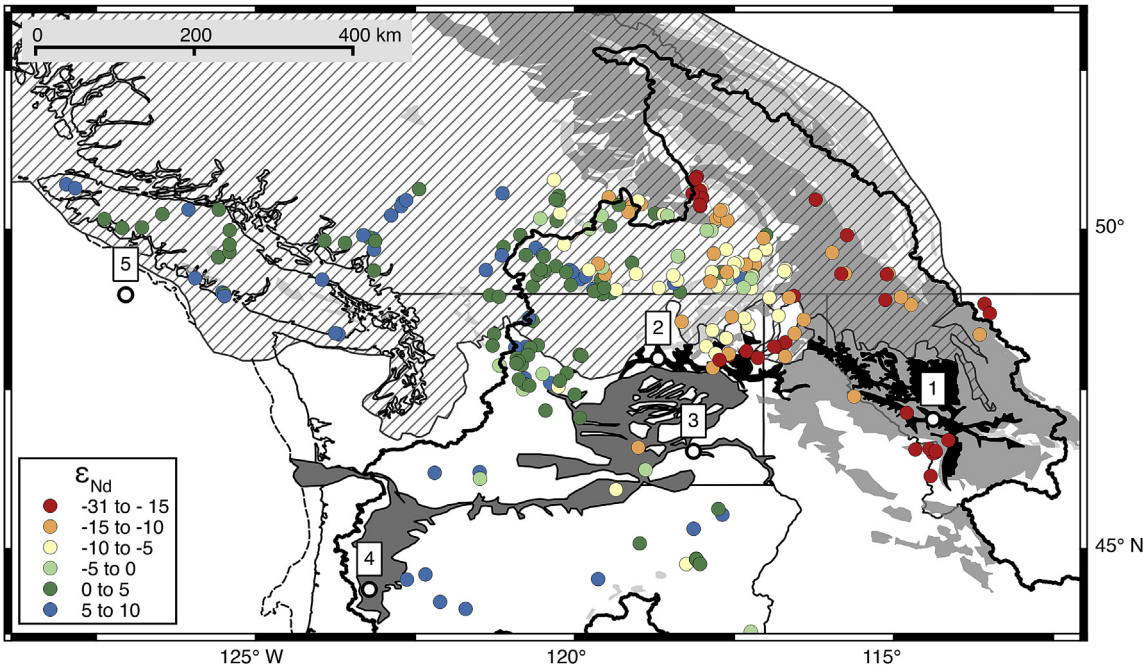

Fig. 2. Summary map of regional neodymium isotope geochemistry from bedrock measurements (Andrew et al., 1991; Carlson et al., 1981; Cui and Russell, 1995; Frost and Winston, 1987; Ghosh, 1995; Halliday et al., 1983; Hart, 1985; Jicha et al., 2009; Matzel et al., 2008; Mueller et al., 1995; Parkinson, 1991; Schwartz et al., 2010; Schmidt et al., 2008; Unterschutz et al., 2002; Whitehouse et al., 1992), with the Columbia River drainage basin outlined in heavy black line.

isotopic mapping of bedrock (Figs. 1–4), they match Scabland Flood slackwater deposits, establishing an isotopic link between coeval glacial megaflood deposits in the Scabland Flood drainage and in MD02-2496.

2. Regional setting

Chemical, isotopic, and sedimentological data from piston core MD02-2496 (38.35 m long; 48°58.47′ N, 127°02.14′ W; 1243 m water depth, Fig. 1) record patterns of glacial, oceanographic, and