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Geology of the Okanogan Lobe Does Not Support Subglacial Catastrophic Flooding from Beneath the Cordilleran Ice Sheet

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The Okanogan lobe (OL) of the Cordilleran ice sheet (CIS) extended south from interior British Columbia in Canada to the subaerial, megaflood-scoured channeled scablands of Bretz (1923) in eastern Washington state. The drumlins and large, overdeepened valleys of the OL have been attributed to glaciofluvial processes that include at least one catastrophic megaflood, or underburst (e.g. Shaw et al., 1999; Lesemann and Brennand, 2009). If correct, the underburst hypothesis would have the OL provide another source, besides glacial Lake Missoula (GLM), for channeled scablands megaflooding. However, the geomorphology and sedimentology of the OL and the channeled scablands to its south appear to rule out megaflood-scale ($\geq 10^6$ m^3/s) underbursts.

Underburst theory posits large subglacial lakes in the deepest valleys of the OL, overlain by relatively thin ice shelves. The largest, the Okanogan Valley, runs north-south 250 km across the US-Canada border, has bedrock-floored basins eroded to up to 650 m below sea level (Eyles et al., 1991), and sediment fill to terrace surfaces 380-420 m above sea level. Advance outwash overlain by till is exposed locally in valley walls, marking the arrival of the ice sheet. Glacial striations on bedrock at or near lowest current exposure elevations show thick glacial ice in the valleys. The last stage of the OL consisted of thick ice in the main valleys. A set of kame terraces deposited between ice and valley walls forms a composite "Great Terrace" 200 km along the sides of the Okanogan and Columbia River valleys, pocked by kettles, with local ice-contact-disturbed bedding. Ice-marginal, side-stream channels were eroded into bedrock adjacent to the Okanogan, Methow, and Columbia River valleys while the main valleys remained choked with last-stage glacial ice. Lacustrine beds in the Great Terrace, deposited in short-lived proglacial lakes, are interbedded with outwash and alluvial fans. A particularly thick, extensive sequence of lacustrine beds, including probable varves, extends for over 100 km along the British Columbia Okanagan Valley and was deposited in a large proglacial lake. In sum, the evidence supports the earlier model (e.g. Clague and Eyles, 1993) that the ice sheet was thickest along the main valley axes and the lacustrine beds in the region formed in proglacial lakes.

In contrast to the channeled scablands to the south, in the OL region there are no major features that can be uniquely attributed to turbulent megafloods – no pendant bars, boulder lags strewn at high levels on outer channel walls, fosses, or potholes, as others have pointed out (e.g. Waitt, 2016).

Underbursts from the interior CIS, passing beneath and discharging from the OL, would deposit large volumes of sediment. However, studies of sediment provenance in megaflood deposits of the channeled scablands have found no significant volume of sediment from the OL; instead, the major source of megaflood sediments in the channeled scablands was GLM, which was surrounded by uniquely identifiable Proterozoic metasedimentary lithologies. Glacial Lake Columbia was a large proglacial lake along the southeastern margin of the OL, into which large volumes of sediment were deposited. A recent provenance, sedimentary facies, and current-direction analysis (Nelson & Clague, 2016) finds that sediment within glacial Lake Columbia was deposited by megafloods from GLM, not from the OL, confirming the most detailed preceding study (Atwater, 1986).

If the evidence across the area covered by the OL and adjacent channeled scablands rules out megaflood-scale underbursts, the subglacial landforms of the CIS, including the drumlins and the overdeepened valleys, must have other causes. Smaller-scale than whole-valley volumes of subglacial water trapped beneath the ice sheet in the overdeepened valleys, and smaller than megaflood-scale glaciofluvial discharges, may have been involved in eroding the largest valleys, including the Okanogan Valley. As for the origin of the drumlins, which have cores that vary from till, to outwash $\pm$ lacustrine beds (commonly topped by till), to bedrock, the evidence outlined here suggests they formed beneath the ice sheet, with water in the interface important in the process, but not in the form of subglacial megafloods.