The Channeled Scabland: Back to Bretz?

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ABSTRACT

The Channeled Scabland, Washington State, United States, is only partly the result of erosion by the catastrophic drainage of Glacial Lake Missoula: there were other sources of meltwater. Recent sedimentary investigations of some sites in the Missoula basin, and in the Channeled Scabland, support a single large late Wisconsin flood, as opposed to multiple floods proposed for this time period. Sediment in the Glacial Lake Missoula basin records rapid infill by jökulhlaups draining into Lake Missoula from upstream, punctuating a long period of normal varve sedimentation. This was independent of sedimentation in the main Scabland tract, where proximal and distal rhythmic beds are explained as resulting from multiple pulses, or surges, within a single flood. Geomorphic and sedimentary evidence supports the conclusion that drainage from the Cordilleran trunk valleys was important, and pulses were probably related to the drainage of these valleys.

INTRODUCTION

Current explanations of the Channeled Scabland of the northwestern United States conclude that it was formed by multiple, discrete outbursts from Glacial Lake Missoula (Waitt, 1980, 1984, 1985a, 1985b; Atwater, 1984, 1987; Clarke et al., 1984; Craig, 1987). Each flood was separated by decades or centuries. Bretz (1969, p. 540) and Baker and Bunker (1985) suggested other potential sources of water in the northern Cascades and the Okanagan Valley, and also that a small number of floods created the Scabland. This paper expands on these suggestions.

The multiple flood Glacial Lake Missoula hypothesis is based on two assumptions: (1) Lake Missoula was the only water source for the Scabland floods; and (2) the Purcell lobe ice dam collapsed completely during each drainage event and then reestablished, resulting in lake refilling over decades or even centuries. Some researchers therefore propose that rhythmites in the Glacial Lake Missoula basin can be correlated with distal rhythmites in the Channeled Scabland in southern Washington: each bed represents a separate catastrophic expulsion from Glacial Lake Missoula (e.g., Waitt, 1980, 1984, 1985a). We present evidence that suggests that only one major late Wisconsin flood is recorded in the sedimentary record, and that sedimentation within the Glacial Lake Missoula basin was independent of sedimentation in the Channeled Scabland. In addition, geomorphology and sedimentology strongly support the view that there was more than one source of water for this Scabland flood.

SEDIMENTS ASSOCIATED WITH THE SCABLAND FLOOD

Four exposures, documenting different aspects of the Scabland flood, are discussed in this paper (Fig. 1). The sites are well documented by previous researchers and are central to the debate of multiple versus single floods. These are the Ninemile Creek section in the Glacial Lake Missoula basin; the Sage Trig section in the western Glacial Lake Columbia basin; the Starbuck section within the Tucannon Valley, east of the main Scabland tract, but proximal to it; and the Burlingame Canyon section in the Walla Walla valley, to the east of the main Scabland tract, but relatively distal to it.

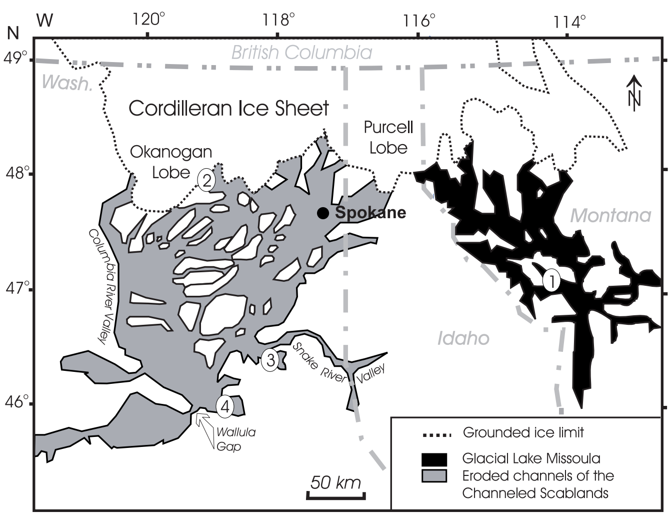

Figure 1. Location map of study area. All sites discussed in text are indicated by their site number: 1, Ninemile Creek; 2, Sage Trig; 3, Starbuck; 4, Burlingame Canyon.

Ninemile Creek Section

Rhythmic sequences at the Ninemile Creek section consist of a thick homogeneous silt bed overlain by a thick clay, alternating with packages of thin silt and clay varves (Fig. 2). Chambers (1984, discussed by Baker and Bunker, 1985) argued that thick silt beds represent the refilling of Glacial Lake Missoula after catastrophic drainage events. Waitt (1980, 1984, 1985a) followed Chambers and suggested that the varves represent lacustrine sedimentation between drainage events and that 40 rhythmic sequences represent 40 floods.

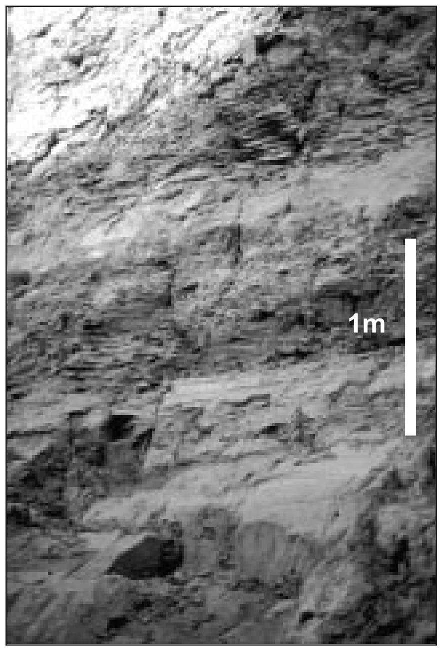

Figure 2. Varved lake sediments interbedded with thick silt beds at Ninemile Creek. Each silt bed is ~30 cm thick.

We interpret the thick silt bed to represent rapid sedimentation causing dish, pillar, and ball and pillow structures (cf. Lowe and LoPiccollo, 1974; McBride et al., 1975; Rust and Romanelli, 1975; Ashley et al., 1982). Turbidity currents generated by jökulhlaups from beneath the Rocky Mountain trench glacier to the north best explain these deposits (cf. Shaw and Archer, 1979). Such drainage events would have punctuated normal varve sedimentation. This interpretation is supported by the thick clay bed above each silt: the thick clay records extremely high sediment input during the jökulhlaup.

Sage Trig Section

Sediments in the Sanpoil arm area (Fig. 1) are interpreted as back-flooding deposits related to drainage events from Glacial Lake Missoula (cf. Atwater, 1984, 1986, 1987). Atwater (1984) suggested at least 15 Missoula flood events for the Sanpoil arm. He interpreted rhythmic beds as varves and noted sand at the base of many sequences with downvalley paleocurrents, indicating discharges from the Sanpoil sublobe to the north. Basaltic clasts, which should occur in the Sanpoil arm with flooding from Glacial Lake Missoula, are absent. We suggest that powerful flows from the north were responsible for sand and gravel cross-beds, diapiric injections of silts and clays into overlying gravelly sands, silt and clay rip-up clasts, and soft-sediment-deformation structures at Sage Trig.

Starbuck Section

The Starbuck section (Fig. 1) (Tucannon 3 of Smith, 1993) is in an area of back-flooding upstream from Wallula Gap (Baker, 1978). Rhythmic sequences fine upward, and rhythmites thin upward (2 m at the base, to ~20 cm near the top) (Fig. 3). Each rhythmite has the sequence: (1) unit A, poorly sorted angular to subangular, predominantly basaltic, cobbles and boulders, with multimodal finer components; (2) unit B, moderately sorted, granular cross-bedding with multiple normal and reverse graded cross-strata (paleoflows record flow both up and down valley, usually within the same rhythmite); and (3) unit C, thin (<40 cm) parallel-bedded fine sand and silt, and, rarely, clay. Unit C was deposited mainly from suspension, although ripple drift cross-lamination indicates some bedload transport. Smith (1993) interpreted massive silt in unit C as the result of bioturbation (insect and rodent burrows). Hence he assumed that these beds had been subaerially exposed. However, the massive beds gradationally overlie laminated beds and are as easily explained by suspension settling. The few burrow casts that he noted may be modern, because networks extending from paleosurfaces are not observed. Dating organic matter in the burrows would resolve the age. Smith (1993) also observed clastic dikes, composed of relatively well sorted gravel, crosscutting the section. Although he reported that most of these dikes were filled from above, we observed dikes extending upward from gravel beds, following horizontal bedding planes, and diverting around large boulders. Banding in the dikes extends upward from in situ beds. Our interpretation of the significance of these dikes is discussed for the Burlingame Canyon section.

Paleoflows from unit B in each rhythmite indicate powerful flows that first surged up the Tucannon Valley, and then swept back toward Wallula Gap. The size and angularity of the clasts and the relatively poor sorting suggest erosion, transport, and deposition of locally derived basalts by hyperconcentrated flows. Abrupt changes in grain size and stratification (unit C) illustrate rapid flow deceleration (Fig. 3). The absence of clay beds at the top of each sequence suggests that sufficient turbulence maintained clay in suspension. The absence of desiccation cracks, rilling, eolian deposits, and paleosols indicates the unlikelihood of subaerial exposure between depositional events. Load casts formed by loading of unit C by overlying unit A show that the silts were underconsolidated and had not been subaerially exposed prior to the deposition of the subsequent rhythmite (Baker, 1973).

Burlingame Canyon Section

About 60 m of rhythmically bedded sand and silt (Touchet beds of Flint, 1938) at Burlingame Canyon (Figs. 1 and 4) have been explained as flood surge deposits (Bretz et al., 1956; Baker, 1973; Carson et al., 1978; Bjornstad, 1980; Baker and Bunker, 1985). Waitt (1985a), however, suggested that each bed records a separate Glacial Lake Missoula drainage event, followed by decades or centuries of subaerial exposure.

There are ~40 bedded rhythmic sequences at Burlingame Canyon, each ~10 cm to ~2 m thick (Fig. 4). Each sequence is composed of: (1) unit A, plane-bedded coarse sand and granules; (2) unit B, fining-upward ripple drift cross-lamination with low-angle climbing ripples at the base increasing in angle of climb to sinusoidal lamination; and (3) unit C, massive silt (Fig. 5). Theory and experiment show that the climbing-ripple drift components accreted in a matter of hours (Allen, 1982; Ashley et al., 1982).

Waitt (1980) argued strongly for subaerial exposure following deposition of each rhythmite. In particular, he stressed that the Mount St. Helens

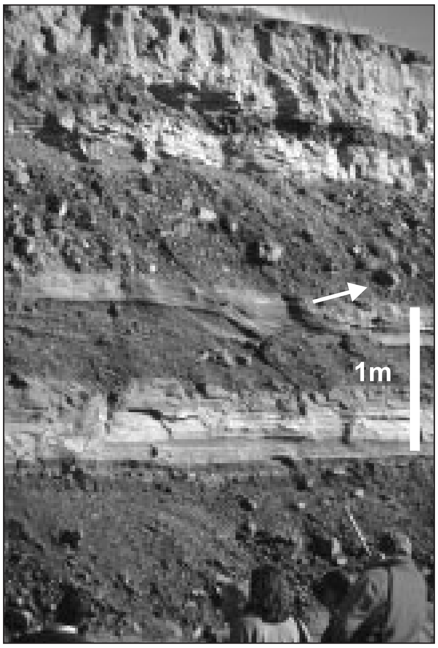

Figure 3. At least 10 fining-upward rhythmites at Starbuck. Bases of some rhythmites are dominated by angular cobbles (arrow), which give way to thick beds of silt.

Figure 4. Clastic dike through rhythmites at Burlingame Canyon. Light colored sediment in dike is composed of silts, and darker material is coarse sand and granules.

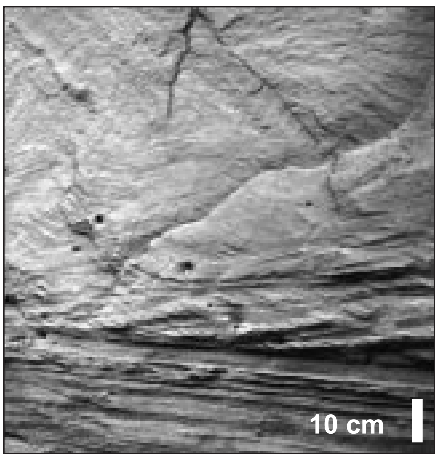

Figure 5. Rhythmite at Burlingame Canyon showing planar laminated granules that grade into climbing ripple sequence. Photo shows ~60 cm (vertically) of sediment.

set-S tephra couplet within unit C of one rhythmite (Waitt, 1980, Fig. 11) must have been deposited subaerially. By extension, he suggested that all unit C beds are eolian. Waitt's (1980) photographs of the ash show dark silt and sand layers intercalated with the lighter ash, suggesting simultaneous deposition of the ash and suspension deposits. Massive silt in unit C certainly resemble loess, yet gradational relationships with climbing-ripple cross-lamination and their regular position, with respect to aqueous deposits as part of a fining-upward sequence, suggest aqueous deposition. We conclude that the ash was deposited from a water column subsequent to air fall.

Minor scours (maximum 80 cm deep) are confined to the basal units of the Burlingame Canyon section, and are noted as evidence of subaerial exposure (Waitt, 1980). However, similar scours also relate to local erosion by underflows (e.g., Rust and Romanelli, 1975). As for the Starbuck section, extensive rilling and channelization, desiccation cracks, eolian sediments, and paleosols are conspicuously absent, making subaerial exposure unlikely.

Clastic dikes contain bands of sand and silt that connect downward and upward to undeformed units in rhythmic sequences. The dikes cut vertically across numerous beds, and many crosscut the entire sedimentary sequence (Fig. 4). The dikes imply the following conditions: (1) pore-water pressures at their point of origin must have been temporarily in excess of lithostatic pressures to allow eruption (Allen, 1982); (2) those cross-cutting the entire succession must have formed after deposition of the entire sequence; and (3) pore-water pressures increase with depth. Sudden lake drainage of dammed waters would have decreased pressure at the lake bed, while the ground-water head at depth in the sediment remained high. An explosive situation ensued and pressure was released as water escaped mainly by lateral flow in sand and gravel toward dikes that carried water and sediment to the surface.

Arguments for multiple floods, with long interludes of subaerial exposure, are contradicted by the sedimentary evidence at this site.

MULTIPLE SOURCE ALTERNATIVE

The source of the Scablands floodwater is evidently crucial to the reservoir volume and flow duration. The geographical distribution of Scabland tracts provides the most direct approach to this question. The Cheney-Palouse Scabland floods were clearly connected to drainage from the north and east, including Glacial Lake Missoula (Fig. 6). This connection is supported by giant ripples and sediments within and outside the former limits of the lake (e.g., Bretz, 1969). By contrast, paleoflow directions and clast provenance in the Sanpoil arm indicate flow from the north, which is difficult to ascribe to drainage of Glacial Lake Missoula. It is also difficult to explain the huge discharges and the magnitude of erosion along the Grand Coulee and the Columbia River valley downstream from the Grand Coulee Dam in terms of outflow from Glacial Lake Missoula about 200 km to the east (Fig. 6). No such difficulties arise if the western Scablands were scoured by outbursts from the ice sheet in the interior of British Columbia (Fig. 6).

Drainage from the interior of British Columbia, by way of deeply incised tunnel channels, is supported by drilling and seismic evidence. Vanderburgh and Roberts (1996) reported coarse gravels on bedrock eroded below sea level. They suggested that extremely powerful subglacial drainage was responsible for this sequence. Eyles et al. (1990) also suggested rapid subaqueous sedimentation fed by meltwater in the Okanagan Valley. Such high-magnitude drainage must have passed down the Okanagan Valley and extended across the western Scablands (Fig. 6).

Benches along the sides of the Okanagan Valley are strongly drumlinized and channelized by erosion of bedrock and surficial sediment (Toutin, 1993). Drumlins and channels are also cut into the high plateau interfluves between anabranching trunk valleys in interior British Columbia (Prest et al., 1968; Clague, 1985). These drumlins are cored by both bedrock and surficial sediment. Shaw (1994) explained hairpin furrows that wrap around the stoss end of such drumlins as products of horseshoe vortices created by obstacles, the residual drumlins, submerged in broad flows. These high Reynolds number flows were powerful enough to remove boulders contained in tills and to erode streamlined forms in crystalline igneous rocks (Shaw, 1996). Other explanations of streamlined forms, e.g., bed deformation (Boulton, 1987; Hart, 1997), fail to account for hairpin furrows or drumlins cut into crystalline bedrock.

Continuing our reasoning, the deep valleys, adjacent benches, and extensive plateaus of interior British Columbia were partly eroded by subglacial meltwater that submerged all but the highest ridges. This inference may be used to account for the broader, regional landscape evolution. Whereas we consider this inference to be a reasonable assumption based on field and experimental evidence, we make no claim that it is an absolute truth. Our reasoning brings us to the conclusion that the Scabland floods might have partially originated from an enormous subglacial reservoir that extended over much of central British Columbia (Fig. 6). Using conservative estimates for the depth and area of this reservoir, the total volume is estimated to have been on the order 10^5 km^3, far exceeding the 2×10^3 km^3 estimated volume of Glacial Lake Missoula. The geomorphological reasoning for a large reservoir supports the geographical arguments for multiple sources. Although meltwater was mainly from surface melt, evidence suggests that subglacial

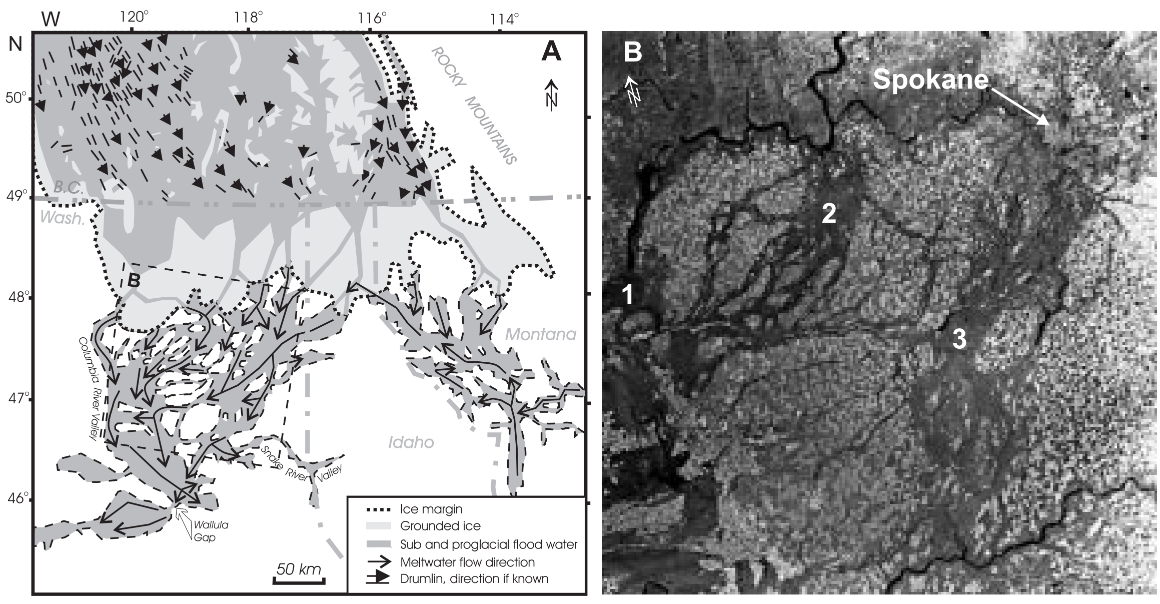

Figure 6. A: Reconstruction of subglacial reservoirs and proglacial routing of water. B: Landsat image 1039 181413 showing anabranching channels of Scabland. Dark zones are result of incision into Tertiary Columbia basalt. Lighter zones are upstanding residuals. Three main channel systems are observed: 1, Grand Coulee; 2, Telford–Crab Creek Scabland; 3, Cheney-Palouse Scabland.

volcanoes may have contributed large volumes of water to subglacial reservoirs (Hickson et al., 1995). In addition, some of the volcanic rocks appear to have erupted into subglacial reservoirs. Consequently, our hypothesis of multiple sources for the Scablands floods is an attractive alternative to the hypothesis that Glacial Lake Missoula was the single source. The increased flow volume adds to the credibility of a single flood for the sedimentary sequences we discuss. Of course, our hypothesis does not hold that Scabland erosion resulted from just one flood; depositional sequences in the Astoria fan off the Columbia River mouth probably record multiple floods.

CONCLUSIONS

Our interpretation of some sediments within the Glacial Lake Missoula basin suggests that they formed independent of sedimentation of the Touchet beds in southern Washington State. We believe that deposits at the Ninemile section represent hundreds of years of normal lake sedimentation in Glacial Lake Missoula and that the thick silt beds record episodic jökulhlaups from upstream glaciers. In contrast, the Sage Trig, Starbuck, and Burlingame Canyon deposits, located downstream from ice dams, are well explained by sedimentation in backwater deposits during a single flood with multiple pulses fed by meltwater from the Cordilleran ice sheet. We therefore follow Bretz (1925, 1969) and Baker and Bunker (1985) in their preference for one, or a few, rather than many floods. Critical supporting evidence must lie in the deposits of the Astoria fan at the mouth of the Columbia River and the abyssal plains of the Pacific Ocean.

The total reservoir volume that eventually drained through the Scabland is estimated to have been on the order of 10^5 km^3. Assuming that the discharge estimates of about 10^6 m^3/s at Wallula Gap (Baker, 1978; O'Conner and Baker, 1992) are correct, this stored volume would have sustained such discharges for a period of about 100 days.

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