Title: A case for repeated outburst floods for the creation of the Channeled Scablands: Observations and interpretations

Author: Kerry J. Cupit

Location:

Simon Fraser University

8888 University Drive

Burnaby, B.C.

Canada V5A 1S6

Contact email: kcupit@sfu.ca

Contact address:

10543 170A Street

Surrey, B.C.

Canada V4N 5H8

Running title: Channeled scablands: observations and interpretations

Keywords: outburst flood, missoula, cordilleran ice sheet, quaternary, scablands, washington

Date submitted: April 17, 2008

(A) Introduction

The channeled scablands in central-eastern Washington state earns its name from its characteristic broken, patchy and eroded appearance, which coincidentally has been the source of controversy in quaternary geology circles since the 1920s. Features are observed in the scablands that are absent elsewhere on the planet while other features are on scales that defy traditional thinking. A number of theories regarding the creation of the scablands have persisted in recent history ranging from meandering and flooding of the nearby Columbia River to repeated inundation from outburst floods of glacial Lake Missoula. More recently, the latter of these has become favored among quaternary geologists. However, the theory is not without contention. When Bretz first proposed it in 1923 it took many decades for his proposal to gain acceptance (Wikipedia contributors 2008). Since it was first proposed, careful analysis of field exposures and aerial photographs by numerous geologists, including Bretz's original work, have given credence to the idea that multiple floodwaters larger than those ever recorded in modern time are responsible for the appearance of the channeled scablands today. Through numerous field investigations in the channeled scablands conducted as part of a quaternary geology class at Simon Fraser University, evidence was collected that generally reinforces the now-accepted glacial outburst theory for the creation of the scablands. Observed features indicating flowing water, ponded water and late-stage drainage and whether or not sediments were subaerially exposed are discussed, with attention paid to the processes required to produce the observed geological responses.

(B) Background

The predominant bedrock of much of central-eastern Washington is the Columbia River Basalts (Fig. 1). These continental flood basalts were extruded during the Miocene from fissures tens of kilometres long which inundated the land with 10-30 km^3 flows, on average (Clague 2008). Covering as much as 40 000 km^2, flows typically ponded in valleys and depressions forming the topography of the preglacial scablands. While the number of flows is outside the scope of this study, locations were visited where up to 10 flows could be counted.

Each flow can be readily identified and divided into two distinct zones owing to how flood basalts cool: the entablature and the colonnade (Fig. 2). The gradual cooling of the lowermost portion of a basalt flow results in a characteristic columnar jointing pattern referred to as the colonnade, where parallel joints form normal to the base of the flow (American Geological Institute 2008). The entablature is in sharp contact atop the colonnade and consists of many smaller columns at a variety of sub-parallel orientations reflecting shorter cooling times (Clague 2008). Due to the complexity of the joints in the entablature, rocks from this section are easily fragmented into fist-sized pieces (Clague 2008).

Atop the Columbia River Basalts are relatively thin layers of loess. These layers are a boon to agriculture in the area (J. Clague, personal communication, 2008), since little soil development occurs otherwise.

During the last major glaciation, the Cordilleran Ice Sheet extended to the northernmost reaches of the scablands (Fig. 3) (Clague 2008). There is strong evidence for the existence of two glacially dammed lakes during this time, namely glacial Lake Missoula and glacial Lake Columbia (Clague 2008; J. Clague, personal communication, 2008). Research suggests that the Purcell lobe of the Cordilleran Ice Sheet was responsible for damming Lake Missoula, and at a lower altitude the larger Okanogan lobe for damming Lake Columbia (Clague 2008; J. Clague, personal communication, 2008).

(C) Flowing water

(i) Dry falls

At the head of the Grand Coulee is an escarpment 5.6 km long and over a hundred metres tall known as the Dry Falls, referring to the fact that no water currently flows over what once appears to have been a very large waterfall (Fig. 4). Features such as a plunge pool and directional fluvial landforms visible on topographic maps of the area suggest that water once flowed here in large volumes. Channeled fluvial landforms adjacent to the Grand Coulee occur downstream at an elevation similar to that of the top of the Dry Falls, suggesting that water levels in the area may have well surpassed the height of the Dry Falls so as to completely infill and overflow the coulee.

Abundant boulders rest on the valley bottom downstream from the Dry Falls (Fig. 5). Since glaciation is known to not have advanced this far (Clague 2008; J. Clague, personal communication, 2008), glaciers cannot be looked upon as a suitable primary transport mechanism. However, fluvial entrainment of these boulders may be responsible for their deposition. Some of these boulders are metres in width and would require extremely large volumes of water moving at sufficient speed to entrain them.

Research by other groups have suggested that due to the morphology of surviving landforms and the size of fluvially transported boulders downstream, water levels may as been as high as 91 m above the top of the Dry Falls, for a total peak depth of 213 m over the edge of the falls. A cursory look at maps of the area indicates there is no water pathway large enough in modern time to have created the features observed today.

Other coulees in the area, including Frenchman's Coulee, show similar plunge pool and plucking features as seen in the Grand Coulee (Fig. 6). Numerous erosional terraces alongside Frenchman's Coulee suggest that multiple events were responsible for their creation, or at least multiple stages within a single event.

(ii) Large-scale ripples

Within the Columbia River valley at Westbar, a number of rolling terraces are exposed on a raised plain adjacent to the modern Columbia River floodplain (Fig. 7). These features are roughly 9 metres tall and many metres wide. They are aligned perpendicular to the trend of the valley, and are thicker on the downstream side than the other. If these features were observed on a much smaller scale, they would likely be classified as ripple marks resulting from asymmetrical flow conditions. Indeed, if these landforms were interpreted as very large-scale ripples they would indicate a down-valley flow direction. Since they are comprised mostly of gravels too large to be transported by wind (J. Clague, personal communication, 2008), a fluvial origin is not unreasonable. However, the sheer sizes of the landforms suggest that the amount of water involved would be on a scale not normally seen, even when compared to the largest of modern floods. If there were repeated events of similar magnitude involved in the formation of the channeled scablands, these ripples would reflect the most recent significant event to have occurred.

(iii) Potholes

A number of decameter-scale potholes dot the landscape throughout the channeled scablands (Mentorn, and WGBH Educational Foundation 2005; J. Clague, personal communication, 2008), eroded into the surface of the Columbia River Basalts. A similar morphology is observed on a smaller scale when rivers flow over bedrock, where turbulence-induced downward spiraling grains are very erosive and cut bowl-shaped holes into the rock over extended periods of time. A possible explanation put forth by geologists in the early 1900s for the formation of these potholes suggest a river similar or larger in size to the Colorado River could have formed them. However, there are no landforms in the area that would suggest a river persisted for long enough time to build typical fluvial landforms like channels, bars, levees and floodplains. Additionally, while a fluvial origin of the potholes is still possible, it would require very large flow velocities and water depths. A glacial outburst flood hypothesis may account for sufficient water depths and velocities. However, modern-day potholes may be formed over hundreds to thousands of years, whereby a single glacial outburst flood likely wouldn't persist for more than a few years at most (J. Clague, personal communication, 2008). Multiple large-scale flooding events or other processes would therefore be required to explain the existence of these potholes.

(iv) Moses coulee outflow problem

One particular problem to the glacial lake outburst flood theory lies in existence of Moses Coulee, near the westernmost part of the channeled scablands. Its appearance and geomorphology is nearly identical to those of other coulees in the scablands, with the notable exception that at the point that Moses Coulee joins the Columbia River Valley, the valley floor is appreciably topographically higher than elsewhere in the coulee. The most plausible explanation is that it is merely a bar along the Columbia River. Again however, the size of the landform warrants closer investigation. Since floodwater from glacial lakes Missoula and Columbia have been traced along the margin of the Okanogan lobe (J. Clague, personal communication, 2008), it would stand to reason that as this lobe receded during deglaciation, floodwaters traveled further westward unimpeded by ice until they reached the Columbia River Valley. Glacial outburst floods traveling down this path may have deposited large amounts of sediment in areas with lower flow velocities, as might be expected at the confluence of the coulee and the Columbia River Valley. This is assuming that glacial outburst floods were still occurring during deglaciation of the Okanogan lobe, while the Purcell lobe was still intact and damming glacial Lake Missoula.

(D) Ponding and late-stage drainage

Two bedrock-controlled pathways to the southwest through which floodwaters could have flowed out of the scablands limit the possible floodwater drainage rates (Clague 2008). One of these pathways, Wallula Gap, shows evidence of both flooding events and large-scale ponding in a couple of well-exposed outcrops. Here, fifteen beds ranging from 10-50 cm thick occur in sequence atop one another, alternating between two distinct lithologies (Fig. 8). The thinner units are predominantly sand with abundant asymmetric current ripples (Fig. 9), whereas the thicker units are comprised of structureless clayey silt. The base of the sand units are undulatory and scoured, whereas the clayey silt conformably overlies the sand units. The current ripples in the sand unit imply they were deposited in higher energy and unidirectional flow conditions compared to the silt layers. Due to the lack of sedimentary structures and fine grain size, the silt beds could have formed from suspension fallout.

A number of vertical fractures crosscut the outcrops. A single-event multi-stage flood hypothesis would suggest that these could be clastic dykes formed through soft sediment deformation. However, the infilling material consists of medium-coarse sands, silts and clays, which lend evidence to the idea that these fractures may have occurred more recently and simply infilled with a variety of available sediment.

Represented at Wallula Gap is rhythmic deposition of higher-energy current-related coarse sediments interlayered with finer grain sediments likely deposited via suspension fallout. Some researchers suggest these beds were deposited in a single multi-stage flooding event with discrete surges. Others suggest each rhythmic couplet represents an individual and separate flooding event. Should the latter be true, the outcrops examined at Wallula could represent over 1000 years of accumulation versus far fewer needed for a single multi-stage flood (J. Clague, personal communication, 2008). Secular variation studies of materials at Wallula indicate that a fair number of years must have passed between the formation of the youngest and the oldest beds.

Any evidence that may indicate ponded water levels disappeared altogether between the depositions of the rhythmic couplets would be beneficial in helping determine the greater likelihood of multi-stage versus repeated single-stage flooding styles. Nonetheless, it appears that a large lake may have once existed here, within which silts and other sediments may have deposited from. Figure 10 shows the extent of this possible inundation.

A second outcrop at Wallula Gap contains two centimetre-scale beds stratigraphically higher than the top of the first outcrop (Fig. 11). They are very fine-grained tephras from Mt. St.

Helens dating from around 13 000 years ago, and geochemical analyses indicate they are indeed from two separate eruptions (J. Clague, personal communication, 2008), despite being nearly stacked atop each other in the rock record. There is infrequent burrowing in the tephras. 2-3 centimetres of loess separates the two tephra layers in some places, the loess of course being the result of subaerial processes. This is the best evidence at Wallula Gap to date that there were multiple floods over an extended period of time, with these tephras indicating the ponded body of water must have dried up before the tephras were emplaced, and before the next rhythmic couplet of clayey silt atop rippled sand was laid down.

(E) Further study

Through the use of cosmogenic nuclide dating techniques, it may be possible to date various landforms within the channeled scablands in order to better pinpoint their ages. In particular, plucked boulders in the various coulees and terraces within Frenchman's Coulee are ideal initial targets.

(F) Conclusion

From evidence observed at various stops around the channeled scablands (Table 1) as well as information gleaned from other sources, a series of glacial outburst floods is indeed a plausible explanation for the variety of features seen throughout the area. Substantial evidence by way of the Dry Falls, plucked bounders, giant ripples and potholes exist for the punctuated catastrophic release of water into the scablands, the movement of this water from the northeast to the southwest, and the ponding of floodwaters by way of lacustrine deposits downstream before they are drained through Wallula Gap. The rhythmicity of subaerially exposed beds at Wallula

Gap, coupled with a lack of typical fluvial landforms throughout the coulees strongly suggest that large, repeated floods were responsible for the creation of the modern-day channeled scablands.

Additional field studies will help elucidate detailed mechanisms and timings for individual flood events. However, much of the interpretation of events in this area are a result of research efforts on many fronts over many decades, including the extent of glacial lakes Missoula and Columbia and the persistence of the Okanogan and Purcell Trench lobes of the cordilleran ice sheet. The repeated glacial outburst flood hypothesis seems to provide a suitable process to the geologic responses we see preserved, however it is strongly subject to the refinement of research involved in piecing together a complex process that has no modern analogue.

(G) References

Clague, J. 2008. Columbia river basalts of the Columbia Plateau: selected notes on a flood-basalt province, Department of Earth Sciences, Simon Fraser University, Burnaby, British Columbia.

Mentorn, and WGBH Educational Foundation. 2005. Mystery of the Megaflood [TV programme].

Wikipedia contributors. 2008. Channeled scablands [online]. Available from http://en.wikipedia.org/wiki/Channeled_scablands [cited 11 April 2008].

American Geological Institute. 2008. Definition of "columnar jointing". [online]. Available from http://glossary.agiweb.org [cited 12 April 2008].

(H) Tables

Table 1: Significant features observed at field stops in the channeled scablands.

Stop number	Stop name	Features of interest
1	Columbia River Basalts along Moses Coulee	Columbia Plateau bedrock, coulee
2	Westbar, along the Columbia River	Large-scale ripples
3	Dry Falls Visitors Center	Boulder plucking, plunge pool
4	Along roadside, 5min drive south of Dry Falls Visitors Center	Recent lake sediments on valley wall
5	Next to Quincy Lake	Pillow basalts atop lake sediments
6	Head of Frenchman's Coulee	Plunge pool, boulder plucking
7	Ginko Petrified Forest State Park	Pillow basalts, petrified forest
8	Zilla, South of Yakima	Wallula Gap, flood drainage
9	Second outcrop at Zilla	Flood drainage, tephras and loess

(I) Figures

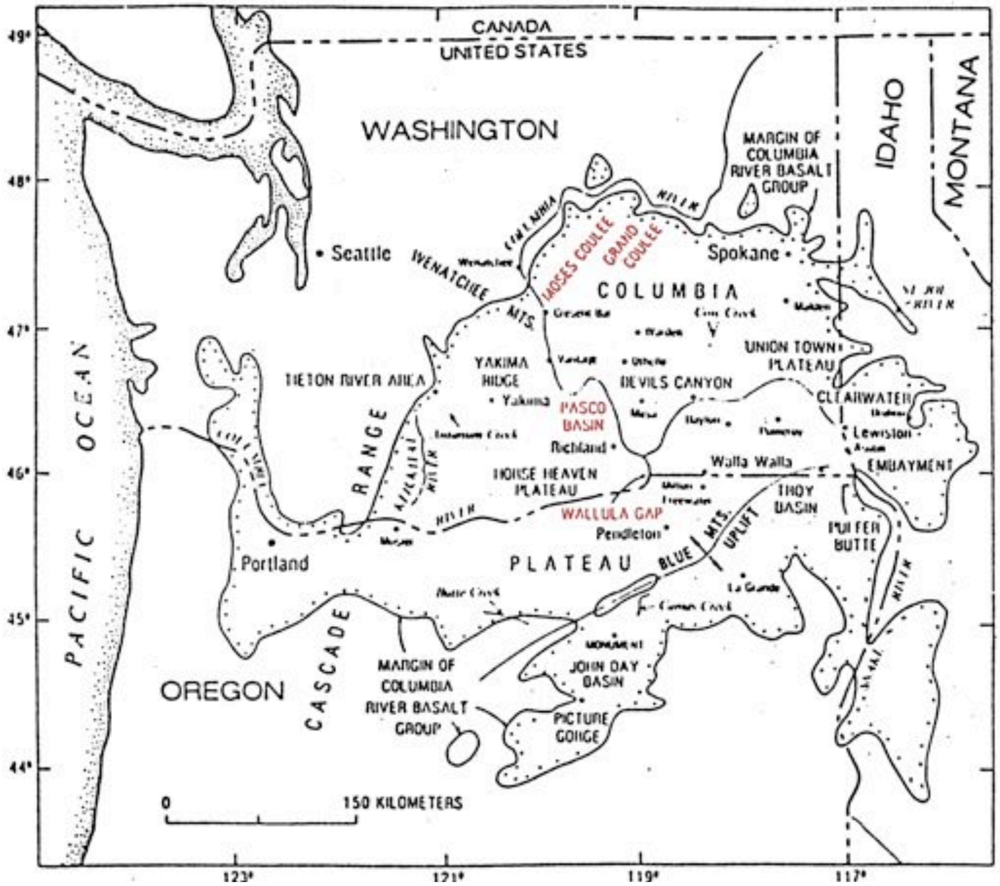
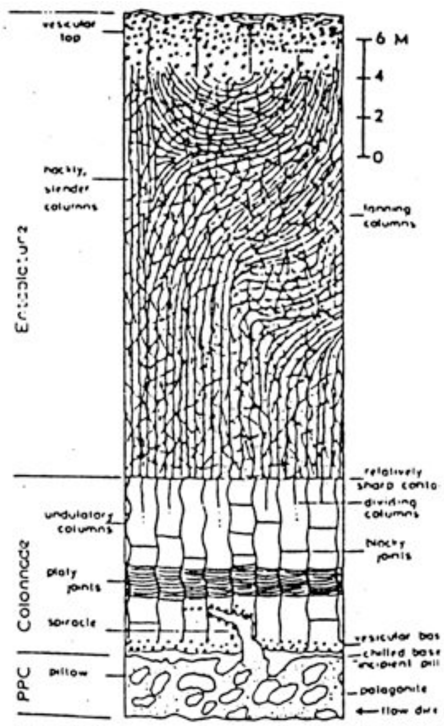


Figure 1: Map showing the extent of Columbia River Basalts in northeastern United States of America. Areas in red are discussed in the text. (Clague 2008).

(a)



(b)

Figure 2: (a) Cross section of an idealized columnar-jointed basalt (Clague 2008), and (b) as observed in multiple flows in the Columbia River Basalts of the channeled scablands.

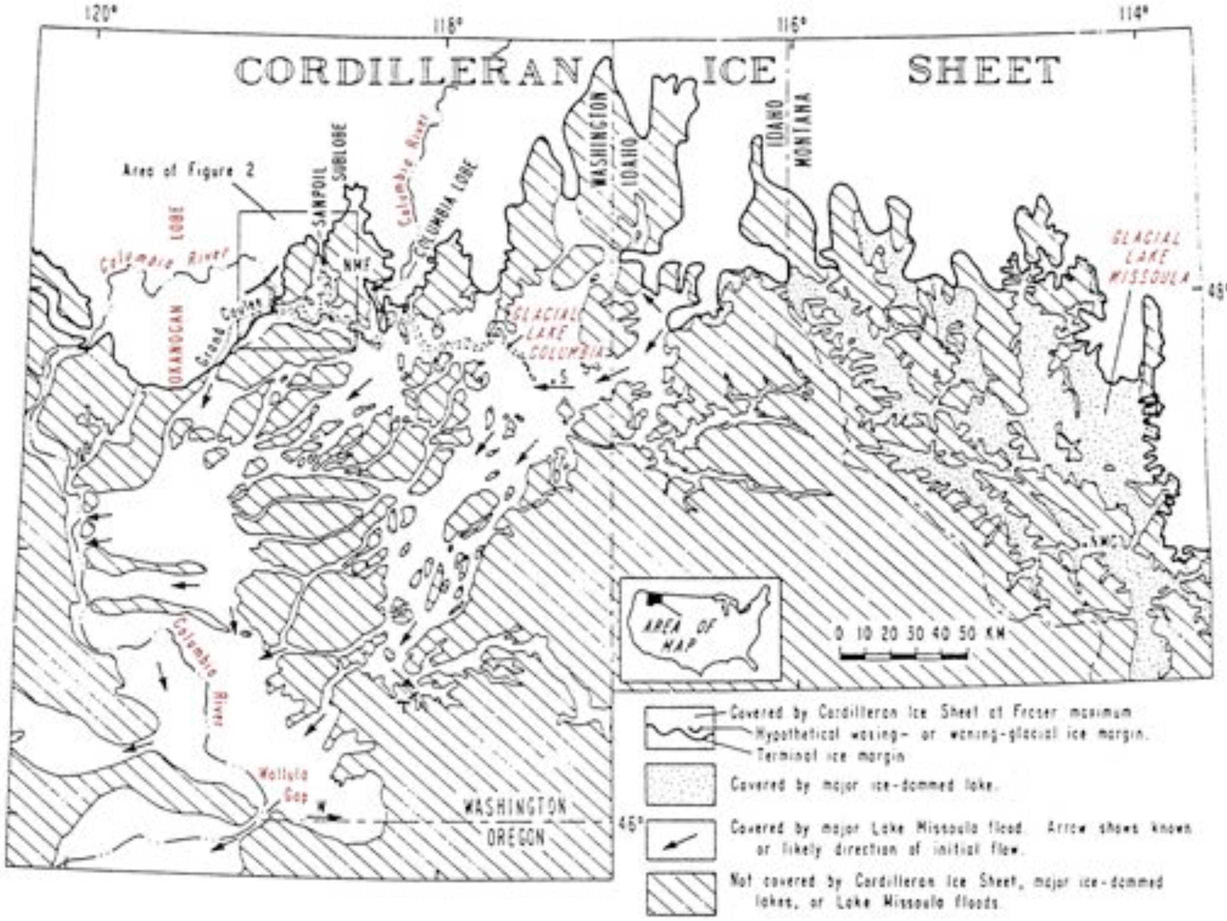


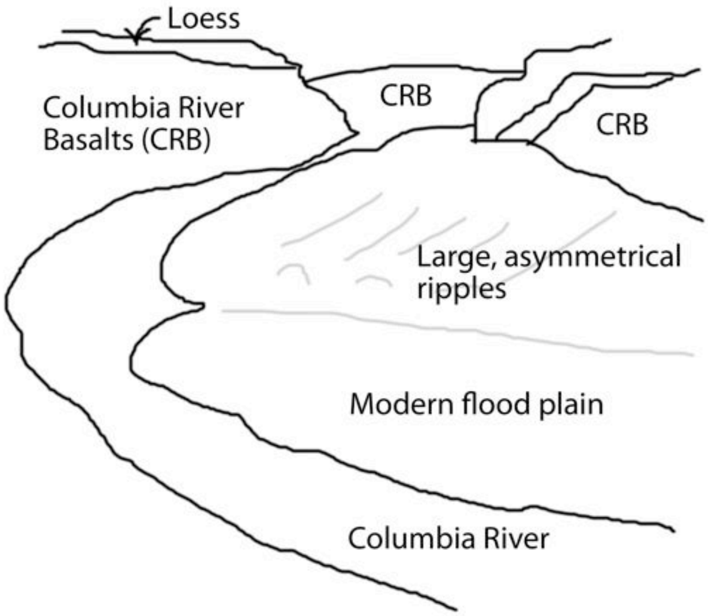
Figure 3: Extent of the cordilleran ice sheet and glacial lakes Missoula and Columbia. Text in red denotes features discussed in the text. (Clague 2008).

Figure 4: Dry Falls and water-filled plunge pool. Note boaters for scale.

Figure 5: Metre-scale boulders on the valley floor at Dry Falls, likely moved by glacial outburst floods.

Figure 6: Plunge pool at Frenchman’s Coulee in the channeled scablands.

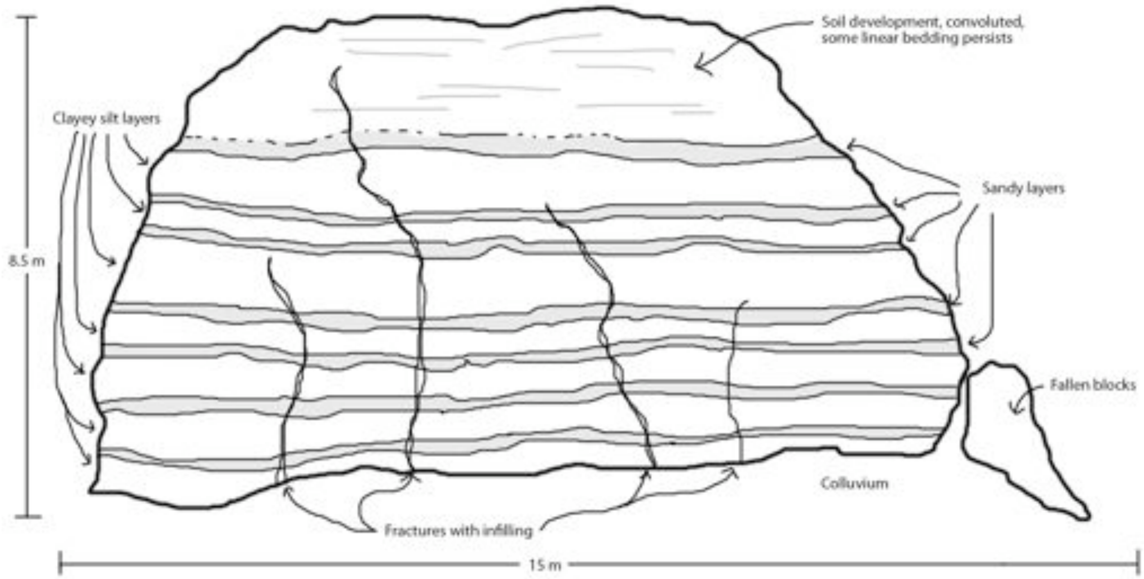
(a)



(b)

Figure 7: (a) Schematic diagram of valley morphological relationships at Westbar along the Columbia River Valley. (b) Photograph of Westbar with large asymmetrical ripples near the centre of the image, indicated by arrow.

(a)



(b)

Figure 8: Outcrop sketch (a) of first outcrop at Zilla, near Wallula Gap in the channeled scablands, and a photo (b) of the same outcrop.

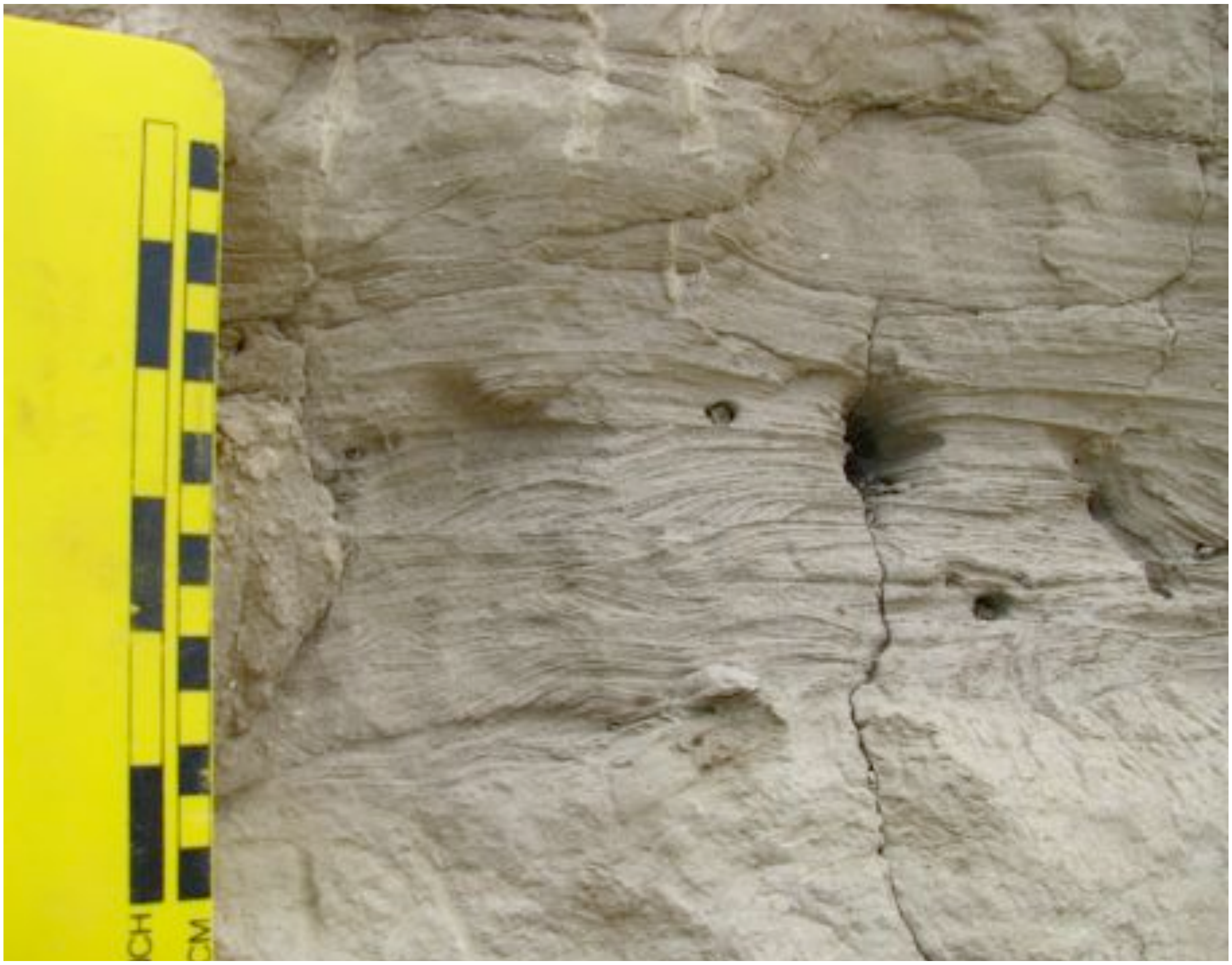


Figure 9: Asymmetrical ripples in sand layers at Wallula Gap.

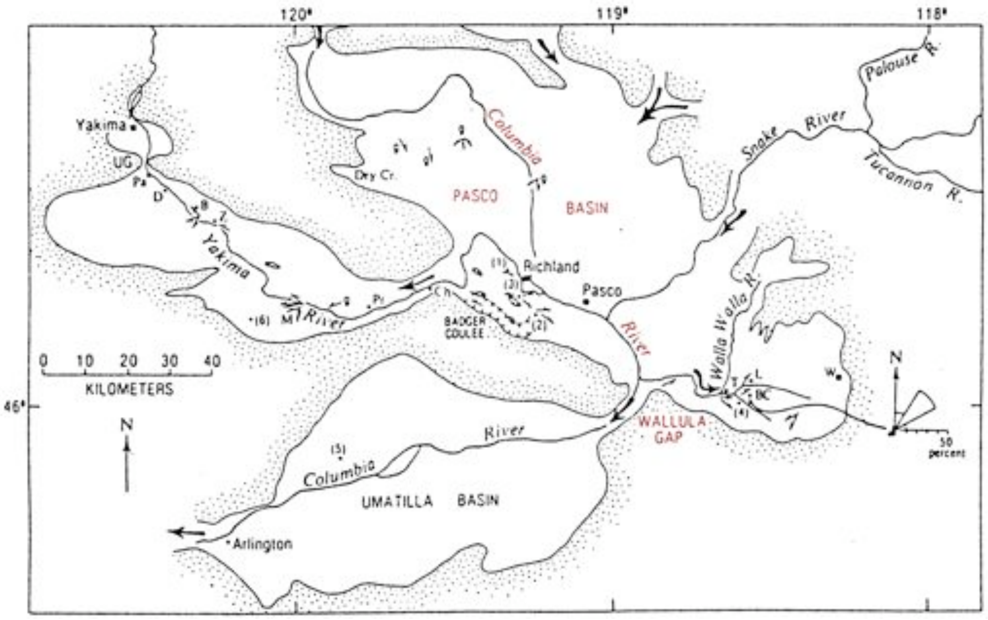


Figure 10: Extent of inundation and ponding by glacial outburst floodwaters at the southwest margin of the channeled scablands, denoted with solid and fringed lines. (Clague 2008).

Figure 11: Two tephras from two separate eruptions of Mt. St. Helens emplaced between rhythmic couplet beds at Wallula Gap in the channeled scablands. The material between the tephras is loess, and varies from 0 – 3.5cm thick.