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Evidence for Only One Gigantic Lake Missoula Flood

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EVIDENCE FOR ONLY ONE GIGANTIC LAKE MISSOULA FLOOD

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ABSTRACT
The Lake Missoula flood was rejected by scientists for 40 years because it seemed too "Biblical" in scale. After geologists carefully examined the Channeled Scabland of eastern Washington, they finally accepted that glacial Lake Missoula existed and created a gigantic flood through eastern Washington, the Columbia Gorge and the Willamette Valley of Oregon. The evidence for this flood and the controversy surrounding it will be briefly discussed. Once the idea of a gigantic flood caught on, researchers, starting with Bretz himself, thought they saw evidence for many floods. In the 1980s Richard Waitt postulated 40 floods based primarily on rhythmites from Burlingame Canyon in the Walla Walla Valley. It was the existence of a band of volcanic ash in these rhythmites that especially convinced Waitt. He was followed soon by Brian Atwater who claimed there were 89 or more floods from the Sanpoil River Valley, northeast of Grand Coulee Dam. This adds up to over 3000 years of periodic flooding near and after the peak of the last ice age. Starting in the 1990s, the number of floods has been scaled back by some researchers. John Shaw and colleagues have published evidence for only one Lake Missoula flood, coming full circle back to Bretz's original idea. The evidence for one gigantic flood is compelling and will be presented. An alternative hypothesis for the deposition of the volcanic ash band during one flood will be developed. The Lake Missoula flood can be used as an imperfect analog for the Genesis Flood, especially for the formation of water and wind gaps.

INTRODUCTION
Early in the 20th century, J Harland Bretz (1882-1981) discovered a number of unusual features of the geomorphology of eastern Washington. He was intrigued by a broad low elevation area east of the Cascade Mountains called the Columbia Basin or the Columbia Plateau (Figure 1). The surface rocks are composed of a series of basalt lava flows that were extruded from southeast Washington and northeast Oregon up to 3 kilometers deep and covering an area 164,000 km^2 [45]. On top of the basalt lava in places lie unconsolidated silt deposits that are believed to be wind blown. These deposits are called the Palouse Formation or Palouse loess. From the Columbia River eastward, the wind-blown silt and basalt has been deeply dissected into diverging and converging channels and canyons. A rough butte and basin geomorphology with overdeepened lakes and what appeared to be abandoned waterfalls, occupy some of the coulees. Bretz noticed the 80 kilometer long Grand Coulee, with what later became known as Dry Falls, dividing it. These coulees are youthful with vertical walls and hanging side valleys. Streamlined silt islands adorn many of the coulees. There are few places on Earth where such unique landforms have developed [18, p. 7]. They are called the Channeled Scabland.

Bretz observed many erratic boulders, mostly of granite, in eastern Washington and the Columbia Gorge. Granite erratics are also abundant in the Willamette Valley of western Oregon, at least 300 kilometers from their nearest source. An especially interesting large erratic is the Belleview Erratic, located about 40 kilometers southwest of Portland, Oregon [1, p. 182-183]. Before tourist chipped away pieces of this erratic, it weighed 145,000 kilograms with dimensions of 6 x 5 x 1.5 meters! Now there are only 82,000 kilograms left (Figure 2). The boulder is composed of argillite, a slightly metamorphosed shale. Argillite does not outcrop in the area and is very similar to the argillite of the Belt Supergroup that outcrops in northern Idaho and western Montana. This boulder could not have rolled into place since the slightly-toughened shale would not have survived the tumbling. The only possible mechanism of emplacement seems to be by iceberg rafting.

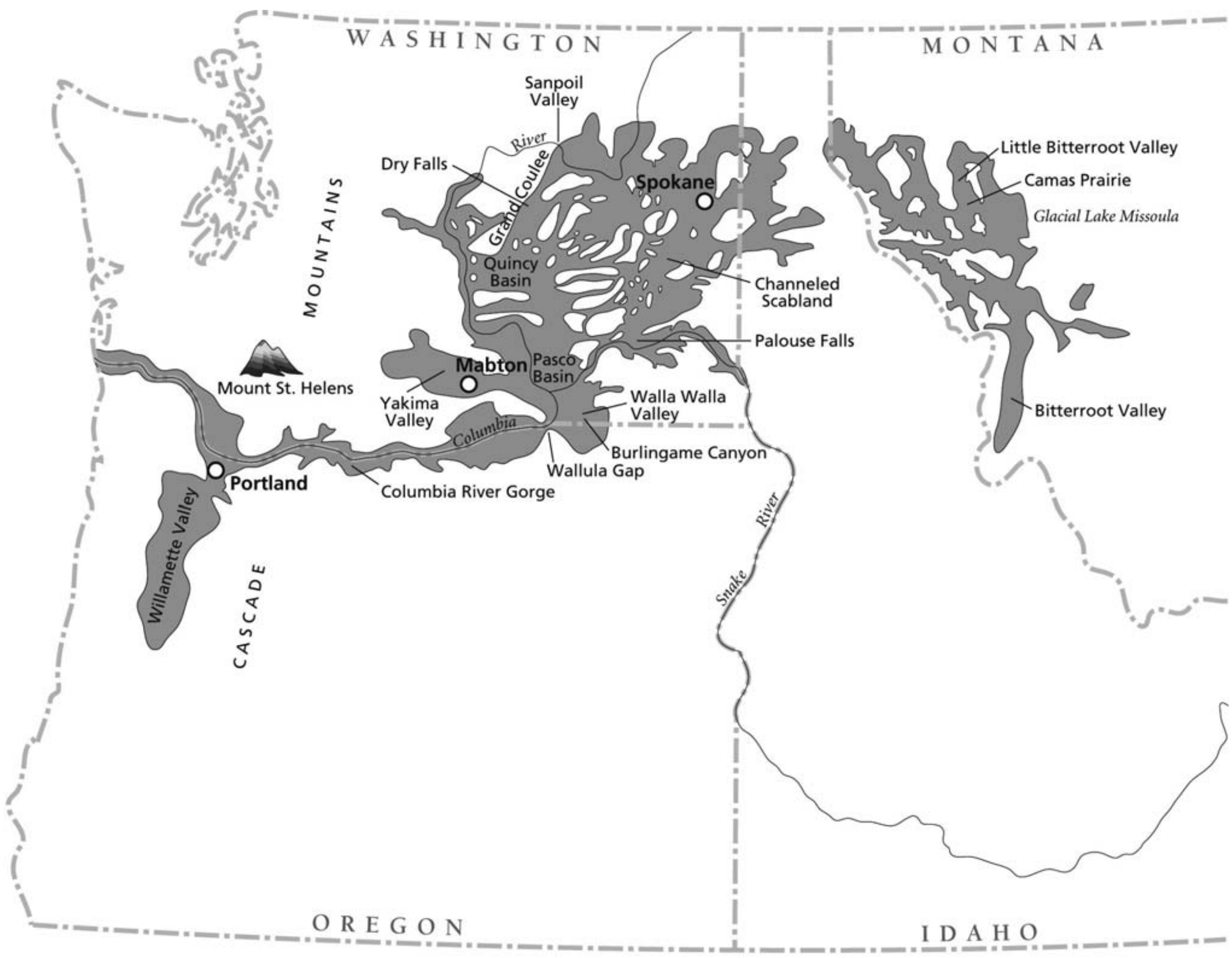

Figure 1. Map of the Channeled Scabland and glacial Lake Missoula in northwestern United States.

Figure 2. Belleview argillite erratic, 40 kilometers southwest of Portland, Oregon. Note camera case provides scale.

It was difficult for Bretz's critics to accept the idea of a flood raging down one channel, but thought it might be explained by meltwater from a shifting ice sheet or the bursting of an ice jam or even, the breaching of a nearby ice-ponded lake. However, Bretz noticed that the heads of all the scabland tracts opened up to the north or northeast at about the *same* altitude of 715 to 780 meters ASL [12,19, p. 527]. Furthermore, all four exits from the 1500 km^2 Quincy Basin developed at the *same* altitude, implying the Quincy Basin was at one time completely flooded [11]. Bretz came to the conclusion that all the tracts and other minor scabland channels must all have been flooded *at the same time*! The outline of these dark channels against the cultivated non-eroded to partially eroded light-colored silt shows up quite clearly from Landsat photos. The width of Bretz's flood, composed of diverging and converging channels, was about 160 kilometers wide, indicating a flood of huge proportions. It is no surprise that the overwhelming reaction among the geological community was one of shock and disbelief.

Not only did Bretz determine that all of the channels were filled at the same time, but he calculated the depth of flow at about one hundred meters, with the exception of narrow constrictions, such as Wallula Gap and the Columbia Gorge where it was about 245 meters deep. Bretz used *high water marks* and the altitude of huge gravel mounds as an indication of the maximum height of flooding [15-17]. Based on their location and other features of gravel mounds, he concluded the mounds were *river bars*. This meant that the flood had to be at least as high as the top of the bar. Since some of these bars were about 100 meters high, the flood had to be at least this depth - a straightforward deduction that scientists of the time rejected. Other height indicators included divide crossings and the altitude at which the erratics were found. Scientists have since refined Bretz's flood estimates. One of the latest is that the flood that roared through Spokane, Washington, was up to 150 meters deep with a discharge of at least 17 million m^3/sec [29]. At this point the Lake Missoula flood represented 15 times the combined flow of all the rivers in the world [8, p. 2]!

For about 10 years, Bretz did not know the origin of the flood water that carved the Channeled Scabland. In essence, he had suggested a sensational hypothesis, based on copious field data, *without a mechanism*. This fact in particular made the scientific community look askance at his hypothesis. Several geologists jumped on this weakness as proof there never was such a flood. But geologists of the time should have known the source of the water, because the existence of glacial Lake Missoula had been suggested before the turn of the 20th century [38]. Faint shorelines are etched on numerous hills above the city of Missoula, on the north and west facing slopes of the Bitterroot Valley south of Missoula [47, p. 27], and the Little Bitterroot Valley, 120 kilometers northwest of Missoula, Montana (Figure 3).

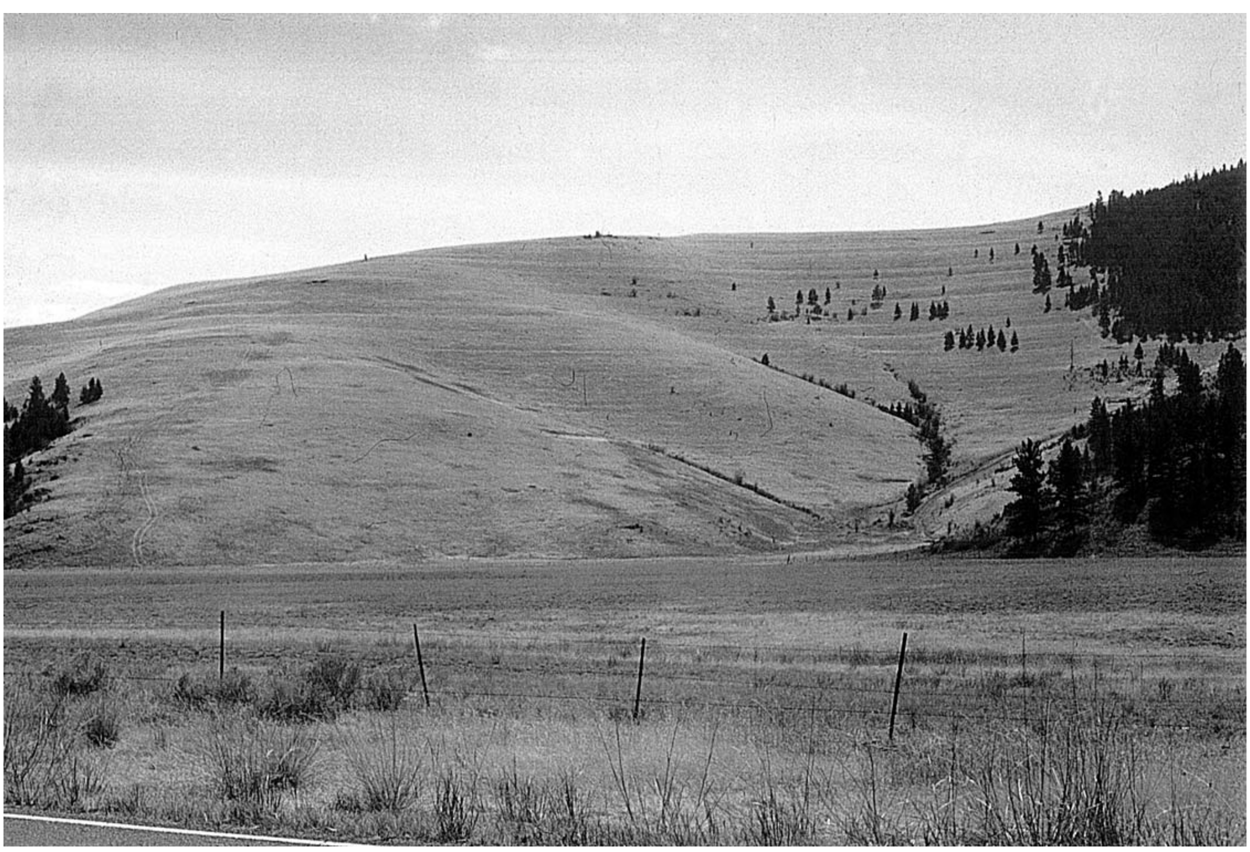

Figure 3. Shorelines of glacial Lake Missoula along the edge of the Little Bitterroot Valley, 120 kilometers northwest of Missoula, Montana.

Based on the highest shorelines, glacial Lake Missoula covered an area of about 7700 km^2 and had a volume of about 2210 km^2. The volume of water was three times the volume of Lake Erie and one half the volume of Lake Michigan. A powerful piece of evidence for the catastrophic drainage of glacial Lake Missoula is shown by the giant gravel ripple marks on the north slope of Camas Prairie, Montana. These ripple marks range from about one meter to 15 meters in amplitude and are spaced 60 to 150 meters apart [39]. The ripple marks look like linear mounds on the ground and are not too distinctive, but from the air they are obvious.

THE FLOOD OF CONTROVERSY

Today it is hard to imagine the storm of controversy that was ignited when the geological community heard of Bretz's flood. To the scientists of the day it sounded far too much like the Biblical Flood, a flood that scientists were convinced never occurred. It was not until evidence for the Lake Missoula flood became overwhelming and irrefutable that it was finally accepted. Because the hypothesis seemed too outrageous to the scientific community, numerous well-known geologists presented an array of bewildering hypotheses and objections to Bretz's "outrageous hypothesis," most without examining the field evidence. Bretz held his ground. Looking back at these alternative hypotheses from the vantage point of history demonstrates how desperate geologists were to oppose any hint of catastrophism. Convinced of uniformitarianism they could only accept slow changes over immense periods of time. They were more comfortable with desperate alternatives that were contrary to field evidence than to give an inch towards catastrophism. Considering the flood of controversy against the Lake Missoula flood, we should not be surprised if geologists miss evidence for the Genesis Flood.

Over the 40 year period that Bretz's hypothesis was rejected, several geologists did examine the field evidence and developed rather sophisticated counter hypotheses. But, they failed to see the significance of the Channeled Scabland. Their hypotheses were as bizarre as Bretz's suggestion appeared to be. Ira Allison [2] at least admitted to much of Bretz's evidence, but instead theorized the unique features in eastern Washington were caused by a huge ice jam, aided by a landslide, over 300 meters thick in the Columbia River Gorge through the Cascade Mountains. The strongest challenge to Bretz came from Richard Foster Flint [23], renown ice age geologist from Yale University, who spent considerable time examining the geological features of eastern Washington. Flint with Ivy League authority believed that glacial sediments were deposited in a large lake, "Lake Lewis," throughout eastern Washington. This lake was caused by a huge landslide over 300 meters deep in the Columbia River Gorge that blocked the Columbia River. When the blockage on the Columbia River failed, the resulting release of water formed many of the unique features in the area through erosion. Flint cited a considerable amount of field data for his hypothesis, resulting in a seemingly believable alternate interpretation to Bretz's hypothesis. He thought the numerous giant gravel bars cited by Bretz as caused by a gigantic flood were instead "modified river terraces from leisurely streams with normal discharge." One lesson to be learned from the revisionists is that no matter how much field data a scientist accumulates or how distinguished they may be, if they start with the wrong premise, they can become blinded to all other possibilities.

With the coming of a new generation of geologists and more field work, the Lake Missoula flood was finally accepted in the 1950s and 1960s. Bretz, himself, returned to the field of eastern Washington in 1952 at age 70, accompanied by a skeptic of the Lake Missoula flood. The skeptic was soon convinced by Bretz, especially since field evidence clearly established that the discontinuous giant mounds of gravel were indeed of river-bar origin. By then, new evidence, aided by aerial photography, established about 100 sets of giant ripple marks on the bars [8, p. 18;19;20]. The signs were obvious and multitudinous for those who were willing to be objective. The Lake Missoula flood has now become widely accepted and quietly incorporated into the uniformitarian paradigm. From there it became easier to visualize multiple Lake Missoula floods – a question that occupies modern debate.

THE MULTIPLE FLOODS CONTROVERSY

After glacial Lake Missoula burst its ice dam, the northern boundary would retain a wall of ice over 600 meters high. Since ice flows like a plastic with velocity proportional to surface slope, the ice sheet would most likely surge southward again and block the Clark Fork River, producing another glacial Lake Missoula. So the last ice age could have caused multiple floods from glacial Lake Missoula. Within the uniformitarian system, a thick ice dam could have formed over and over again at the peak of the last ice age, which would have lasted a few thousand years. Within the model of one rapid post-Flood ice age [32], the surging ice would have produced a much thinner ice dam for two reasons: 1) it would have spread its volume from north of the former ice dam southward over a significantly large area with a southerly surface slope, and 2) the ice sheet would be melting rapidly. Although the second reason would cause a more rapid filling of glacial Lake Missoula, it would also have kept the ice dam from growing. So at least one more partial filling of glacial Lake Missoula would be anticipated. There is evidence from Camas Prairie, Montana, that glacial Lake Missoula refilled to about 25% of its highest volume [28]. Whether it caused another flood of lesser intensity is another story, since the water could have leaked slowly through its barrier. Lesser floods would have mainly affected the Columbia River Valley and the western Channeled Scabland.

When Bretz was doing his landmark research in the Channeled Scabland, he believed in two glaciations – a common belief of the times. So, it was natural for him to postulated two floods from each glaciation, the second of which was believed to be small [13]. So, he essentially believed in one large flood, until late in his life. During his field trip in the 1950s, Bretz believed he saw evidence for at least 7 floods, five down Grand Coulee and two affecting the Columbia Valley only [20, p. 1045]. In his last paper on the subject, he concluded that there were at least 8 floods [19]. Part of the reason for Bretz's deductions was because of the multiple ice age theory [19, pp. 509-513]. Bretz did point out field evidence for his beliefs, but later workers admit that many of these features could be explained by one large flood that waned with time [6, p. 35]. So the idea of multiple floods was in the air, thanks to Bretz himself, but most workers in the 1960s and 1970s leaned towards one large Lake Missoula flood, spearheaded mainly by Victor Baker [5].

The best area to examine whether there had been multiple Lake Missoula floods is in protected tributary valleys along the edge of the flood path. These areas would theoretically not be eroded as much as the main channels and scabland tracts. They may record floods other than the last. There are many tributary valleys along the main flood pathway that meet this criterion. When the water ponded behind Wallula Gap forming a lake 245 meter deep, the water flooded the tributary valleys of south central Washington. The flood formed "slackwater" deposits that are especially noticeable in the Yakima and Walla Walla Valleys. These slackwater deposits are 8 to over 30 meters deep in the valley bottom and form rhythmites, a repeating vertical sequence of two or more sediment types in a particular order. The rhythmites associated with the Lake Missoula flood are composed of three units from bottom to top: unit A, plane-bedded coarse sand or cobbles; unit B, fining-upward ripple drift cross-laminated sand; and unit C, massive silt [42, p. 606].

The best exposure of rhythmites is found in Burlingame Canyon, which is located in the Walla Walla Valley, 15 kilometers upvalley from where the valley narrows and about 5 kilometers south of Lowden, Washington [46, pp. 655-659]. The Burlingame Canyon is a narrow, 30 meter deep erosional slice with vertical walls. It is sometimes referred to as the "Little Grand Canyon." There are 39 graded rhythmites exposed in the Canyon (Figure 4). The rhythmite couplets are 1 to 2 meters thick near the bottom and thin with height to about 23 centimeters by the top. A white volcanic ash layer about 5 centimeters thick is observed on top of the 28th rhythmite from the bottom. This layer can be found within the rhythmites in the other valleys of south central Washington and is most likely from an eruption of Mount St. Helens.

Researchers such as Baker thought the rhythmites could be deposited in one flood. But, we are left with the question of how a very muddy flood could have laid down a fairly pure layer of ash. The ash layer essentially gave birth to the modern multiple flood hypothesis by Richard Waitt and others. O'Connor and Waitt [30, p. 56] describe how this volcanic ash became the "Rosetta Stone" for deciphering that each rhythmite represented a separate large Lake Missoula flood:

> When rhythmic stacks of sand-silt beds in the Walla Walla valley were revisited in late 1977, the Mount St. Helens "set-S" ash couplet was found within the sequence, atop one particular bed that was not substantially different from any other bed in the section. Yet how could this be, if all beds were deposited by just one great flood?...Burlingame Canyon thus became the "Rosetta stone" for deciphering similar beds all over the region.

Since the tops of each rhythmite looked the same, and the ash indicated subaerial deposition, then the tops of each rhythmite must represent subaerial exposure, and hence each rhythmite a separate flood. This explains how 40 floods were postulated from Burlingame Canyon [46].

Based on a sequence of rhythmites, separated by non rhythmites, in the Sanpoil Valley, a northern arm of the Columbia River northeast of Grand Coulee Dam, Brian Atwater [4] pushed the number of floods up to about ninety. The non rhythmites, mostly graded sand layers, were interpreted as Lake Missoula flood deposits, while the rhythmites were assumed to be varves, each couplet believed to be a one year depositional unit. There were generally 30 to 50 "varves" between each postulated flood deposit, suggesting this amount of time between each flood. The total time for the 90 floods, all from the last ice age, is calculated to be about 3000 years. This is too much time for the short chronology of Scripture

Figure 4. View south of Burlingame Canyon rhythmites with thin vertical clastic dikes, 5 kilometers south of Lowden, Walla Walla Valley, Washington. Rhythmites almost entirely eroded from subvalley to south with top of rhythmite sequence evenly truncated.

Figure 5. Mount St. Helens ash couplet from near Mabton, Lower Yakima Valley, Washington.

and a rapid post-Flood ice age [32]. It is for this reason that the number of floods is of interest to creationists.

ONE COLOSSAL LAKE MISSOULA FLOOD MORE LIKELY

The multiple floods hypothesis became widely accepted by scientists [3]. However, cracks in this hypothesis began to show up in the mid and late 1990s. Gary Smith [44] agreed with Waitt that each rhythmite in the Walla Walla and Yakima Valleys probably represented a separate flood, but he also concluded that one flood was able to lay down more than one rhythmite in other areas. This was sort of a middle of the road stance. Although he leaned more towards Waitt's view, his research did open up the way for revising to fewer floods.

John Shaw and seven colleagues from the University of Alberta at Edmonton reanalyzed the Channeled Scabland with a fresh perspective and deduced that there was *only one Lake Missoula flood* [42]. They thought that the one flood was bolstered by another flood flowing under the ice in southeast British Columbia and south down the Okanogan River Valley and into the Columbia River. Shaw and colleagues' deduction remains controversial and their evidence seems to have been ignored or rejected [26]. If Shaw is correct, the number of Lake Missoula floods will have gone full circle back to Bretz's original position in the 1920s!

What does the evidence suggest? After 10 years of research, I am convinced that the evidence indicates there was only one colossal flood with possibly several smaller floods afterwards, as concluded by Shaw *et al*. [42]. The best place to examine the evidence in regard to the number of floods is still Burlingame Canyon. From pictures of the rhythmites and recognizing the violent nature of the flood or floods, I expected the canyon to be in some protected pocket at the edge of the Walla Walla Valley. In this case, an even series of rhythmites, showing no or few signs of erosion between floods, would have accumulated undisturbed over a few thousand years. I expected fairly strong currents in this valley at times, especially at the start of each flood as the water rushed up the valley and quickly obtained a depth of a hundred meters or more. That is why a protected spot would be necessary.

I was surprised that Burlingame Canyon was in the *middle* of the Walla Walla Valley, on the front line of each flood assault! Burlingame Canyon is a south trending coulee cut perpendicular to an east-west ridge that starts near the city of Walla Walla and extends westward for about 30 kilometers, petering out near the entrance to the valley near Wallula Gap. The top of this ridge is so flat that an irrigation ditch runs the length of the ridge. That in itself amazed me since about 90 floods, many over 100 meters deep, were supposed to have swept across the ridge. Strangely, during all the many postulated floods, little or no erosion occurred on top of the accumulating rhythmites. Thus, from the physical appearance of the rhythmites, little erosion occurred at the ridge line during *any* of the postulated floods. This contrasts with the remainder of the valley to the north and south, which has been almost totally excavated of rhythmites. The ridge is about 1.6 kilometers wide and 40 meters high while the subvalleys to the north and south are each about 8 kilometers wide. Thus, approximately 95% of the volume of rhythmites has been eroded out of the Walla Walla Valley. Still, the question remains: Why is there little or no sign of erosion in the middle of the valley?

The ridge does not exist because it is more resistant; the rhythmites are actually quite soft and easily erodible. This was amply demonstrated by the creation of Burlingame Canyon itself. It was formed in only 6 days when the water from the irrigation ditch that runs the length of the ridge was diverted down a side channel [21]. The side channel was only 3 meters deep and 2 to 3 meters wide at the time and dropped south into Pine Creek. The canyon formed in March, 1926, when persistent, strong winds piled tumble weeds into the irrigation ditch near the concrete constriction at the diversion canal. The wind blew steadily for six days and the 2.6 m^3/sec flow within the irrigation ditch was rerouted down the diversion canal because the Ditch Riders feared it would flood the agricultural fields. This diversion canal was not lined, so the ditch soon became a gully, which then became a gulch and finally a canyon. The water eroded 1.8 million kilograms of rhythmites an hour and removed about 133,000 m^3 of earth – all in 6 days from a flow of only 2.6 m^3/sec. How could this ridge have withstood more than one Lake Missoula flood?

The lack of cut and fill structures at the edge of the ridge reinforces the geomorphological deduction of only one major flood. If more floods impacted the Walla Walla Valley, signs of erosion would be evident along the north and south edges of the ridge, as each flood laid down a rhythmite during the upvalley surge and eroded the sides of the ridge during the downvalley draining. Each subsequent flood should drape a rhythmite over the eroded area at an angular unconformity with the stack of rhythmites already deposited. This scenario should repeat dozens of times. In other words, the north and south edges of the ridge should be a jumble. What we see are horizontal rhythmites with the top of the sequence sharply truncated (Figure 4) with no evidence of cut and fill structures or angular unconformities. The geomorphology of the rhythmites at Burlingame Canyon and the centerline ridge provide strong evidence for only one large flood depositing rhythmites over the entire valley during the upvalley flow, followed by the almost complete removal of the rhythmites during downvalley flow along the sides of the valley.

Another feature of the canyon that supports the one flood hypothesis is the extensive clastic dikes that form a polygonal pattern in the sequence. The dikes are 1 mm to a few meters thick with variable dips and strikes, but most of the large ones are nearly vertical, cutting through the *whole* sequence. These dikes, which can barely be seen in Figure 4, are unique in that they *repeat* the rhythmite sequence of sand and silt with even a few silt rip up clasts. One would not expect clastic dikes slicing through the whole sequence if each rhythmite was deposited by a separate flood, in which case each rhythmite should have its own set of dikes, generally separated from other rhythmites. Clastic dikes appear to be evidence for rapid deposition of all the rhythmites, again supporting the one flood hypothesis.

How did all 39 of the Burlingame Canyon rhythmites form in only one flood? I believe the explanation lies in surges or pulses of water moving up the slackwater tributaries, as suggested by early investigators. This hypothesis was postulated by Bretz [17, p. 539], himself, and later Victor Baker, who considered each rhythmite to be a type of turbidite:

> Any disturbance in the water surface of the main scabland channels was propagated up these tributaries in the form of transient surges (water-surface waves). Such surges would bring into the tributary valleys a mixture of main channel flood sediments in the form of a density flow or turbidity current [5, p. 46].

Turbidites can be deposited within minutes, and each rhythmite would represent an upvalley surge. There are several mechanisms that could have caused these surges [7; 10, pp. 60-62; 22]. First, a variable discharge from glacial Lake Missoula due to the torturous valleys of western Montana and the narrows within the main channel through which the lake drained. Second, convergent and divergent water flows would have occurred in the scabland due to the numerous and varied channels, splitting and recombining downstream. Convergent flow would result in deeper water and a surge wave. The higher water surface in the convergent flow would have caused an accelerated water flow resulting in sediment loading. A divergent flow would result in the opposite. Third, landslides, ice blocks, or gravel bars would have temporarily interrupted water flow in some scabland channels. Fourth, sudden channel deepening would also cause a surface wave. Multiple beds would occur as the surges repeatedly propagated up the tributary valleys.

Such surges in a single flood have been seen to produce multiple beds today. A good example is the well-stratified slackwater deposits that result when tributary canyons to the Pecos and Devils Rivers in West Texas are flooded [37]. A recent observation of a catastrophic outburst flood in Iceland provides a close analog to the situation in the tributary valleys of the Lake Missoula flood [41]. A subglacial volcanic eruption melted a portion of the glacial ice. The water flowed under the ice and burst from the edge on November 5, 1996. The peak discharge was 45,000 m^3/sec, only 0.2% of the peak flood discharge of the Lake Missoula flood. The Icelandic flood lasted 36 hours. During the later half of the flood, the discharge from under the ice switched outlets, so that the original outlet became a *slackwater embayment*. The embayment rapidly filled with sedimentary layers through slackwater flooding. Two hundred planar rhythmites and 100 prograding rhythmites of fine gravel and course sand formed a section 15 meters thick in just 17 hours! This is one rhythmite every 3 to 4 minutes! These rhythmites were deposited by repeated turbulent flow *pulses*. So, the formation of 40 or more relatively thick rhythmites in tributary valleys during one Lake Missoula flood is easily conceivable, especially in view of the fact that the Lake Missoula flood eroded 200 km^3 of basalt and overlying silt.

Other evidence for one flood is provided by the two-dozen rhythmites that are exposed in a railway cut about 2 kilometers northeast of Wallula Gap [10, p. 75]. Just the initial onrush of water in each flood should have destroyed any accumulating rhythmites in this location. But one flood could have deposited them in an eddy in front of Wallula Gap, leaving this patch as an erosional remnant after the lake finally drained.

ALTERNATIVE EXPLANATIONS FOR THE ASH LAYER

If the rhythmites in Burlingame Canyon and other features support only one gigantic flood how do we explain the evidence for multiple floods presented by Waitt and colleagues? Waitt's strongest argument comes from the ash layer at the top of the 28th rhythmite in Burlingame Canyon. At first glance, it does appear more reasonable to think the ash landed on a dry surface, implying multiple floods, than that Mount St. Helens just happened to erupt at the time of a one week long flood. Many scientists have been persuaded by Waitt's strongly-stated arguments.

When I first saw the ash band in Burlingame Canyon, as well as at many other locations since then, I noticed features that appeared contrary to Waitt's interpretation. I noticed that the ash layer, although fairly pure and of generally even thickness in most areas, often forms a couplet (Figure 5). This implies that the silt and sand layer between the couplet was deposited rapidly with little subsequent mixing. This pattern did not seem conducive to multiple floods because the wind should have mixed the ash, silt and sand during up to 40 years of subaerial exposure. Furthermore, the initial onslaught of the next flood should have wiped out this sequence. It is more reasonable that the ash layer was rapidly deposited and buried in one flood thereby preserving its purity and evenness, and forming a couplet over an extensive area. Shaw *et al*. [42, p. 607] came to a similar conclusion:

> 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 [unit B of the rhythmites] and their regular position, with respect to aqueous deposits as a fining upward sequence, suggests aqueous deposition. We conclude that the ash was deposited from a water column subsequent to air fall.

Another damaging observation to Waitt's multiple flood position is that at the Mabton site in the Yakima Valley, thin ash laminae are also found on the top of the rhythmites *above and below* the prominent ash band [31, p. 108]. So it appears that the volcanic ash was falling into the water while at least three rhythmites were laid down. The ash would mainly show up at the top of the rhythmites because this is the location of a low energy pause in deposition.

It is still an interesting coincidence that an ash layer from Mount St Helens ended up near the top of a rhythmite sequence during one flood. Waitt [46, p. 665] exclaims: "The enclosure of even a single layer of tephra would be extraordinary in a sediment that accumulated in less than one week." But what Waitt did not understand is that it is possible for *one giant flood to trigger the volcanic eruption*. This deduction seems quite speculative, but there are indications from modern research that this indeed is likely.

It has been known for many years that artificial reservoirs, which fill slowly after construction, cause earthquakes. The strongest earthquakes caused by a filling reservoir occurred at the Koyna Dam reservoir, west-central India, starting in 1962 [24]. More than 150 quakes of magnitude greater than or equal to 4.0 were recorded. Several have been much stronger:

> At least 10 events with magnitude equal or above 5.0 have occurred since impounding of the Koyna Reservoir. To date, the largest (M6.3) reservoir-induced earthquake in the world occurred on December 10, 1967, near the Koyna Dam. This earthquake claimed over 200 human lives [24, p. 145].

A magnitude 6.3 quake is a strong quake indeed, especially caused by a reservoir slowly filling up for the first time. One would expect much stronger earthquakes with the sudden ponding within a few days of water 245 meters deep and a volume of about 1000 km^3 in the Pasco Basin of south central Washington.

New evidence indicates that strong quakes can trigger eruptions from volcanoes that are close to erupting [27, 43]. For instance, the 1992 magnitude 7.3 Landers earthquake in southeast California triggered a remarkably sudden and widespread increase in earthquake activity across most of the western United States [25, 27]. This included the Long Valley, California, and Yellowstone volcanic fields. The Long Valley, a collapsed volcano 400 kilometers northwest of the Landers earthquake, shuddered hundreds of times a day and sensitive instruments detected swelling of the pool of magma underneath the surface [43]. A 7.0 magnitude earthquake on southern Kodiak Island triggered sudden earthquake activity of small magnitude underneath volcanoes in the Katmai area of the Alaska Peninsula [40]. A statistical study of very large quakes indicates that earthquakes can touch off volcanos within 750 kilometers:

> The geophysicists reported in the Oct. 29 NATURE that 8 of the study's 204 earthquakes of magnitude 8.0 or greater seemed to trigger same-day eruptions within 750 km [43].

Such a statistical relationships in this case is strongly significant. The reason that more volcanos did not erupt is because they must be ready to erupt.

Mount St. Helens is one of the most active volcanos in North America; it erupts fairly frequently. Mount St. Helens would have been only 240 kilometers from south central Washington. It stands to reason that the catastrophic increase of water in south central Washington would have triggered at least one very large earthquake that would have caused the eruption of Mount St. Helens. The ash from this eruption would generally spread eastward in the prevailing westerly winds, as in the 1980 eruption.

ALTERNATIVE EXPLANATION FOR THE SANPOIL SEQUENCE

Another question that needs to be resolved is the claimed 89 floods from the Sanpoil Valley. Shaw and colleagues [42, p. 606] discovered what seems to be fatal evidence against these 89 flood/varve sequences representing repeated Lake Missoula floods:

> He [Brian Atwater] interpreted rhythmic beds as varves and noted sand at the base of many sequences with *downvalley* paleocurrents, indicating discharge from the Sanpoil Sublobe [of the Cordilleran Ice Sheet] to the north. Basaltic clasts, which should occur in the Sanpoil arm with flooding from Glacial Lake Missoula, are *absent*. We suggest powerful flows from the north...(emphasis and brackets mine).

The lack of basalt clasts seems especially fatal, since the northern edge of the Columbia River Basalt Group lies only a few kilometers to the south of the Sanpoil Valley. A Lake Missoula flood had to transverse the basalt before reaching the Sanpoil Valley. It should have left basalt sand and clasts in the non-rhythmite sand deposits up the valley. This sequence in the Sanpoil Valley is more likely to have been caused by repeating meltwater pulses from the ice sheet to the north that would have discharged south into glacial Lake Columbia. In regard to the so-called varves separating the non-rhythmite deposits, it is now known that there are many other mechanisms that form multiple silt/clay couplets within a year, sometimes as many as two each day [33,34].

ANALOG FOR WATER AND WIND GAPS

The Lake Missoula flood can be used as an imperfect analog for the Genesis Flood, especially for the explanation of wind and water gaps. A water gap is: "A deep pass in a mountain ridge, through which a stream flows; esp. a narrow gorge or ravine cut through resistant rocks..." [9, p. 559]. A wind gap is defined as: "A shallow notch in the crest or upper part of a mountain ridge, usually at a higher level than a water gap" [9, p. 564]. Uniformitarian geologists often have trouble explaining water and wind gaps. There are three main hypotheses, antecedence, superposition and piracy, but there rarely is any evidence for them [36].

The Zagros Mountains, southwest Iran, have peaks commonly up to 3,350 to 4,600 meters with more than 300 water gaps [35]. The deepest water gap is about 2,400 meters deep, significantly deeper than Grand Canyon. These water gaps, cut through mountains that rose in the "Pliocene" and "Pleistocene" of the uniformitarian geological time scale, seem to defy rationality. Oberlander [35, pp. 1, 89] describes the amazing Zagros water gaps:

> The Zagros drainage pattern is distinctive by virtue of its *disregard* of major geological obstructions, both on a general scale and in detail...Certain streams *ignore structure completely*; some appear to "seek" obstacles to transect [emphasis mine, quotes his].

There are several occurrences of a stream that cuts through the *same* transverse ridge anywhere from two to five times. This would be like the Willamette River of western Oregon cutting through the Cascade Mountains to the east and then back again – twice! The Zagros drainage system is distinctive, but similar water gaps are found in other mountain ranges:

> The drainage history of this region is as obscure as is that of most of the Cenozoic and older mountain systems of the world whose transverse streams have been deduced, in the absence of evidence to the contrary, to be antecedent, superimposed, or the result of headward extension under unspecified controls." [35, p. 149]

It is logical that these water and wind gaps would form during the erosive draining of the Genesis Flood waters. Evidence that a catastrophic flood can rapidly carve out water and wind gaps is demonstrated by the Lake Missoula flood. Washtucna Coulee is an east-west coulee that lies generally parallel to the Snake River about 15 kilometers to the north. The ridge between was breached in two places by the Lake Missoula flood. These breaches are called the Palouse Canyon and Devils Canyon. Each was cut 500 feet deep through the ridge in a few days. Palouse Canyon is now a water gap. The Palouse River that used to flow westward down Washtucna Coulee and eventually into the Columbia River was diverted 90^0 to the south to flow into the Snake River after the Lake Missoula flood [14]. The beautiful Palouse Falls can be seen in this section. Devils Canyon is a wind gap through the ridge 24 kilometers west of Palouse Canyon. A rock sill 30 meters above Washtucna Coulee at the entrance to Devils Canyon keeps the latter dry. If a geologist did not know about the Lake Missoula flood, he would postulate one of the three main uniformitarian hypotheses for the formation of these water and wind gaps. But these formed rapidly during the Lake Missoula flood. Similarly, the Genesis Flood could have rapidly carved out the water and wind gaps that we see all over the world.

CONCLUSIONS

There has been controversy over whether the Lake Missoula flood occurred, mainly because the flood was too catastrophic. Now that geologists have accepted the flood after 40 years, they are now debating the number of floods. Richard Waitt and Brian Atwater have postulated about 90 Lake Missoula floods, based mainly on an ash layer in slackwater rhythmites of south central Washington and a series of rhythmites and graded sand layers in the Sanpoil Valley of north central Washington. However, there is strong evidence against the multiple gigantic flood hypothesis, especially from the geomorphology of the Walla Walla Valley with an uneroded ridge of rhythmites running down the centerline of the valley. The volcanic ash band near the top of the rhythmites, the main evidence for the multiple flood hypothesis, can be explained by the sudden large lake temporarily ponded north of Wallula Gap. The lake likely triggered at least one large earthquake that subsequently initiated the eruption of nearby Mount St. Helens. There is strong evidence that the Sanpoil Valley sequence was formed by sedimentation from the Cordilleran Ice Sheet to the north and not from glacial Lake Missoula. The Lake Missoula flood can be used as an imperfect analog for the formation of water and wind gaps that are relatively common over the surface of the Earth. Palouse and Devils Canyon are examples of a water and wind gap, respectively, formed rapidly during the catastrophic Lake Missoula flood.

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