Glacial Lake Missoula and the Ice Age Floods

Camas Prairie Basin. Photo by D. Bennett, All Rights Reserved.

Montana Geology 2018

January

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			

March

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

April

Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

May

Su	Mo	Tu	We	Th	Fr	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

June

Su	Mo	Tu	We	Th	Fr	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

When J. Harlen Bretz first proposed in the 1920s that massive scale floods were behind the channeled scabland features of the Pacific Northwest, the idea was not well received by the geoscientific community. It took the work of geologist Joseph T. Pardee to make the connection between Bretz's concepts and the evidence of Glacial Lake Missoula. From the late 1920s through the 1940s, Pardee included the above images (scanned from his original lantern slides) in presentations to help demonstrate this evidence of the Ice Age floods.

July

Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

August

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

September

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

October

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

November

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

December

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

MBMG
Montana Bureau of Mines and Geology

Butte Office
1300 W. Park Street
Butte, Montana 59701-8997
406-496-4180

Montana Bureau of Mines and Geology

Billings Office
101 Grand Avenue
Billings, Montana 59101
406-272-1600

The Ice Age Floods Story

Glacial Lake Missoula, and the cataclysmic floods associated with its rapid draining, are popular interpretative themes of geology for western Montana (fig. 1). Together these themes are referred to as the "Ice Age Floods Story."

During the last Ice Age (about 21,000 to 12,000 years ago), a lobe of the Cordilleran ice sheet advanced far enough south to block the path of the Clark Fork River near present-day Sandpoint. As the waters rose behind this greater than 2,000-foot-high dam of ice, the valleys of western Montana began to flood. The resulting lake, Glacial Lake Missoula, held over 500 cubic miles of water at its maximum extent—as much as Lakes Erie and Ontario combined.

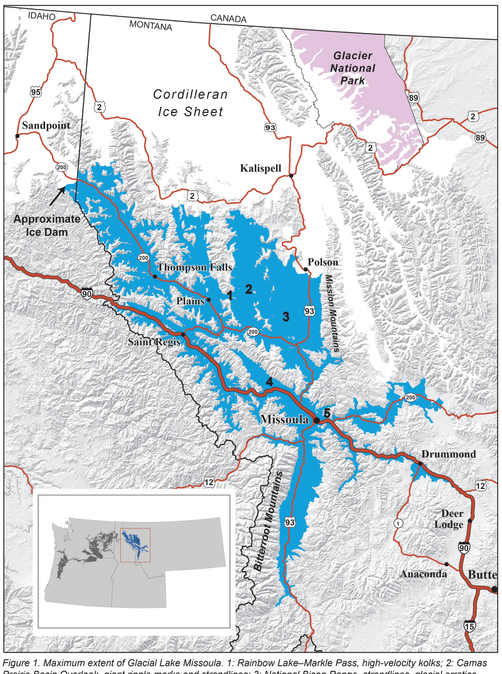

Figure 1. Maximum extent of Glacial Lake Missoula. 1: Rainbow Lake–Markle Pass, high-velocity kolks; 2: Camas Prairie Basin Overlook, giant ripple marks and strandlines; 3: National Bison Range, strandlines, glacial erratics, and lake sediment; 4: Ninemile, lake sediment rhtyhmites; 5: Mounts Jumbo and Sentinel, strandlines.

The ice dam, however, was subject to repeated failure. The failure of the dam was often catastrophic in scope, resulting in a large flood of ice and water that would rush across the Pacific Northwest, eventually draining into the Pacific Ocean. The peak rate of flow is estimated to be 10 times the combined flow of all the rivers of the world, and the huge lake may have emptied in as little as 2 or 3 days. Over a period of years, this process was repeated scores of times until the ice sheet eventually ceased its advance at the end of the Ice Age, finally receding to the north.

The shorelines etched into the hillsides above the valleys and the "giant ripple marks" of the Camas Prairie Basin (front photos) are among some of the more dramatic examples of the presence of Glacial Lake Missoula. The more subtle reminders of the lake and the power of the flood waters are the remnants of glacial lake sediments, scoured flood channels, high-velocity kolks (underwater vortices), and gulch fills found along the Clark Fork and Flathead River drainages.

The Human Story

Early settlers in east-central Washington state recognized that the landscape was different than in other places, but were not sure why. Closer examination of the enigmatic features of the Columbia Basin in the early 1920s led one geologist, J. Harlen Bretz, to propose that only a sudden and cataclysmic flood on a scale never before considered possible could account for the phenomenal size and distinctive characteristics of the landforms. Bretz first published his findings in a series of scientific papers starting in 1923 (Bretz), but he was unable to identify the source or cause of the catastrophic flooding at such a scale.

Figure 2. Joseph T. Pardee, Spring 1941.

In 1910, prior to any of Bretz's work in eastern Washington, geologist J.T. Pardee, from Philipsburg, Montana, published "The Glacial Lake Missoula, Montana" and documented the presence of an immense lake in western Montana that had been impounded by the Purcell Lobe of the Cordilleran Ice Sheet when it blocked the drainage of the Clark Fork River. Pardee (1910; figs. 2, 3) described the height of the lake at approximately 4,200 feet; probable location of the glacial dam at the southern end of Lake Pend Oreille, Idaho; extent of lake wave terraces and glacial erratics; and locations of gravel flats at the 4,000-foot level. He also identified that the outflow of the dammed lake was by way of Spokane. These conclusions were based upon previous field work by U.S. Geological Survey (USGS) geologists Frank Calkins and T.C. Chamberlin, in addition to Pardee's own field observations over the previous decade.

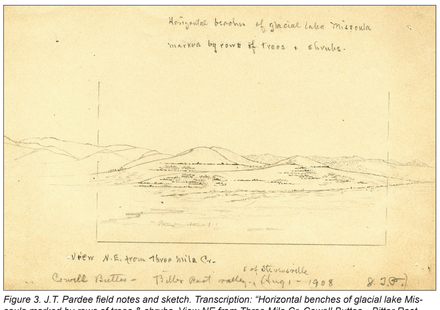

Figure 3. J.T. Pardee field notes and sketch. Transcription: "Horizontal benches of glacial lake Missoula marked by rows of trees & shrubs. View NE from Three Mile Cr. Cowell Buttes—Bitter Root valley E of Stevensville (Aug 1–1908 J.T.P.)"

Bretz initiated one of the great debates in the history of geology when he formally introduced papers in 1923 indicating that the extreme bedrock channel erosions of the Scablands required great depths and flows of water. This "catastrophic flood" hypothesis brought intense criticism and alternative theories from leaders in the field of geology throughout the 1920s–1930s. Pardee publicly kept quiet during the two decades of vicious controversy. His superior at the USGS, W.C. Alden, was a vehement critic of Bretz's interpretations, and there is evidence of his stifling Pardee's collaboration. Privately, Pardee wrote to Bretz in 1925 suggesting that Lake Missoula be considered as a possible source for his Spokane Flood. By 1928, Bretz privately resolved that the source of the Spokane Flood had to be Lake Missoula (Baker, 2008).

In 1940, the American Association for the Advancement of Science meeting organized presentations of seven papers of non-cataclysmic origins of the Channeled Scablands. The eighth speaker was J.T. Pardee, whose paper was titled "Ripple marks (?) in Glacial Lake Missoula." Pardee began by reviewing the information from his 1910 "Glacial Lake Missoula, Montana" paper and then quietly and methodically presented his new evidence that the ice dam had failed catastrophically, with a rapid drainage of the enormous lake westward. He described in detail giant coarse-gravel ripple marks of an extraordinary size; giant channel gravel bars; denuded bedrock surfaces up to 1,000 feet in the numerous constricted narrows of the lake system; and high eddy deposits of gravel 1,000 feet above the Clark Fork River. The failure of the ice dam permitted a great outrush of water at least 1,000 feet deep that reached 9.5 cubic miles per hour through the Eddy Narrows (Pardee, 1942). He concluded his presentation without further comment. However, the astoundingly obvious connections to Bretz's findings were made by members of the audience in the formal discussion that followed (Baker, 2008). Thus, prompt resolution of the great Channeled Scabland controversy was achieved.

Pardee waited until after his official retirement from the USGS in 1941 to publish the manuscript of his revolutionary 1940 oral presentation. This timing ensured that publication of "Unusual Currents in Glacial Lake Missoula, Montana" in 1942 could not be blocked by his former supervisor. Esteemed peers Frank Calkins, D.F. Hewett, and Russel Gibson described Pardee as "having great patience, lack of harsh words, talent as a brilliant musician and illustrator, of high integrity, and with an uncanny understanding of people, especially people who were not completely genuine—a gentle person and a perfect gentleman" (fig. 4).

Pardee was a true native son of Philipsburg, Montana. He made his fortune with gold and sapphire placer mines on Rock Creek, annually returned to his hometown during his 31-year USGS career based in Washington, D.C., moved back after retirement, and is buried in the Philipsburg cemetery.

Figure 4. J.T. Pardee, 1916, Pioneer, Montana.

"Giant Ripple Marks" of the Camas Prairie Basin

As the history of the floods debate shows, one piece of information seems to have done more to tip the balance in favor of Bretz's theories than any other: the suggested origins for the large sets of rolling landforms found in the Camas Prairie Basin of western Montana (fig. 5). When the interpretations were finally presented, Pardee (1942) successfully demonstrated that these features were none other than "giant ripple marks." He theorized that they could have only been created by deep and fast-moving water, the result of the rapid draining of Glacial Lake Missoula when the ice dam broke.

Figure 5. "Giant Ripple Marks" of the Camas Prairie Basin. Photo by David Bennett, All Rights Reserved.

Pardee (1942) estimated that to form these giant ripples, the lake waters moved through this area at more than 50 miles per hour (fig. 6). Not long after Pardee's explanation for the presence of these smooth, parallel ridge-rows in the Camas Prairie was accepted, Bretz and others began applying the same interpretation to similar features found along the flood water's path from western Montana to the Pacific Ocean.

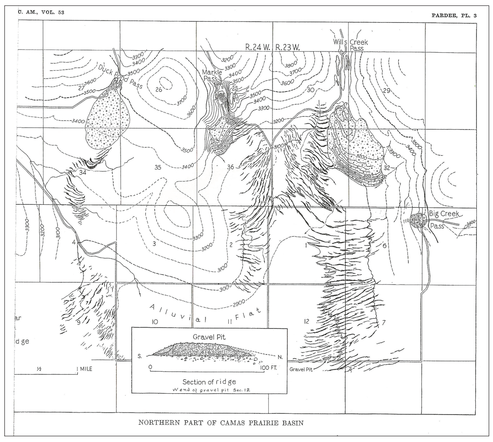

Figure 6. Pardee plat of mapped ripple marks. Modified from Pardee, 1941.

The size of each ripple (or more accurately: dune) is up to 20 feet in height, 100 feet long, and spaced as far as 500 feet apart. The trains of rounded (in profile), straight-crested bedforms are made up of cobble-sized gravel. The dunes are overlain by glaciolacustrine silts correlative to the Lake Missoula beds. The silts are only inches to a few feet thick in the interdune areas. These relationships are similar to what is seen elsewhere in the basin: the high-velocity flows occurred during earlier drainages of Glacial Lake Missoula; the silts represent transgression and deposition in a later lake-stand; and later draining of the lake did not cause the higher velocity flows characteristic of the earlier events (Pardee, 1942; Chambers, 1971, 1984; Smith, 2006).

Glacial Lake Strandlines

Along the valleys once occupied by Glacial Lake Missoula are unmistakable parallel, horizontal lineations etched into the surrounding slopes (fig. 7). Examples of these features on Mounts Jumbo and Sentinel were first mentioned by Pardee in his 1910 Journal of Geology article titled "The Glacial Lake Missoula, Montana." The most obvious conclusion regarding the discovery of these shoreline features is that a large and deep lake once occupied this portion of western Montana. The recognition of the existence of a large body of water and its connection to the ice age floods that swept across the Pacific Northwest would later become important to Bretz's geologic interpretations.

Figure 7. Mount Jumbo, above the city of Missoula. Photo by David Bennett, All Rights Reserved.

References

Baker, Victor R., 2008, The Spokane Flood debates: Historical background and philosophical perspective: Geological Society, London, Special Publications, v. 301, p. 33–50.

Bretz, J. Harlen, 1923, The Channeled Scabland of the Columbia Plateau: Journal of Geology, v. 31, p. 617–649.

Chambers, R.L., 1971, Sedimentation in glacial Lake Missoula: MS thesis, University of Montana, Missoula.

Chambers, R.L., 1984, Sedimentary evidence for multiple Glacial Lakes Missoula: Montana Geological Society 1984 Field Conference—Northwestern Montana, p. 189–199.

Pardee, J.T., 1910, The Glacial Lake Missoula: Journal of Geology, v. 18, no. 4, p. 376–386.

Pardee, J.T., 1942, Unusual currents in Glacial Lake Missoula: Bulletin of the Geological Society of America, v. 53, p. 1569–1600.

Silkwood, J.T., 1998, Glacial Lake Missoula and the channeled scabland: A digital portrait of landforms of the last ice age, Washington, Oregon, northern Idaho, and western Montana, United States Forest Service, Northern Region, Minerals & Geology, Geology Program Digital Mapping.

Smith, L.N., 2006, Stratigraphic evidence for multiple drainings of Glacial Lake Missoula along the Clark Fork River, Montana, USA: Quaternary Research, v. 66, p. 311–322.

Acknowledgments

Content provided by the Glacial Lake Missoula Chapter of the Ice Age Floods Institute, with special thanks to Christopher Rye, Mindy Mason, and Diane Adams. Layout and editing by Susan Barth, MBMG. Cartography and GIS work by Susan Smith, MBMG; Paul Thale, MBMG; Daniel Coe, Washington Geological Survey, and Hilary Rigby, U.S. Forest Service. Portions of the glacial map were modified from Silkwood (1998). Thank you to David Bennett and the Pardee family for photos.

MONTANA BUREAU OF MINES AND GEOLOGY
Montana Tech of The University of Montana

Scope and Organization

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 as a non-regulatory public service and research agency for the State of Montana, to conduct and publish investigations of Montana geology, including mineral and fuel resources, geologic mapping, and groundwater quality and quantity. In accordance with the enabling act, the MBMG conducts research and provides information.

Contact Us:
http://mbmg.mtech.edu

Coal/Coalbed Methane and Hydrogeology	272-1601	Groundwater Investigation Program	496-4152
Director's Office	496-4180	Environmental Hydrogeology	496-4157
Earthquake Studies Office	496-4332	Mineral Museum	496-4414
Economic Geology	496-4171	Oil & Gas	272-1602
Geologic Mapping	496-4883	Public Inquiry, Publication Sales	496-4174
Groundwater Assessment Program	496-4306	Publications Division	496-4687
Groundwater Information Center	496-4336		