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Were the Wind River Terraces Caused by Multiple Glaciations?

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Abstract

Geologists believe that fifteen terraces in the upper Wind River Basin of northwest Wyoming are correlated to multiple ice ages. However, field examination reveals only four significant terraces: WR1, WR3, WR7, and WR9. The bottom two, WR1 and WR3, were connected to glacial outwash from an ice cap over the Wind River Mountains but were likely formed during the same glaciation, not from two distinct ice ages, called the Pinedale and Bull Lake glaciations in the uniformitarian scheme. Although terrace WR7 is claimed to be linked to the Sacagawea glaciation, the moraine in the type area for this glaciation is not physically connected to terrace WR7. This moraine has similar geomorphology to the "Bull Lake" and "Pinedale" moraines, suggesting just one glaciation for all these moraines. Terrace WR7 also has contradictory dates ranging up to about 660 kyr, based on dates from the Lava Creek B ash in WR7. This date indicates three missing glaciations. The few terraces above WR7 are not associated with any glacial feature, despite geologists' claims. Due to uncertain dating of WR7, the dates of higher terraces are equally uncertain. Terraces above WR3 are best understood as pediments and planation surfaces formed during channelized Flood erosion and runoff in currents moving toward the southeast through the Upper Wind River Basin.

Introduction

Multiple, elongated terraces flank the sides of river valleys all over the world. These terraces lie parallel to and above the river and its immediate floodplain. There are two main types: depositional and erosional. Depositional, or gravel, terraces are composed of gravel, cobbles, and boulders, collectively called coarse gravel, laid down on a floodplain during flooding. When the river returns to normal stage and erodes its bed, it leaves flat terraces of gravel with a steep embankment along the valley sides. This can happen more than once, resulting in a flight of gravel terraces (Figure 1). Some valleys can have a dozen terraces. Terraces are especially common and large if the valley was a drainage conduit for glacial meltwater from an ice sheet,

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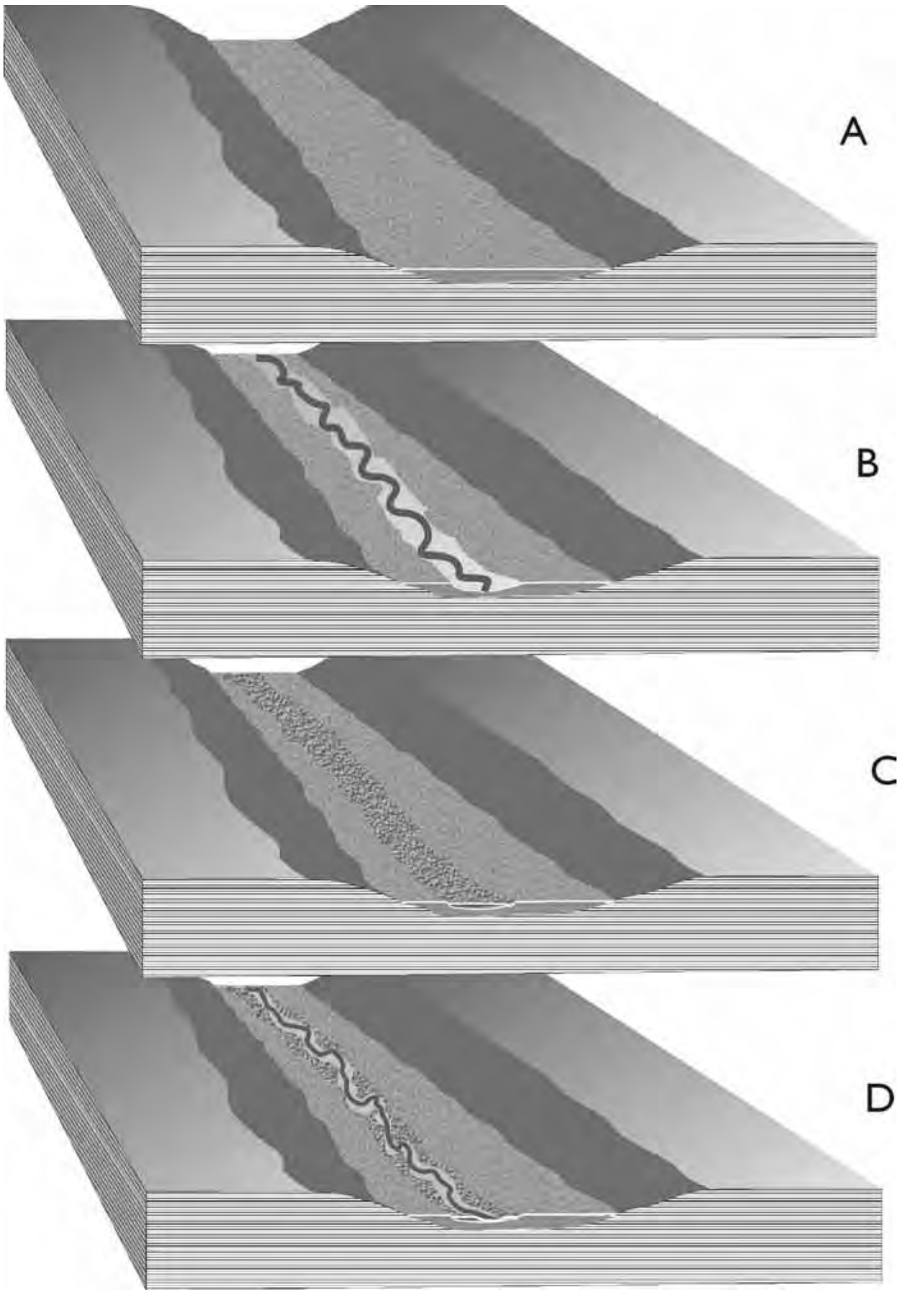


Figure 1. The formation of two gravel terraces in a river valley. (A) The river valley is first carpeted with a layer of coarse gravel. (B) The river erodes this gravel, leaving gravel terraces on either side of the valley. (C) A second depositional event partially fills the eroded valley with coarse gravel. (D) The river erodes the second layer resulting in new gravel terraces. (Drawn by Peter Klevberg)

ice cap, or mountain glacier at the end of the Ice Age. For example, two large terraces formed along the upper Snake River Valley of Jackson Hole Valley, Wyoming (Figure 2) during the melting of the Yellowstone ice cap.

The second type of terrace is erosional on hard rock and is called a *strath* terrace. Strath terraces are elongated planation surfaces cut in bedrock along valley slopes and covered with a thin layer of coarse gravel. Uniformitarian scientists believe strath terraces are remnants of a broad, flat bedrock floor, called a strath that extended across the *whole* valley from an earlier age in which the river eroded *laterally* and not downward. Upon subsequent downward cutting of the bedrock, the strath is left hanging on the sides of the valley with a thin veneer of coarse gravel on top (Neuendorf et al., 2005, p. 632). Just like with depositional terraces, multiple strath terraces can form in a single valley (Figure 3).

Both types of terraces occur in the upper Wind River Valley, northwest Wyoming. They are predominantly strath terraces, and are attributed to multiple uniformitarian ice ages associated with the classical location for mountain glaciers in the Wind River Mountains. Geologists have identified 15 depositional and strath terraces, which they correlate to different ice ages, although each ice age did not form a distinct terrace that remains. This is based on a possible date of 1.7 Ma (million years ago) for the top terrace (Chadwick et al., 1997). This date is based on the astronomical theory of the ice ages in which ice ages occur every 100 kyr (thousand years) for the last 900 kyr and cycle every 40 kyr older than 900 kyr.

General Geology of the Upper Wind River Area

The upper Wind River broad valley lies between the Absaroka and Owl Creek Mountains on the north and the Wind River Mountains on the south. Yellowstone National Park lies to the northwest and Teton National Park to the west (Figure 4). The rocks in most of these mountains are quite different. Those in the Teton, Beartooth, and Wind River

Figure 2. Two large, coarse gravel terraces along the Snake River at Snake River Overlook, Jackson Hole, caused by outwash from the melting Yellowstone ice cap.

Mountains are composed mostly of Precambrian granite and gneiss, while the Owl Creek Mountains are composed of an east-west uplifted Precambrian granite core covered by sedimentary rocks (the geological column and ages are used for discussion purposes only).

The Wind River Mountains are capped by an extensive planation surface (Figure 5), while other flat surfaces along their flanks are likely pediments (Figures 6 and 7). This mountaintop planation surface is eroded into granite and gneiss, as well as some of the steeply dipping sedimentary rocks, such as at Gypsum Mountain. Because the planation surface is cut on both Precambrian granite and gneiss and Phanerozoic dipping sedimentary rocks, some geologists believe the planation surface formed during the Laramide orogeny of the Late Cretaceous to early Eocene with the final uplift during the Oligocene (Steidtmann et al., 1989). Blackwelder earlier deduced:

> The age of the Wind River summit peneplain [planation surface] is debatable, but, by a process of finessing, it may be worked out with some degree of assurance. It will be admitted by all that, since it trunkates [sic] the structures produced by the folding at the close of the Cretaceous, it must be of Cenozoic age. (Blackwelder, 1915, p. 202)

However, it is also possible that the planation surface cutting into the granite could be exhumed—part of the Great Unconformity overlying Precambrian igneous and metamorphic rocks over much of the western and central U.S. The same, or a similar, unconformity is seen in Grand Canyon, separating Paleozoic sedimentary rocks from underlying Precambrian sedimentary rocks and igneous and metamorphic basement (Figure 8). Arguments in favor of the one on the Wind River Mountains being an exhumed planation surface are (1) the faulted planation surface, on top of what is probably the same granite and gneiss on the Beartooth Mountains, has a 480-meter thick, early Paleozoic erosional remnant on top of the granite and gneiss, and (2) the flat top of Mount Moran in the Teton Mountains, the same Precambrian granite and gneiss, has a

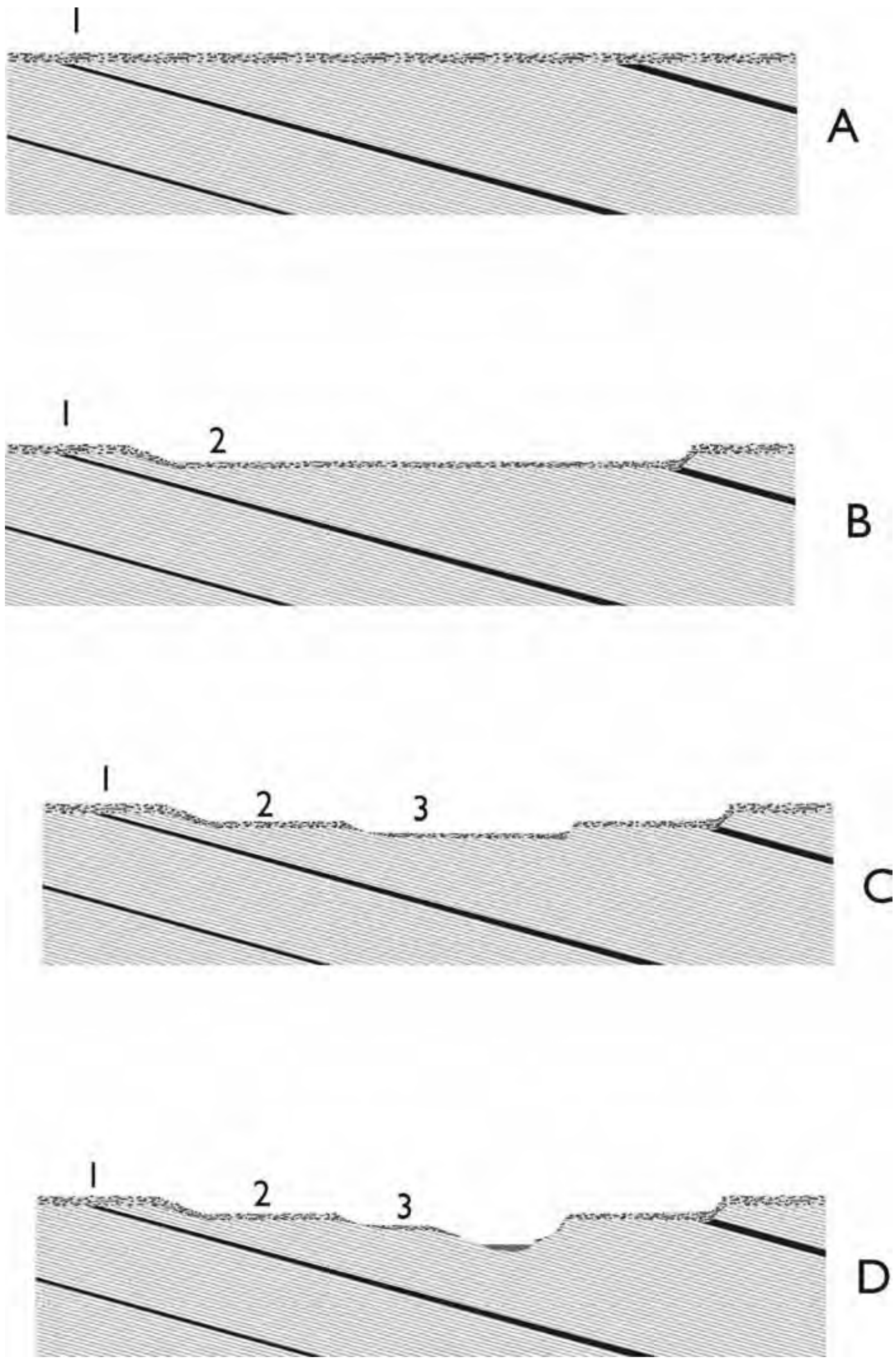


Figure 3. The formation of three strath terraces in a river valley. (A) The river first erodes a nearly flat planation surface, or "strath," on hard rock and deposits a thin veneer of coarse gravel across the entire valley. (B) The river erodes some of the bedrock, leaving strath terraces on either side of the valley. (C) A second erosional event creates a second set of strath terraces. (D) A third episode forms a third set of strath terraces. (Drawn by Peter Klevberg)

15-meter thick patch of Cambrian Flathead Sandstone on top. The evidence is well explained by a combination of early Flood erosion of basement rocks and late Flood erosion caused by Flood runoff during differential vertical tectonics.

The uplift of the Wind River Mountains was caused by a thrust fault. Motion was to the southwest, inclined about 30° from the horizontal with a vertical throw of about 14 kilometers and a horizontal displacement of 26 kilometers. It uplifted basement granite relative to the sedimentary fill of the Green River Basin.

The Absaroka Mountains are composed of the Absaroka Volcanics (Figures 9 and 10), which were formed by multiple debris flows of volcanic material that accumulated over an area of 23,000 km^2 and reached a thickness of 1,830 m (Hergenrather et al., 2012; Sundell, 1993). This is the material in which the so-called fossil forests of Yellowstone National Park are located (Figure 11). The Absaroka Volcanics are dated as Eocene by uniformitarian geologists. The top has been planed flat, and the planation surface is still visible in the southern Absaroka Mountains (Love et al., 2007). Afterward, the mountains were deeply dissected by valleys up to about 1,200 m deep. This sequence of events fits well with the late-Flood, two-stage erosion—sheet erosion followed by channelized dissection—during the retreating stage of the Flood (Oard, 2008; Walker, 1994).

In addition to the Absaroka Volcanics in the northern and eastern park, volcanic rocks of Yellowstone National Park consist of almost all types of lava from basalt to rhyolite. It represents the largest supervolcano in the world and is believed to be composed of three major Pleistocene super eruptions: (1) Huckleberry Ridge dated at 2.1 Ma, (2) Mesa Falls dated at 1.3 Ma, and (3) Lava Creek dated at 0.65 Ma (Love et al., 2007). Ash from these eruptions spread over most of the western and central United States, and westward into the

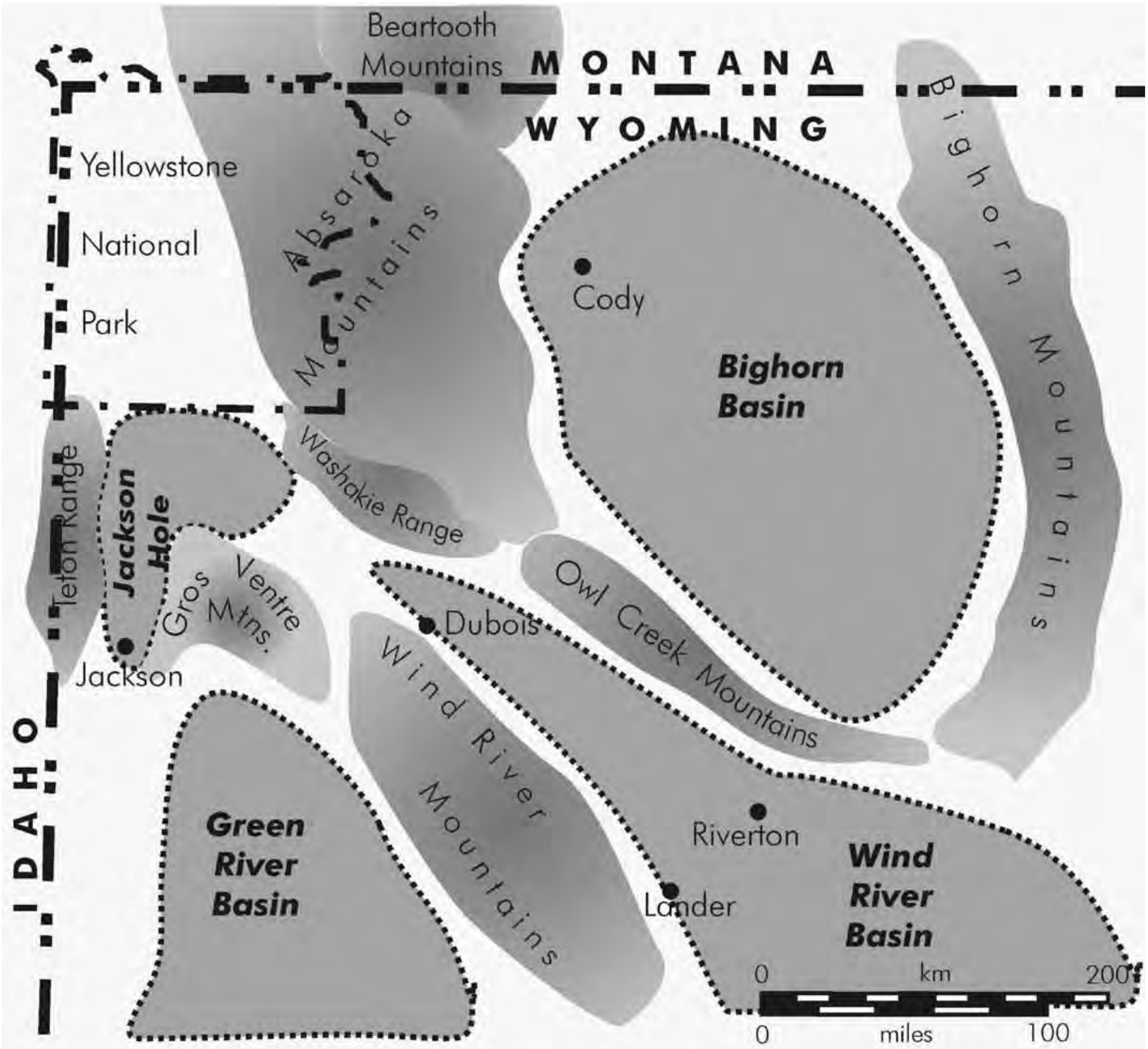


Figure 4. Map of northwest Wyoming showing the study area of the upper Wind River Basin between Dubois and Riverton. (Drawn by Peter Klevberg)

Pacific Ocean, well off the West Coast, where it is believed to have been found in deep-sea drill cores (Sarna-Wojcicki et al., 1987).

As the mountain ranges uplifted, the Wind River Basin and other basins sank and were infilled by thick sediments that now reach over 8,500 m in thickness in the Wind River Basin (Love, 1960; Thornbury, 1965). But the top of this valley fill has been eroded by as much as 850 m, based on erosional remnants in the Wind River Basin (McMillan et al., 2006). Crowheart Butte (Figure 12) is a remnant about 300 m high in the center of the upper Wind River Basin that represents the minimum erosion in the northwest part of the greater Wind River

Figure 5. Planation surface on the top of Wind River Mountains.

Figure 6. Pediment or planation surface remnant along the southeast Wind River Mountains.

Figure 7. Large pediment along the northeast Wind River Mountains.

Figure 8. The Great Unconformity (solid line) on eastward tilted Precambrian sedimentary rocks in the eastern Grand Canyon. The Greatest Unconformity (dashed line) is between the Precambrian rocks and the igneous and metamorphic rocks below.

Figure 9. Absaroka Volcanics (view northwest from Brooks Lake, Wyoming, at about 2,900 m msl).

Basin. Erosional remnants north of the Wind River in the northwest Wind River Basin show about 700 m of erosion (Fan et al., 2011). So, during the formation to the Wind River Terraces, deep valley erosion was occurring.

The Wind River Terraces

The upper Wind River is believed to possess a classical series of terraces. It is claimed that there are fifteen fluvial, mostly strath, terraces in the upper Wind River Basin above Riverton, labeled WR1 to WR15, from the lowest to the highest (Hancock et al., 1999). However, only WR1, WR3, WR7, and WR9 are of any significant size (Figure 13). WR1 is just above the modern floodplain in the upper reaches but merges with the cur-

Figure 10. Close up of Absaroka Volcanics at Brooks Lake.

Figure 11. Multiple levels of petrified trees in the Absaroka Volcanics at Specimen Creek, northwest Yellowstone National Park.

rent floodplain downriver toward Riverton. WR3 is about 40 meters higher and is composed of around 25 m of gravel near Dubois, thinning to a few meters downstream near Riverton. Although shown as continuous on Figure 13, WR7 consists of isolated remnants and is about 140 meters above the river. WR9 is located around Riverton and is about 190 m above the river. WR15 consists of only one small fragment south of Bull Lake and is 300 meters above the river (Hancock et al., 1999). The coarse gravel on the strath terraces includes granite or gneiss from the Wind River Mountains, volcanics from the Absaroka Mountains, and exotic, well-rounded quartzite rocks from central Idaho (Oard, 2008).

Most of the other terraces are not distinct or significant; some are just disconnected buttes and mesas (Chadwick et al., 1997). As a result of few distinct terraces, a considerable difference exists in mapped terraces between various investigators (Hall and Jaworowski, 1999). Blackwelder (1915) could identify only three terraces in the area, which are now called WR1, WR3, and WR15.

Terraces Correlated with Multiple Glacial/Interglacial Oscillations

The terraces are assumed to have been caused by glacial/interglacial oscillations from classical mountain glacial episodes in the Wind River Mountains (Hancock et al., 1999). Scientists claim there have been many such episodes every 100 kyr for the past 900 kyr and every 40 kyr older than 900 kyr, based on Milankovitch astronomical cycles. However, moraines for only three ice ages are claimed in the field; evidence for older ice ages cannot be found (Hall and Jaworowski, 1999). These ice ages are: (1) the Pinedale glaciation (WR1), (2) the Bull Lake glaciation (WR3), and (3) the Sacagawea Ridge glaciation (WR7). WR1 and WR3 are both strath and gravel terraces in different locations. All the others are considered strath terraces.

The youngest episode is the Pinedale glaciation, identified from moraines around Pinedale, Wyoming, along the southwest edge of the Wind River Mountains. Its glacial maximum is dated by cosmogenic beryllium-10 to about 21,700 years (Gosse et al., 1995). The classical ice age moraines from the next-youngest ice age, the Bull Lake glaciation, are from the northeast Wind River Range north of Bull Lake, which also has Pinedale moraines.

Figure 12. Crowheart Butte.

Problems with the Pinedale and Bull Lake Glaciations

It is difficult to link the Pinedale and Bull Lake terminal moraines to separate glacial episodes. The moraines may show a slight difference in weathering, but they appear similar. The Bull Lake terminal moraines (Figure 14) are composed of 15 nested moraines, some of which are supposedly from the Pinedale ice age (Chadwick et al., 1997). However, there is much confusion on the dating of these classical moraines.

> Thus, stratigraphic names, such as Bull Lake, are not tied to a clear understanding of glacial chronology in the type localities…. In the Wind River Basin, it has not been clear which, if any of the Bull Lake deposits represent late Illinoian advances [from the second to the last or Bull Lake ice age]. (Chadwick et al., 1997, p. 1,443)

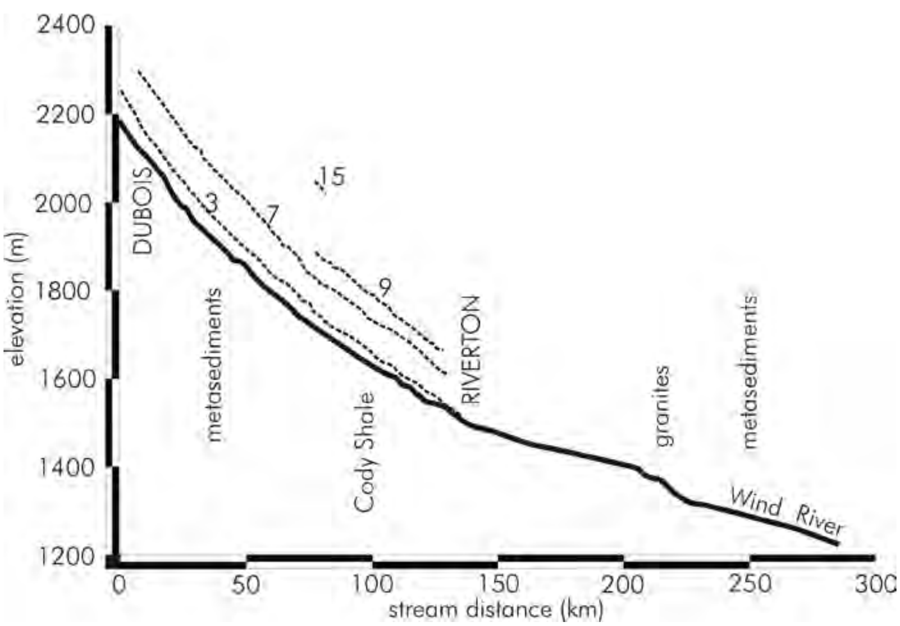


Figure 13. A plot of the terraces in relation to the Wind River (redrawn from figure 3 of Hancock et al., 1999 by Peter Klevberg). In reality WR7 is patchy.

Regardless, these researchers simply correlate the Bull Lake ice age to marine isotope stage 6, which is the second to the last ice age, based on their belief in astronomical cycles. But they do admit there could be younger or older ice ages represented in the Bull Lake terminal moraines. Although the chronology of Rocky Mountain glaciation has been under almost constant revision, researchers simply correlate supposed ice ages to the marine isotopic record, which is based on deep-sea cores (Chadwick et al., 1997; Hall, 1999).

The Bull Lake terminal moraines are simply farther out along the edges of tributary valleys in the Wind River Mountains than the Pinedale terminal moraines. The sequence of terminal moraines look like nested terminal moraines from *one* ice age. The weathering differences of the "Bull Lake glaciation" are likely due to longer exposure to acid

Figure 14. One of the terminal moraines at Bull Lake.

Figure 17. Coarse gravel of WR3 as seen from WR1.

Figure 15. Edge of either a Pinedale or Bull Lake lateral moraine northeast of Dinwoody Lakes.

Figure 18. The Sacagawea Ridge lateral moraine east of Dinwoody Lakes.

Figure 16. Outwash and WR3 from moraine in Figure 15.

Figure 19. Bull Lake lateral moraine east of Dinwoody Lakes.

Figure 20. The top of a Pinedale lateral moraine east of Dinwoody Lakes.

Figure 21. Small outwash fan from Sacagawea Ridge moraine shown in Figure 18.

rain caused by Ice Age volcanism (Oard, 2004a).

Outwash fans from the Pinedale and Bull Lake terminal moraines blend into the two lower terraces, especially WR3, which is very extensive (Figures 15 to 17). WR1 and WR3 could simply be two terraces from distinct erosional events during the same ice age, like the two large terraces in Jackson Hole that both formed during the melting of the Yellowstone ice cap (Figure 2). This confusion in relative timing may explain why uniformitarian scientists have so many problems dating WR3 (Sharp et al., 2003).

Sacagawea Ridge Glaciation Illusory and Not Connected to WR7

The next oldest glaciation after the Bull Lake glaciation is the Sacagawea Ridge glaciation. Its type area is just east of Dinwoody Lakes, and it is supposedly represented by terrace WR7 (Lindsey et al., 2007). However, the lateral moraine representing the Sacagawea episode is still sharp-crested (Figure 18) and indistinguishable from the adjacent Bull Lake (Figure 19) and Pinedale (Figure 20) lateral moraines, suggesting that these are simply nested moraines from one ice age.

Moreover, the Sacagawea Ridge moraine has a small outwash fan to the east (Figure 21); although it is east of Dinwoody Lakes, it is *not* connected to terrace WR7 west of Dinwoody Lakes (Figure 22). The correlation of WR7 with the Sacagawea Ridge moraine is based only on their *similar* altitude: "Outwash adjacent to the younger of two Sacagawea Ridge moraines has been correlated with this river terrace [WR7] on the basis of very similar elevations" (Hall and Jaworowski, 1999, p. 1,248). I verified this in the field—there is no physical connection. This is probably why Hancock et al (1999, pp. 47, 56) qualified that the Sacagawea Ridge outwash *may be* or *appears to be* correlated to WR7. It is also the likely reason that Blackwelder (1915) never included WR7 as one of his glacial terraces in the area.

The supposed Sacagawea glaciation is fraught with problems. Based on the location of its lateral moraine just outside the Bull Lake lateral moraine east of Dinwoody Lakes, one might expect it to be the third most recent glacial episode. But there are three missing glaciations between the Bull Lake and Sacagawea glaciations, based on the Milankovitch 100 kyr cycle and the "solid" date of 660 kyr for terrace WR7. This date for WR7 is based on the date of the Lava Creek B ash from the last Yellowstone eruption found just above bedrock at several locations on WR7, including the terrace west of Dinwoody Lake (Chadwick et al., 1997, p. 1,447). Therefore, the Sacagawea event would have been the *seventh* most recent glaciation with three leaving no evidence at all. Figures 23 and 24 show one of the ash outcrops on WR7 west of Dinwoody Lake. The ash is dated by tephrochronology (Dethier, 2001; Hancock et al., 1999).

However, terrace WR7 has also been dated by cosmogenic radionuclides (CRNs), radioactive nuclides formed by the cosmic ray bombardment of Earth's surface. The subsequent decay of the isotopes supposedly gives a time for the exposure at or near the surface. CRN dating of WR7 yielded an age of only about 300 kyr (Hancock et al., 1999). Others think WR7 could be as young as 250 kyr (Phillips et al., 1997). Sharp et al (2003) came up with dates ranging from 140 to 315 kyr. Such dating discrepancies are explained away by supposed eolian erosion:

> A possible explanation for these discrepancies is that eolian deflation [erosion] reduces the thickness of loess mantling Wind River terraces through time leading to overestima-

Figure 22. The top of WR7, a pediment erosional remnant along the Wind River Mountains, west of Dinwoody Lakes.

Figure 23. Lava Creek B ash layer from the last Yellowstone Park super eruption on top of bedrock in WR7 (Hans and Lisa Reinhardt for scale).

> tion of cosmogenic-nuclide production in the underlying gravel and too young cosmogenic ages. (Sharp et al., 2003, p. 148)

Hancock et al (1999) earlier suggested this explanation, and they also admit the difficulty of dating by cosmogenic radionuclides:

> Our work on the older terraces illustrates the continuing difficulty of precisely dating depositional surfaces older than a few 100 ka [thousand years] with CRN, because of the uncertainties in the geologic history of the surfaces and the large errors arising from calibrations of the rate of production which are inherent in dating surfaces with CRNs. (Hancock et al., 1999, p. 57)

On the other hand, if the CRN dates are considered correct, an explanation must be found for the older date of the Lava Creek B Ash. The standard "reworking" explanation appears to be the current favorite, having been "reworked" from older terraces (Hancock et al., 1999, p. 57), which, unfortunately, do not exist. Also, it is unclear how reworking from higher terraces would result in patches of nearly pure ash, like those found on terrace WR7 (Figures 23 and 24).

Problems with Terraces Higher than WR7

Terraces higher than WR7 are not associated with moraines or any other glacial indicator (Chadwick et al., 1997, p. 1,450; Hall and Jaworowski, 1999, p. 1,247). WR9 is a large, flat terrace northwest of Riverton on which the airport was built (Figure 25). The ages of these higher terraces are based on simple extrapolation of the linear incision rate of the upper Wind River from WR7 down to the river (Hancock et al., 1999), which makes the dating of WR7 especially crucial. If the date of 660 kyr is accepted, the extrapolated date for WR15, the highest terrace, is 1.7 Ma (Chadwick et al., 1997). That would imply that the very small WR15 is a remnant of approximately the 30th most recent glaciation, based on the Milankovitch cycle theory, which posits one every 100 kyr back to 900 kyr and one every 40 kyr from 900 kyr back through the 2.6 million years of the Pleistocene (Walker and Lowe, 2007). There are now supposed to be around 50 regularly repeating ice ages during the Pleistocene. But if the younger dates on WR7 are real, then WR15 is only 431 to 511 kyr (Hancock et al., 1999), which is much younger.

Higher Terraces Carved during Channelized Flood Runoff

If the glaciation explanation is unreliable for all but WR1 and WR3, then how do we explain the other terraces and terrace remnants? First, we must accept the results from the field, not the hypothetical inferences of Milankovitch cycles. Second, we must look for alternate explanations. One such theory is that they were created by late Flood-channelized runoff. Do the predictions of that theory explain the field data better than the uniformitarian glaciation theory?

WR7 really is the remnant of a pediment (Figure 22), a planation surface at the foot of mountains. Pediments in valleys would also be considered strath terraces. Pediments are not forming today but being destroyed by local erosion. Pediments appear to have formed by strong channelized flow down a given valley, cutting its sides to form planation surfaces (Oard, 2004b).

WR9 is a planation surface capped by coarse gravel (Figure 25), a small percentage of which is well-rounded quartzite rocks with percussion marks (Figure 26). WR9 formed in the center of the valley around Riverton. The closest source of the quartzite is central Idaho (Oard, 2008). Exotic rocks transported long distances and covering planation surfaces is not unusual; they have been explained by the late Flood runoff mechanism (Oard, 2008).

Other terraces observed in the Wind River region can be explained by this mechanism. If cut into the edges of mountains, they would be "pediments," and if cut across valley fill, they would be planation surfaces. Both occur at multiple levels in the upper Wind River Basin (Figure 27). Geologists claim that both pediments and planation surfaces in the Wind River Basin are strath terraces because both are cut into hard rock.

Adjacent basins, like the Bighorn Basin to the northeast, have similar features. That basin was eroded an average of 470 m (McMillan et al., 2006), leaving pediments along its edge and remnants of two planation surfaces in the central and northern parts of the basin. Similarly, in the channelized flow of the Flood, the top of a thick valley fill was eroded during uplift of the area. During erosion, planation surfaces were carved by fast currents leaving behind a lag of coarse gravel as the currents slowed. The erosion of the valley fill at the edge of the valley produced pediments with a coarse gravel cap. Increasing and decreasing

Figure 24. Close up of Lava Creek B ash.

Figure 25. WR9 northwest of Riverton upon which the airport is built.

Figure 26. A quartzite cobble with percussion marks from the gravel capping WR9.

Figure 27. Multiple planation surfaces or pediments in the upper Wind River Basin.

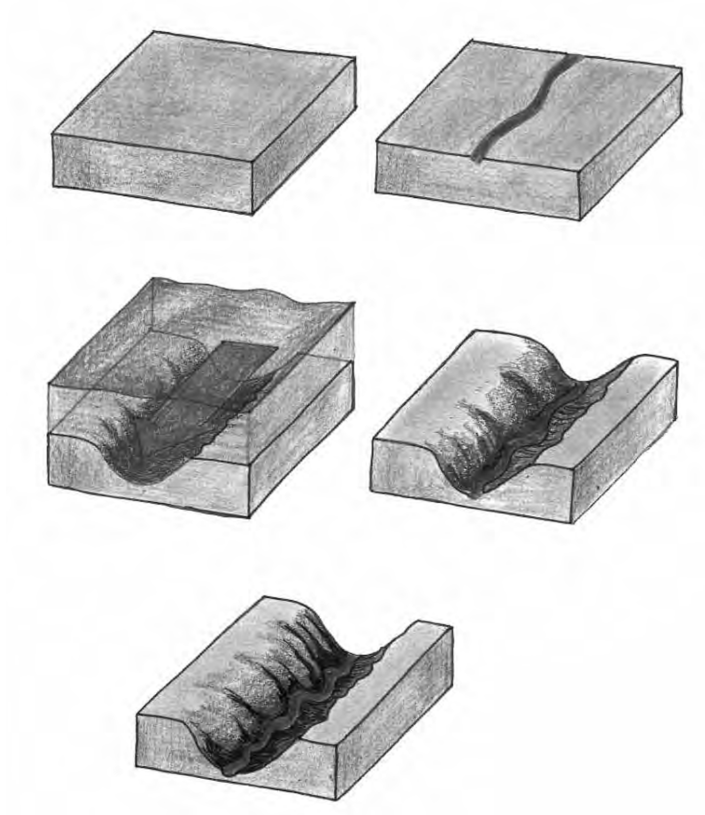
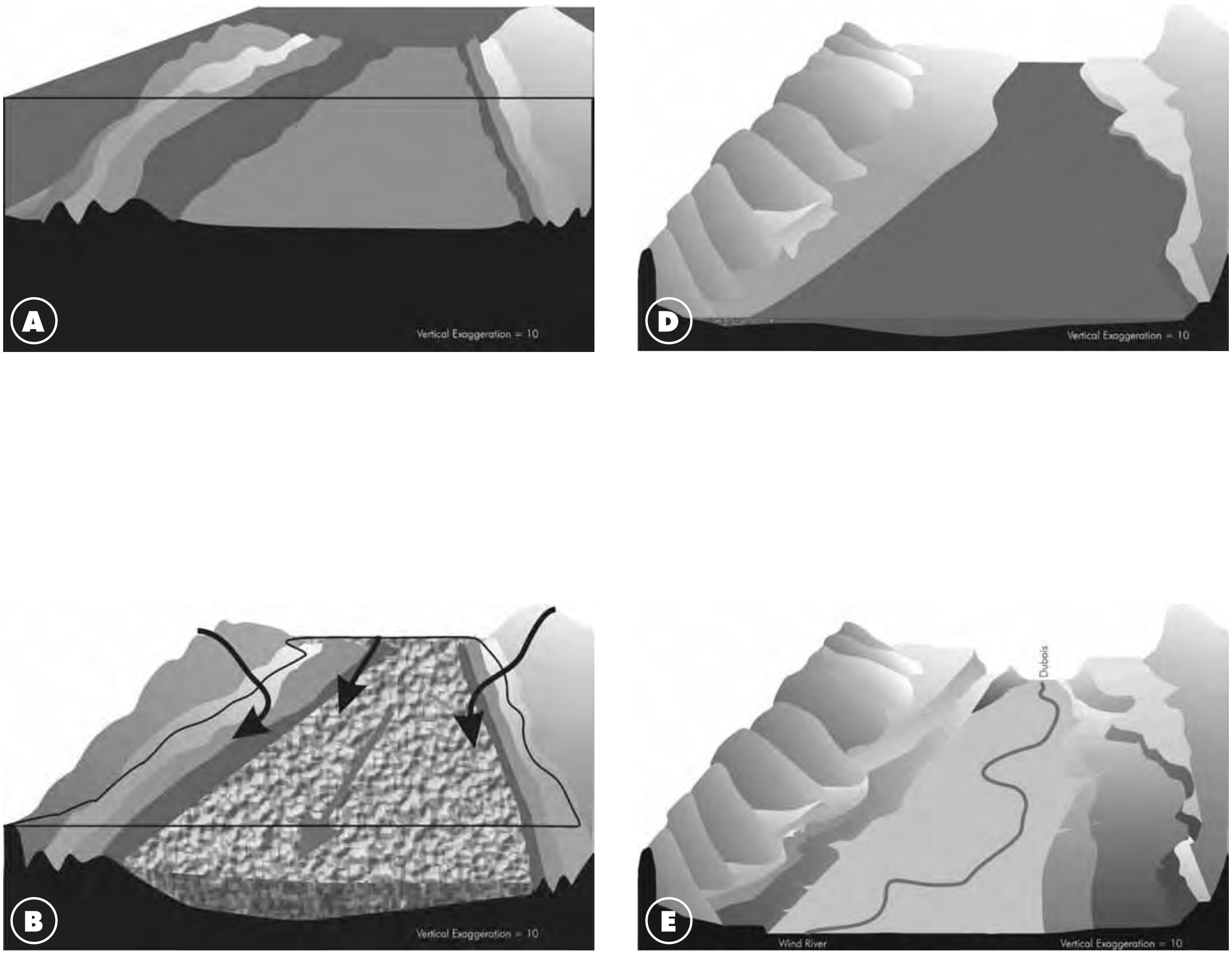


Figure 28. Comparison of the two highly disputed hypotheses for the origin of valleys around the year 1800 (drawn by Mrs. Melanie Richard). One group believed the valley came first through catastrophic erosion (left), while others believed the valley was eroded slowly over millions of years (right).

flow during channelized Flood runoff would result in multiple erosion events with planation surfaces and pediments at different altitudes, as observed in the upper Wind River Valley. The last erosion event produced the narrow river valley that exists today, which was modified by post-Flood glaciation with the forming of gravel-outwash terraces.

In summary, the "strath terraces" higher than WR3 are pediment and planation surface remnants formed during late Flood-channelized runoff and erosion moving southeast down the valley. The lower two, WR1 and WR3, were subsequently formed after the Flood by glacial outwash erosion and deposition during the post-Flood rapid Ice Age. Figure 28 presents a schematic on the origin of valleys, contrasting the uniformitarian and diluvial theories. Figure 29 is a schematic showing how Flood runoff could have formed pediments and planation surfaces in the upper Wind River Valley. Table 1 compares the uniformitarian explanation with the Flood runoff mechanism for the four significant upper Wind River terraces. The other terraces are small and insignificant, and terraces older than WR7 are not related to glaciation, the evidence of which supports only one ice age.



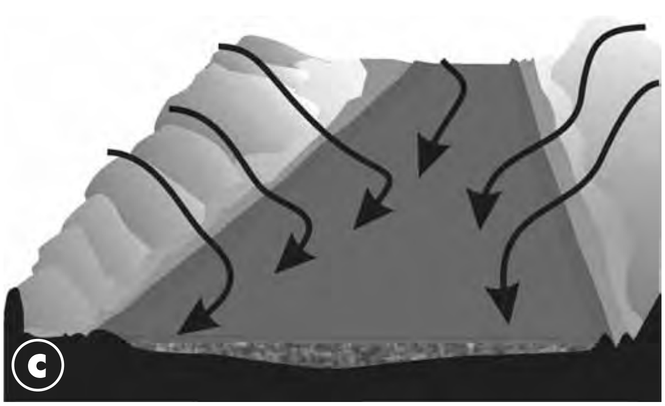


Figure 29. Schematic of valley erosion from Dubois to Bull Lake during the channelized-flow phase of the Genesis Flood (drawn by Peter Klevberg). (A) Thick sediments deposited in the Upper Wind River Basin. (B) As Floodwater continues to go down, sediments continue to accumulate (gray area in the valley represents the total Flood erosion). (C) As Floodwater channelizes, erosion develops. (D) Continued draining of the Floodwater with erosion and the formation of pediments and planation surfaces. (E) The Floodwater drained leaving behind multiple pediments and planation surfaces before glaciation develops.

Table 1. Comparison between the uniformitarian and Flood erosion/runoff explanations for the significant terraces in the upper Wind River valley of northwest Wyoming. The claimed Sacagawea moraine is similar to the Pinedale and Bull Lake moraines with three missing moraines earlier than the Sacagawea moraine. There is no evidence for glaciation for any terrace higher than WR7.

Terrace	Uniformitarian explanation	Flood explanation
WR1	Pinedale glacial outwash terrace	Lowest Ice Age terrace
WR3	Bull Lake glacial outwash terrace	Highest Ice Age terrace
WR7	Sacagawea glacial outwash terrace	Pediment remnant from Flood runoff
WR9	Glacial strath terrace remnant	Planation surface from Flood runoff

Strath Terraces Common Worldwide

Strath terraces are common in valleys all over the world. There are numerous strath terraces in the western United States (Hancock and Anderson, 2002; Merritts et al., 1994). Nearly all the terraces along rivers and streams draining the western Oregon coast range are strath terraces (Personius, 1995). As in the upper Wind River Basin, uniformitarian scientists propose formation by glacial deposition and erosion in the valleys over dozens of ice ages:

> The well-preserved strath-terrace sequences found in many river systems of western North America record discontinuous incision into bedrock throughout the late Quaternary. (Hancock and Anderson, 2002, p. 1,132)

Strath terraces are also common in the valleys that have dissected the Appalachian Plateau Province west of the Valley and Ridge Province of the Appalachians. The most prominent is called the Parker strath terrace and lies about 100 m above the bottom of the valleys (Oard, 2011). Figure 30 shows the Parker Strath terrace along the edge of the Cumberland Plateau of the southern Appalachian Plateau.

Strath terraces are also reported in Alaska, eastern Tibet, and eastern Bolivia (Montgomery, 2004); Taiwan (Shyu et al., 2006; Yanites et al., 2010); the Tien Shan Mountains (Molnar et al., 1994); along the Somme River of France (Merritts et al., 1994); and along the valleys of the western Andes of South America (Hall et al., 2008). These are just a small sample from the literature. Strath terraces likely are present by the thousands in valleys all over the world.

Strath Terraces Can Form after the Flood

Although the strath terraces higher than WR3 in the upper Wind River Basin are simply pediment and valley planation surface remnants of the Flood (Figure 29), this research shows that “strath terraces” also formed during Ice Age runoff. That is consistent with the literature. Since post-Flood valley erosion has been slight since the Flood, post-Flood strath terraces would be expected to be of limited extent and close to the altitude of the river.

Like the lower two terraces in the upper Wind River Basin, which vary between being strath terraces and gravel terraces, strath terraces can form in glaciated areas from the action of extensive meltwater. These would be near the valley bottom, as seen in the Upper Wind River Basin. In addition, strath terraces could have been cut during heavy, early-Ice Age rainfall. The above conditions may be responsible for some of the lower strath terraces west of the Oregon coast range (Personius, 1995) and in the western Olympic Mountains of Washington (Wegmann and Pazzaglia, 2002).

Small strath terraces could have formed after the Flood by two processes: (1) weathering of bedrock banks between the low and high water line (Montgomery, 2004; Stock et al., 2005), and (2) flood erosion along the banks (Crickmay, 1974).

Origin of Most Strath Terraces Unknown

Since the straths are remnants of flat, wide valleys carved in bedrock, their formation appears to represent a period of valley widening with little or no deepening. I believe the uniformitarian interpretation is close, but many strath terraces are remnants of valleys tens of kilometers wide! In the uniformitarian model, this would require a river similar to those of today to meander back and forth over a wide area, planing the bedrock to a flat surface *with little or no downward dissection* (Hancock et al., 1999, p. 42). This is mechanically inconsistent; meandering rivers typically are found in areas of low gradient and

Figure 30. The rolling Parker strath terrace (left arrow) west of the planation surface of the Cumberland Plateau (right arrow).

deposit sediment in a floodplain. Rivers in areas of higher gradient, which erode into bedrock, typically do not meander and tend to incise in deeper channels. The uniformitarian model simply assumes what they need, as indirectly admitted by Hancock and Anderson (2002, p. 1,134):

> Investigation of the valley-widening processes in rock-floored channels and of the controls on widening rates is sorely needed. However, lateral planation that far exceeds vertical incision over time is a key field observation that must be reproduced in this model.

The formation of a valley-wide planation surface seems difficult, if not impossible, by river erosion, since rivers normally cut downward and will cut laterally only during flooding and can leave strath terraces along the edge of the river over only small areas (Crickmay, 1974). To achieve large-scale terraces and valley-scale planation by this process would require much larger currents.

Although some strath terraces appear linked to river floods, especially during Ice Age runoff, most strath terraces are difficult to explain, especially when the area never underwent glaciation: "Despite the widespread use of strath terraces in fluvial and tectonic geomorphology, the conditions surrounding planation of a strath surface are not well understood" (Fuller et al., 2009, p. 467). This is especially the case for the relatively high strath terraces. Hancock and Anderson (2002, p. 1,132) write:

> The timing, duration, and mechanisms of strath terrace formation are difficult to infer solely from field observations because terrace sequences represent incomplete records, are difficult to date, and formed during fluvial conditions that differ from the present.

Note that they admit a violation of the principle of actualism. Some scientists believe the valley-wide bedrock was beveled during a time of increased sediment supply when the valley was at a higher level (Fuller et al., 2009). Others think strath terraces were formed by meander migration and cutoff (Finnegan and Dietrich, 2011). Still others state that they are caused by an as-yet-unknown factor that caused an accelerated incision rate (Hancock and Anderson, 2002). Accelerated uplift is suggested by others (Merritts et al., 1994).

Summary and Discussion

The two lower gravel-and-strath terraces in the upper Wind River Basin appear to be a result of deglaciation, and field evidence suggests both were cut during the same glacial episode. But that does not necessarily imply that the higher terraces were also a result of glaciation. Unfortunately, uniformitarians assume that to be the case, based on the circular reasoning application of Milankovitch cycles, which would include up to 50 episodes during the Pleistocene. This circularity again appears when geologists use the occurrence of strath terraces in other river valleys and basins to infer Pleistocene glaciation. An alternative explanation, supported by the higher terraces in the Wind River Basin, is planation and pediment formation during channelized runoff during the last stage of the Flood (Oard, 2004b, 2008). Those terraces higher than WR3 are pediments and planation surfaces that formed during high velocity, down-valley Flood erosion and runoff during differential vertical tectonics (Figure 29).

Since strath terraces are common worldwide, it is likely that the mid- to high-level, rock-floored terraces are pediments or planation surfaces also caused by Flood runoff. If so, these Pleistocene-aged terraces are best explained by the Flood. This implies that the post-Flood boundary is in the mid-Pleistocene, in some places, based on strath terrace remnants. This is the same location proposed by the late Roy Holt (1996) after extensive field research.

A mid-Pleistocene post-Flood boundary in the upper Wind River Basin is also suggested by the existence of the Lava Creek B ash between the bedrock and the coarse gravel cap on pediment remnants of WR7 (Figure 23 and 24). This ash is dated as mid-Pleistocene, 660 kyr in the uniformitarian timescale. Since it is from the last major eruption of the Yellowstone supervolcano, it demonstrates that the large Yellowstone eruptions occurred late in the Flood, not afterward. Since Yellowstone ashes are found across the western and central United States and are used to date fossils, this Flood date would have radical implications for the death of these fauna, if the identification of Lava Creek B ash at these distal locations is correct. The occurrence of Lava Creek B ash above fossils would suggest those organisms died in the Flood, while those found above the ash would likely have died after the Flood. Clearly, more information from other locales is needed, along with an in-depth analysis of tephrochronology.

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CRSQ: Creation Research Society Quarterly

JOC: Journal of Creation, Technical Journal, or Creation Ex Nihilo Technical Journal

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