# Long-Distance Flood Transport of the Nenana Gravel of Alaska—Similar to Other Gravels in the United States

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## Abstract

The origin and significance of the Nenana Gravel north of the Alaska Range is documented. The Nenana Gravel possesses similarities to other coarse gravels studied in the western United States, and even from the Appalachian Mountains. The long-distance transport of these gravels would have required large currents of high flow velocities. The necessity of such currents challenges uniformitarian explanations and is more readily explained within a Flood paradigm, mainly the Recessive Stage of the Flood.

## Introduction

It is common to find coarse gravel, defined as gravel, cobbles, and boulders, transported long distances away from mountain ranges (Oard, in press). This coarse gravel is commonly rounded to well-rounded, indicating the transporting agent was mostly water. Various types of mass flow could have been involved during part of the transport, especially when first eroded from the mountains.

This paper will document the long-distance transport of coarse gravel north of the Alaska Range and show that it is similar to far-traveled coarse gravel away from other mountain ranges in the lower 48 states.

### The Alaska Range

Alaska is considered a mosaic of tectonic terranes assembled by plate tectonic collisions (Muhs et al., 1987). The Alaska Range (Figure 1) is an arc-shaped, generally east-west trending mountain range 600 miles (965 km) long in southern Alaska that merges with the Wrangell and St. Elias Mountains on the southeast and the Aleutian Range on the southwest (Wahrhaftig, 1958). The Denali fault system runs parallel to the mountains of the Alaska Range and is 750 miles (1,200 km) long. The mountains are believed to have started uplifting from a land of low relief in the late Cenozoic about 5 to 6 million years ago, based on apatite fission track thermochronology and "geologic constraints" from basins to the north, such as the Nenana Basin, and to the south, at Cook Inlet (Fitzgerald et al., 1995). Thus, the Alaska Range is "young" within the uniformitarian paradigm.

The highest mountain in North America, Denali (formerly Mount McKinley) at 20,315 ft (6,194 m) above sea level (asl), lies within the western Alaska Range. Most mountains in the Alaska Range are much lower, with their crests averaging between 7,000 and 9,000 ft (2,135 and 2,745 m) asl.

**Figure 1. Shaded relief map of Alaska. The Alaska Range (arrow) is the arc-shaped mountain range that extends from southwest Cook inlet to near the Alaska-Canadian border. (From U. S. Geological Survey.)**

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The lowlands north and south of the Alaska Range are relatively low. The Tanana Basin to the north is a broad, swampy lowland with average elevations between 395 to 820 ft (120 and 250 m) asl (Bemis, 2004). These basins likely were caused by the subsidence associated with the uplift of the Alaska Range (Thoms, 2000).

## Gravels

### Coarse Gravel North of Alaska Range

Before the uplift of the Alaska Range, the Usibelli Group, consisting of five poorly consolidated formations, was deposited during the Oligocene and Miocene (mid to late Cenozoic) of the uniformitarian timescale. The Usibelli Group is about 1,965 ft (600 m) thick and consists of pebbly sandstone interbedded with coal and mudstone. Paleocurrent directions have been determined, especially from planar and trough crossbeds in sandstones and imbrication of oblong rocks in the gravel. They show south to southwest flowing paleocurrents (Bemis, 2004; Ridgeway et al., 1999). The Usibelli Group likely eroded from the Yukon-Tanana Terrane to the north and east.

The Nenana Gravel was deposited over the Usibelli Group, and the two units are separated by a "paraconformity," a postulated unconformity that shows no evidence of past erosion, over an area of 5,400 $mi^2$ (14,000 $km^2$) [Thoms, 2000]. Figure 2 shows the area of the current outcrops of the Nenana Gravel and their measured paleocurrent directions just north of the Alaska Range. The gravel, deposited in basins just north of the Alaska Range, is massive to thick-bedded, poorly consolidated, and well sorted (Bemis, 2004) (Figure 3). It is up to about 3,935 ft (1,200 m) thick at its type section east of Healy, which is on the main highway linking Anchorage to Fairbanks. The gravel thins northward to about 1,640 ft (500 m) just north of the Alaska Range foothills.

The coarse gravel consists of a wide variety of rock types. The lower part of the Nenana Gravel is dominated by sandstone, conglomerate, and volcanic rocks, while higher in the formation, plutonic and greenstone (metamorphosed basalt) clasts predominate. The different lithologies help reconstruct the depositional history. The lower Nenana Gravel was derived from sedimentary basins south of the Alaska Range. As the Alaska Range began to be uplifted, its igneous roots were unroofed, and the upper Nenana Gravels reflect those lithologies. Also, there was a drainage reversal: the southward flowing currents

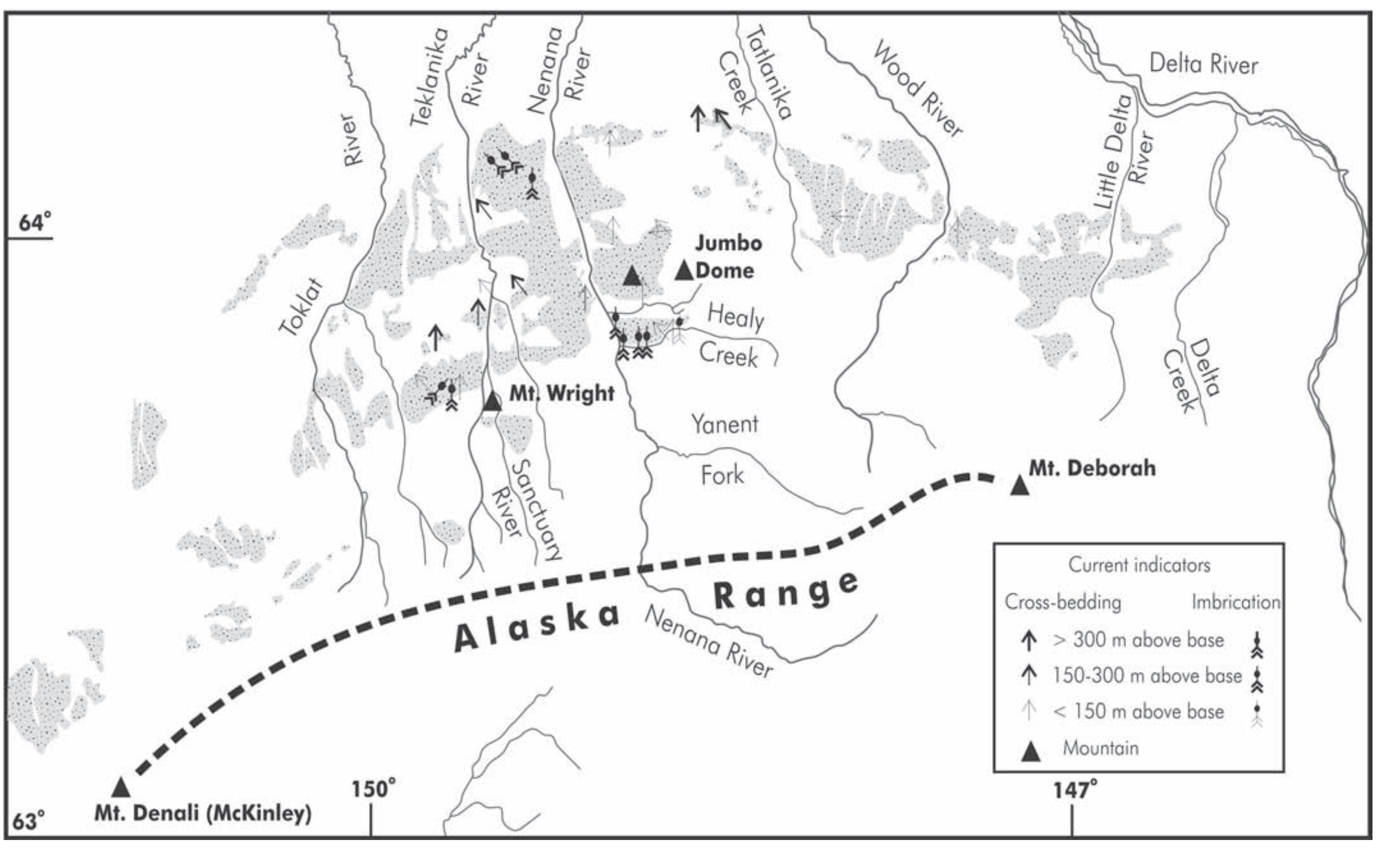



**Figure 2. Map of the Nenana Gravel outcrops with paleocurrent directions. Modified from Thom (2000, p. 31).**

**Figure 3. Bedded Nenana Gravel in road cut about 10 miles north of Healy.**

**Figure 4. Nenana Gravel about 3 miles north of Healy. Individual in center background provides scale.**

of the Usibelli Group changed to northward flowing water during deposition of the Nenana Gravel (Ridgeway et al., 1999). The gravels coarsen upward, yet fines northward (Thoms, 2000). They are also rounded to well-rounded (Ridgeway et al., 1999), indicating significant erosional action by water (Figure 4). The average size of the coarse gravel is 0.5 to 3 inches (1 to 8 cm) (Bemis, 2004) with the maximum clast size being nearly 18 inches (0.5 m) [Wahrhaftig and Black, 1958]. The Nenana Gravel contains interbedded sand and silt (Bemis, 2004; Thoms, 2000), with the rocks commonly coated by an iron patina (Wahrhaftig and Black, 1958). The gravel is dated as "Pliocene" (late Cenozoic) within the uniformitarian geological column (Thoms, 2000, p. 23).

The gravel is widespread and thick north of the Alaska Range and can be observed up to 60 miles (95 km) away from the crest of the Alaska Range (Thoms, 2000). As one drives north from Healy to Nenana, the flat surface of the Nenana Gravel becomes covered with loess, wind-blown silt. The gravel continues in the subsurface, as indicated by 2,460 ft (750 m) of Nenana Gravel in a well drilled about 15 miles (25 km) west of the town of Nenana (Thoms, 2000). The gravel is thought to underlie much of the Tanana basin (Thoms, 2000). After deposition, the formation was dissected by generally north-south valleys in which rivers now flow through water gaps (Bemis, 2004).

The Nenana Gravels are interpreted within the uniformitarian paradigm as coalescing alluvial fans and braided stream deposits (Ridgeway et al. 1999; Thoms, 2000). This paleoenvironmental designation is often carelessly applied by uniformitarians to explain sheet-like gravels transported away from mountains. Alluvial fans have a distinctive fan-shaped geomorphology and much of the sedimentation takes place by debris flows, which contain rocks of various shapes and sizes floating in a fine-grained matrix (Miall, 1996). Furthermore, braided streams that also flow on top of alluvial fans generally have a cut-and-fill texture (Miall, 1996). Thus, alluvial fans with braided stream deposits should exhibit rapid facies changes with a chaotic texture, such as observed on top of the Trollheim Fan in Death Valley (Miall, 1996). If the Nenana Gravel is an alluvial fan deposit, there should be a wide variety of angular to rounded rocks within the gravel, but the clasts found in the Nenana are actually rounded to well-rounded!

The morphology of the Nenana Gravel also contradicts the uniformitarian interpretation. When alluvial fans coalesce (a bajada) in front of a mountain range, one would expect that there would still be thicker areas in front of valleys (the fans) and thinner areas between the valleys. Although erosional processes would work to level the surface, the top of coalesced alluvial fans would not be flat but gently undulating in a transect parallel to the mountain range. But the top of the Nenana Gravel is flat (Bemis, 2004), more indicative of watery sheet flow deposition. Even where dissected, the Nenana Gravel forms *flat* or gently northward dipping plateaus and buttes (Thoms, 2000). Such features seem inimical to the uniformitarian paleoenvironmental interpretation.

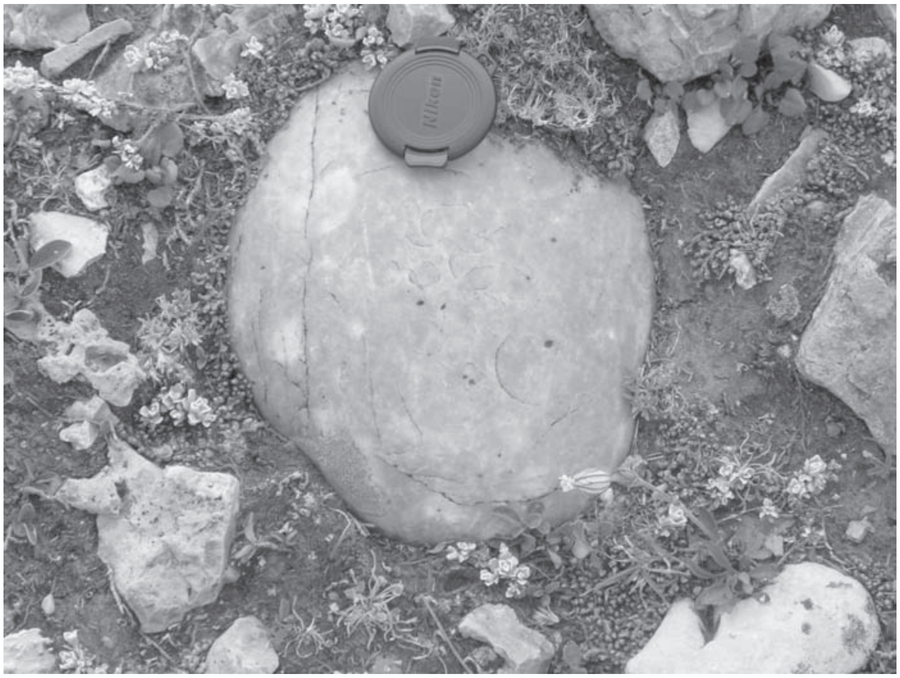
## Northern Rocky Mountain Gravels

The Nenana Gravel joins the list of other widespread, thick gravels that have been transported long distances away from mountain ranges in the lower forty-eight states.

The Rocky Mountains of northwestern Montana and central and northern Idaho, as well as the adjacent Canadian Rockies, are composed of a variety of rocks. One of the hardest is quartzite, but quartzite is a minor proportion of the sedimentary rocks. Quartzite is a very resistant metamorphic rock, formed by the recrystallization of sandstone under elevated heat and generally high pressure, probably caused by rock burial. It makes up about 10% of the Belt Supergroup—an extensive sedimentary deposit in the northern Rocky Mountains (Figure 5). Argillite, a slightly metamorphosed shale, makes up most of the rest of the Belt rocks. Quartzite sources are mostly found near the Montana/Idaho border and in central Idaho.

Well-rounded quartzite cobbles and boulders have been transported hundreds of miles both east and west from their sources in the Rocky Mountains (Hergenrather, 2006; Klevberg and Oard, 1998; Oard, in press; Oard and Klevberg, 1998; Oard et al., 2005; 2006a; 2006b; 2007). These gravel deposits range from as far away as western North Dakota and southwestern Manitoba to the Pacific Ocean! During transport the eroded quartzites were quickly rounded, and the turbulence of flow created percussion marks (semicircular cracks on the face of the clasts)


**Figure 5. Outcrop of Belt Formation and Idaho Batholith in the northern Rocky Mountains of northwest Montana, north and central Idaho, and northeast Washington. Quartzite makes up about 10% of Belt Formation with the metamorphic grade generally increasing westward.**



*(left)* Figure 6. Percussion marks on a quartzite boulder from the top of Red Mountain, northern Teton Mountains, northwest Wyoming. Lens cap (top center) added for scale.

*(below)* Figure 7. Locations of rounded quartzite gravel on the plains of northern Montana and adjacent Canada, east of the inferred source area located in the Rocky Mountains. Glacial till covers much of the area including most of the quartzite locations that are in situ. Only the western Cypress Hills and Flaxville plateaus and adjacent Wood Mountain plateau are considered unglaciated. Quartzite also occurs between the in situ outcrops in most of the area and is hardly weathered from the glaciation. Paleocurrent rose diagram (top center) shows west-southwest paleocurrents for the Cypress Hills Formation. Modified from Vonhof (1965).

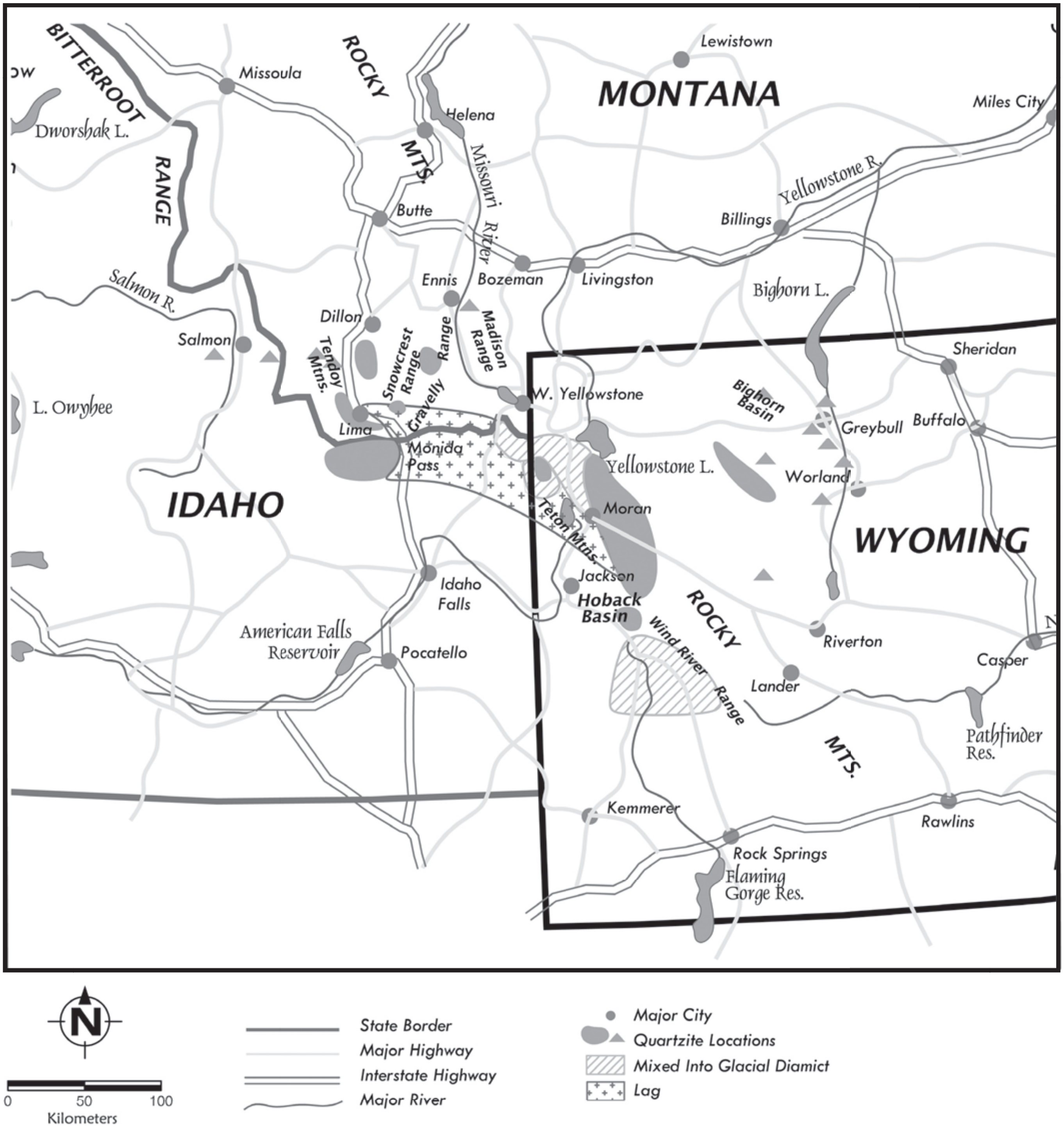



**Figure 8. Quartzite gravel locations in southwest Montana, northwest Wyoming, and adjacent Idaho.**

on most of the larger quartzite clasts (Figure 6).

Figure 7 shows well-rounded quartzites capping the highest two planation surfaces east of the Rocky Mountains in northern Montana and adjacent Canada. The gravels on the highest plateau are called the Cypress Hills Formation, while those on the lower plateau are called the Flaxville Formation. Since both rock units appear identical, I simply call them the "Cypflax" gravel, despite their different uniformitarian ages (Oligocene vs. early Pleistocene). Intermediate level "Cypflax" gravel

**Figure 9. Pressure solution marks on an iron-stained quartzite boulder from the top of Red Mountain, northern Teton Mountains, and northwest Wyoming. Lens cap (center) added for scale.**

also is present on the Wood Mountain Plateau, where in situ gravel is as much as 100 ft (30 m) thick (Leckie, 2006). Quartzite gravel is found extensively between and around these plateaus at lower levels, being eroded during the ice age and mixed with other types of rocks. The whole area was likely carpeted with a thin layer of quartzite gravel prior to ice age glaciation. The quartzite gravels beneath the glacial deposits in southern Saskatchewan and southwestern Manitoba are not shown in Figure 7, but are extensive (Whitaker and Christiansen, 1972). They are called the Empress Formation and can be found as far northeast as between Saskatoon and Prince Alberta, Saskatchewan (Dixon Edwards and Scafe, 1996).

Note the rose diagram in the top center of Figure 7. It shows the paleocurrent directions derived from the gravel and its sand interbeds, demonstrating that the quartzite was transported from the west-southwest. A more recent publication shows a direction more from the south-west or even south-southwest (Leckie, 2006). The average is from the southwest. Bedded quartzite layers, such as seen in the Rocky Mountains, do not outcrop on the High Plains, so the water current indicators demonstrate that the quartzites originated in the Rocky Mountains, the closest source to the southwest.

Since the outcrops plotted in Figure 7 are east of the Continental Divide, one would presume that the quartzite was eroded from the east side of the Rocky Mountains. However, the quartzite gravel plotted on Figure 7 is high grade and is found west of the continental divide. Amazingly, these very hard, vitreous, high-grade quartzites on the plateaus of the High Plains originated west of the Continental Divide. According to Leckie and Cheel (1989) and Leckie (2006), the quartzites likely originated from the western Rocky Mountains, generally near the Montana-Idaho border or from central Idaho. That certainly leads to the question of how these rocks were transported over the Continental Divide, and then for hundreds of miles out onto the plains. The uniformitarian explanation fails on several fronts.

Note the scale in the lower left of Figure 7. If the quartzite gravel in extreme eastern Montana and western North Dakota originated from near the North Fork of the Flathead River (shown on Figure 7), then it was transported about 450 miles (720 km) up and over the Continental Divide and down a low slope well out onto the High Plains. However, if the source was in central Idaho, then the quartzites were transported even farther—more than 600 miles (1,000 km). Alden (1932) claimed that these distinctive rocks can be traced as far as 145 miles (230 km) farther east of the northeast corner of Montana along the 49th parallel. This means these quartzite rocks in North Dakota, as well as in southwest Manitoba and between Saskatoon and Prince Albert, Saskatchewan (Dixon Edwards and Scafe, 1996) have been transported at least 745 miles (1,230 km), if their source is central Idaho. Quartzite rocks also have been transported well away from the Rocky Mountains of Canada northeastward into northern and central Alberta (Dixon Edwards and Scafe, 1996).

Quartzite gravel is also extensive in southwestern Montana, northwestern Wyoming, and adjacent parts of Idaho (Figure 8). This is an area of crustal extension causing high mountains and deep paleovalleys that are partially filled with sedimentary rocks and volcanic material. Well-rounded quartzite cobbles and boulders accumulated mainly in deep paleovalleys between the mountain ranges and reach thicknesses of 3 miles (5 km). One of the most interesting locations for these quartzites is on top of Red Mountain, one of two flat-topped mountains (a remnant of a planation surface) in the northern Teton Mountains of northwestern Wyoming (see Figure 6). An especially widespread and thick outcrop of rounded quartzites has accumulated east and northeast of Jack-


**Figure 10. Locations of quartzite gravels in western Idaho, Oregon, and Washington.**

son, Wyoming. Love (1973) estimated the original volume as 600 mi$^3$ (2,500 km$^3$), but much of it has been eroded since the original deposition (Love, 1973). Burial pressure has fractured and caused pressure solution marks on most of these quartzites (Figure 9). Some of the quartzite boulders in northwest Wyoming are quite large. One in the northern Teton Mountains was measured at 58 inches (1.4 m) long (Love, 1973). Quartzites were transported east into the eastern Bighorn Basin, a distance of about 300 miles (500 km) from their source in Idaho. Love (1960) reported that quartzites were transported all the way to the southwestern Powder River Basin, about 75 miles (120 km) farther east. Thus, the total transport distance from central Idaho is nearly 400 miles (640 km).

Quartzite cobbles and boulders also were transported and deposited west of the Rocky Mountains into Washington and Oregon (Figure 10). There are numerous sites, some that extend as far as the Pacific Ocean, up to 440 miles (700 km) from the nearest source in Idaho (Oard et al., 2006a). The quartzites are found at several locations on top of the Wallowa Mountains. Well-rounded quartzite cobbles, a few with percussion marks, are even found in the Puget Sound area, mixed in with the glacial debris (Mustoe, 2001). One of the most impressive locations for well-rounded quartzite gravel is on top of Gold Hill, about 30 miles (45 km) north of Burns, central Oregon. Gold Hill has an altitude of 6,425 ft (1,959 m) asl. A second location in central Oregon is about 40 miles (60 km) west-northwest of Gold Hill in the Beaver Creek drainage, 9 to 15 miles (15 to 25 km) east of Paulina. These locations in central Oregon make it difficult for uniformitarian scientists to attribute the quartzites to "ancestral" Columbia, Clearwater, Salmon, or Snake Rivers. Well-rounded quartzites are found on every basalt lava ridge in southwest Washington east of the Cascade Mountains up to an altitude of 4,000 ft (1,220 m) on the Horse Heaven Hills.

## Arizona Rim Gravels

Although not as laterally extensive as the quartzites spread from the northern Rocky Mountains, large quartzites and other exotic rocks also are found in Arizona (Figure 11). These rocks are the Rim Gravels of the Mogollon Rim in central and northern Arizona, along the southwestern edge of the Colorado Plateau (Oard and Klevberg, 2005). They are often found on the highest terrain of the Mogollon Rim, generally on ridge crests at elevations of 6,900 to 7,900 ft (2,100 to 2,400 m) (Scarborough, 1989).

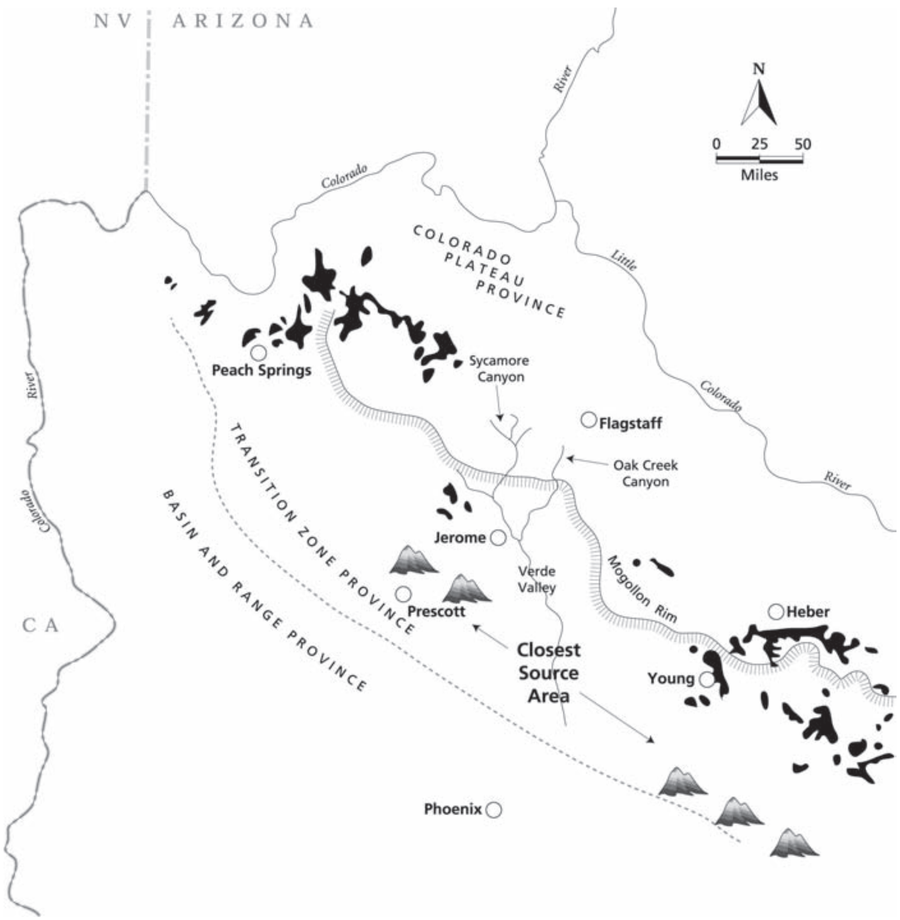



**Figure 11. Location of Rim Gravel in Arizona in black. Physiographic provinces of Arizona also are shown. Nearest sources for the Rim Gravel along the northwest and east-central location Mogollon Rim pointed out, but this does not necessarily mean the gravels originated from these locations, since there are many sources to the south and west. Drawn by Mark Wolfe and modified from Elston and Young (1991, Figure 1).**

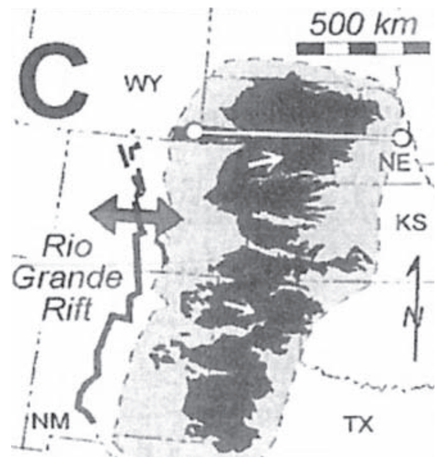



**Figure 12. Distribution of the Ogallala Group on the central and southern High Plains of the United States, modified from Thornbury (1965) and Heller et al. (2003). Map shows observed (black) and inferred (shaded) original distribution. White arrows show generalized paleocurrent directions.**

The lithology of the gravels varies considerably. There is a significant amount of exotic quartzite. The quartzites observed are well rounded, large, and display percussion marks. The largest quartzite I have personally observed is 24 inches (60 cm) long and 20 inches (50 cm) across, with abundant percussion marks. Along with the exotic rocks, there are also many clasts derived from local "Paleozoic" rocks, especially sandstones.

One of the most amazing characteristics of the Rim Gravels is that current indicators show paleocurrents flowed from areas to the south or west that are now lower than the elevation of the gravels (Elston and Young, 1991; Peirce et al., 1979). The closest source for quartzite and other igneous and metamorphic exotic rocks of the Rim Gravel in the northwest Mogollon Rim is near Prescott, about 50 miles (80 km) to the south (Koons, 1948; 1964). The closest source for the east-central Rim Gravel is a short distance from the rim, but the rocks could have originated at any number of locations farther south and west, where the exotic lithologies outcrop extensively, especially in the mountain ranges. Clearly, a large erosional event must have occurred over the Basin and Range Province of southwestern Arizona.

## The Ogallala Group

An extensive deposit of predominantly sandstone with dispersed interbedded coarse gravel or conglomerate was deposited east of the central and southern Rockies across the High Plains of the United States (Frye et al., 1956; Heller et al., 2003; McMillan et al., 2002; Thornbury, 1965). These sedimentary rocks are the Ogallala Group and are composed of a wide variety of igneous and metamorphic rocks, especially quartzite and vein quartz (Bretz and Horberg, 1949; Swinehart et al., 1985). The thickness of the Ogallala Group ranges from about 800 ft (240 m) to less than 3 ft (1 m). The sand and gravel extend from southern South Dakota into Texas. It was originally more extensive, but erosion has removed part of the unit, especially along the eastern fringe (Figure 12). The present area is around 300,000 mi$^2$ (768,000 km$^2$), while the inferred maximum area was 590,000 mi$^2$ (1.5 million km$^2$).

Cobbles and boulders of the Ogallala gravel are found in central Texas, generally on top of higher areas, such as interstream divides (Byrd, 1969; 1971). The gravel is not associated with well-developed river terraces. The gravel near Uvalde is found 400 to 1,000 ft (120 to 300 m) above the Rio Grande River, indicating much channelized erosion following Ogallala deposition. Based on the interfluve outcrops in central Texas, the Ogallala gravel has been transported about 500 miles (800 km) from its nearest source in central New Mexico (Byrd, 1971).

### Appalachian Mountain Gravels

The long-distance transport of resistant rocks also has occurred on either side of the Appalachian Mountains in the eastern United States. The gravel, often found at the highest elevations, has been given many different names. The resistant gravel west of the Appalachian Mountains is generally called the Lafayette Gravel. It is found in scattered upland locations over a wide area east of the Mississippi River Valley, from the Ohio River in the north into the southern states (Autin et al., 1991; Ehlers, 1996; Thornbury, 1965). The original extent of the gravel is enigmatic, since so much of it has been eroded (Bresnahan and Van Arsdale, 2004). The larger rocks in the gravel are typically iron stained and composed mostly of chert, a form of silica similar to quartzite. Quartzite, sandstone, and vein quartz are minor constituents of this gravel (Note: Vein quartz forms by hydrothermal deposition within cracks in rocks and is generally white colored). The gravels are rounded to subrounded and up to 4 inches (10 cm) in diameter. A significant amount of finer-grained material accompanies the gravel. It appears that a regional sheet of gravel once covered a planation surface (the Lexington Plain) that extended across much of the area west of the Appalachians, in some places even beyond the Mississippi River (Autin et al., 1991; Potter, 1955b; Thornbury, 1965). After deposition of the gravel, the area was dissected by channelized erosion.

The Lafayette Gravel shows paleocurrent directions toward the northwest. According to Ehlers (1996) and Thornbury (1965), the Lafayette Gravel was transported from the Appalachian Mountains westward as far as the Mississippi River. Potter (1955a; 1955b) noted that the sand and some of the rocks in the gravel originated from the Blue Ridge Mountains, while other clasts likely were eroded from local sources. The distance from the Mississippi River in western Kentucky eastward to the Blue Ridge Mountains is about 500 miles (800 km). So, the gravel and finer-grained material has been transported as a sheet a long distance over a low slope.

Resistant gravels also were deposited east of the Appalachian Mountains, and now cap the highest terrain. For instance, a sheet-like deposit of gravel around 25 to 30 ft (7 to 9 m) thick covers approximately 600 mi$^2$ (1,530 km$^2$) of the coastal plain of southern Maryland (Schlee, 1957). There are also some isolated upland gravels on the Virginia coastal plain. Upland surfaces near the coast from northeastern Maryland, Delaware, southeastern Pennsylvania, and New Jersey are also covered by the Brandywine and Bryn Mawr Gravels (Owens and Minard, 1979; Pazzaglia, 1993; Stose, 1928).

Sand with quartzite pebbles also has been found south of the Appalachian Mountains in Florida (Froede, 2006). These deposits stretch as far south as the northern Florida Keys, where they are found in the subsurface by drill holes. Such quartzites are widespread and consistently about 1.5 inches (3.8 cm) long with some up to 3 inches (7.7 cm) in their longest dimension. The quartzites appear to have been transported more than 650 miles (1,040 km).

### Widespread Gravels Are Common Worldwide

Long-distance transport of resistant rocks as gravels has occurred worldwide from many mountain ranges. Well-rounded boulders up to 3 feet (1 m) in diameter were spread southwest from the Zagros Mountains, Iran, up to 15,000 feet (4,575 m) thick (Oberlander, 1965, pp. 29-36). Conglomerates were shed southward all along the south edge of the Himalaya Mountains and formed the upper Siwalik Formation (Gansser, 1964, p 246). Coarse gravel also was spread south of the Pyrenees Mountains (Riba, 1976). The variables of transport, deposition, and erosion often differ from those described above; lithologies, current velocity, and local tectonics all vary. But there is one common theme; the long-distance transport of gravel is a global theme, much more than would be expected from river erosion over millions of years.

## Uniformitarian Challenges

The widespread, thick gravels that show evidence of transport over hundreds of miles in water currents of tremendous velocity in regional-scale sheets presents a serious challenge to the uniformitarian paradigm. Several hypotheses have been invented to explain such observations. For the gravels on the High Plains, uniformitarian scientists have appealed to rivers, either in a confined valley that has since disappeared, or within a very wide braided stream (Leckie, 2006; Vonhof, 1965). However, rivers cannot transport gravels many hundreds of miles from their source unless there is a dramatic gradient to provide sufficient energy to move the larger clasts (Klevberg and Oard, 1998). Another problem for uniformitarians is the evidence of the source existing west of the present continental divide. Erosion, either occurring prior to or simultaneously with the sheet deposition, created four large planation surfaces, finally eroding the plains down to the present elevation of many of the rivers, approximately 2,500 ft (760 m). The uniformitarian scientists do not consider various types of mass flow mechanisms, such as debris flows or hyperconcentrated flows, which may have been significant close to the Rocky Mountains (Klevberg and Oard, 1998).

Recognizing that rivers could not have deposited the cobble and boulders over such distances, a few uniformitarian geologists have proposed that the Sweetgrass Hills and Bears Paw Mountains between the Rocky Mountains and the Cypress Hills and Flaxville Plateaus were uplifted, which would have provided a "northeastward gravel boost" (Leckie and Cheel, 1989). But this hypothesis seems to be nothing more than special pleading. It relies on the gravels first reaching these small mountains, coinciding precisely with their uplift (Oard et al., 2006b). The Sweetgrass Hills are 60 to 90 miles (100-150 km) east of the Rocky Mountains, while the Bears Paw Mountains are 125 miles (200 km) east of the Rockies. Both are relatively small mountain ranges. Any "boost" would have had to push billions of quartzite cobbles and boulders at least several hundred miles farther east. One would expect significant amounts of quartzite boulders and cobbles in these areas, left from the "great gravel boost." There are few high-grade quartzites left around these mountain ranges. Furthermore, if the uplift of these hills provided a gradient "boost," the final gravel deposits should include significant amounts of those local lithologies, but they do not.

There have been four uniformitarian hypotheses invented to account for the huge volume of quartzite gravel transported from central Idaho through southwest Montana and adjacent Idaho into northwest and north central Wyoming (Oard et al., 2006b). Only one is considered viable today: the eastward transport by alluvial fans and/or rivers (Janecke et al, 2000; Lindsey, 1972). Could rivers and local alluvial fans have really transported large quartzites from central Idaho to as far east as Jackson Hole and the Bighorn and Powder River Basins—over 400 miles (640 km)? There is no published quantitative support for this idea. Neither is there any explanation of why the range of local lithologies all along the "paleorivers" is absent in the gravels, which are more than 90% quartzite (Love, 1973). The current altitude of the source area is about the same or even a little lower than that of the final deposits in northwestern Wyoming. Therefore, the present gradient cannot provide the energy needed to move the large clasts over such great distances. If the energy came from the gradient, the source area altitude in central Idaho would have to be over 20,000 ft (6,100 m) high (Klevberg and Oard, 1998).

River transport by some "ancestral" Columbia, Salmon, Clearwater, or Snake River is the suggested mechanism to account for the quartzite gravels in Washington and Oregon (Fecht et al., 1987). These hypothetical rivers have been described as "torrential" flows (Allen, 1991). However, the "ancestral river" hypothesis cannot account for the quartzite gravels found on high ridges on the eastern side of the Cascade Mountains, in the Puget Sound area, or the quartzite boulders found in central Oregon. The regional distribution suggests a regional sheet flow, followed by mountain uplift (carrying quartzite rocks to the tops of mountains), followed by channelized flow and erosion of the gravels into the present-day remnants (Oard et al., 2006b).

Other gravels are also problematic. Byrd (1971, p. 7) stated that the origin of the Ogallala (Uvalde) gravel is a major problem.

> A major problem of origin and history of the Uvalde gravels exists because there is no apparent direct connection between the Uvalde gravels and existing drainage in central Texas. Transportation of gravels of such large size is beyond the competence of existing rivers. No source for such coarse siliceous gravels exists in the major basins of present central Texas streams.

Uniformitarian scientists have known about the Rim Gravel for at least 80 years (Koons, 1948). However, there are conflicting interpretations of the ages and origins of the deposits (Holm, 2001). A tabular-shaped, surficial gravel deposit capping an erosion surface, which was subsequently eroded into erosional remnants, is the simplest explanation yet is singularly difficult to accommodate in any uniformitarian scenario because that style of deposition is not one seen in modern environments.

Ray (1965, p. 22) summarized the relative geological events related to the Lafayette Gravels, and the controversy over their origin.

> Factors causing dissection of the Lexington Plain and deposition of the present high-level gravel deposits have been the subject of much speculation. The terrain now consists of a series of widespread dissected gravel-capped erosional remnants and, near the major stream valleys, gravel-mantled bedrock benches.

Uniformitarian scientists have had considerable trouble understanding the gravels east of the Appalachians. Pazzaglia (1993, p. 1,617) stated:

> The origin, age, and correlation of middle Atlantic upper Coastal Plain and Fall Zone…fluvial deposits, long thought to represent proximal facies of a well-known post-Oligocene marine sequence in the Salisbury Embayment…have challenged geologists for more than a century.

The "fluvial deposits" are represented by the gravels. Since uniformitarian geologists assume a river transported the gravel, they simply consider the deposits as fluvial. That may be a large part of their interpretive problems.

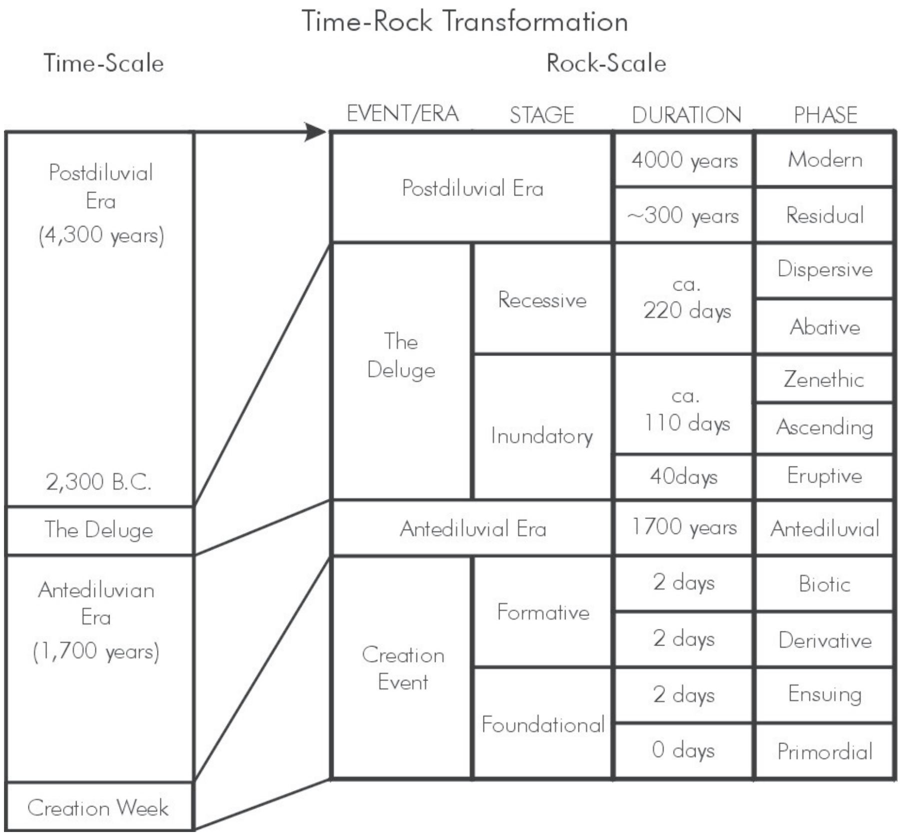



**Figure 13. Walker's (1994) biblical geological model (modified by P. Klevberg).**

## Flood Explanation

The Recessive Stage of the Genesis Flood (Walker, 1994) provides an elegant, simple explanation of all of these gravels, and subsequent erosion. During the Recessive Stage, large-scale currents were moving as sheets, especially on "shallow continents" (Barnette and Baumgardner, 1994). This is called the Abative or Sheet Flow Phase in Walker's (1994) model and resulted in sheet erosion and widespread high-energy deposits (i.e., gravels). Then as more mountains and plateaus emerged, the sheets were transformed into the channels of the Dispersive or Channelized Flow Phase (Figure 13), which would have bisected the gravel sheets.

The energy of the currents is seen in the presence of percussion marks on many of the hard quartzite clasts, especially on those capping the Cypress Hills. It takes a powerful blow to produce a percussion mark on hard quartzite. One possible source of these marks is saltation, a process by which large rocks "bounce" along the bottom of a channel because the current energy is not quite high enough to carry them in suspension. As the rocks are briefly carried upward during fast, turbulent stretches, they then crash back to the bottom, often impacting each other (Klevberg and Oard, 1998). Percussion marks imply turbulent, catastrophic flow. Because of the catastrophic conditions required for their formation, percussion marks rarely form in modern environments.

The velocities of those currents can be calculated by open-channel flow equations used in civil engineering. Percussion marks indicate that small to medium rocks were briefly taken up into suspension in highly turbulent flows (Figure 14). There is a relationship between the horizontal and vertical components of the velocity of rocks falling from suspension, if the maximum rock size can be estimated. It is important to note that estimates of current velocity are of the minimum speed. The minimum current speed required to lift and move a bullet-shaped rock 6 inches (15 cm) across, is over 68 mph (110 kph) with a minimum water depth of 180 ft (55 m). This velocity is about three times faster than the fastest flash floods (Klevberg, 1998; Klevberg and Oard, 1998). It approaches the maximum velocity of water flowing from large dam breaches, such as the one that caused the Lake Missoula flood (Oard, 2004). In addition to these parameters of depth and velocity, the current flowing off the Rocky Mountains must have been hundreds of miles (over 500 km) wide, given the original uneroded extent of the gravels (central Canada to northern Montana). No uniformitarian model can account for such an event. The gravels are powerful evidence for the Flood (Oard et al., 2007).

Furthermore, the Rocky Mountain gravels are not unique. Similar deposits are found all over the world. Erosion of the High Plains of Montana and adjacent Canada indicates that after the Cypress Hills Formation was deposited on its planation surface that subsequent erosion cut the land surface down as much as another 2,500 ft (760 m), forming three more planation surfaces during the process, before cutting the river and stream valleys (Alden, 1932). This sequence of events is what is expected during the Recessional Stage of the Flood (Walker, 1994).

### Implications for the Flood/Post-Flood Boundary

Deposition of the gravels and the accompanying erosion occurred late in the uniformitarian timescale—during the "Cenozoic," especially the "late Cenozoic" (Bresnahan and Van Arsdale, 2004; Elston and Young, 1991; Holm, 2001).

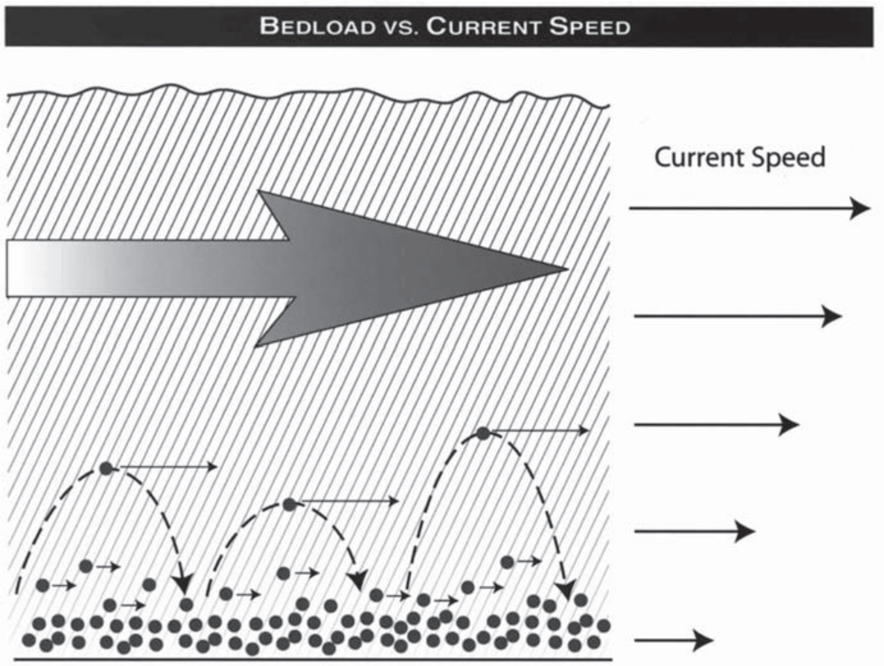



**Figure 14. Schematic of turbulent gravel transport in high velocity water. The large rocks are dragged along the bottom as bedload, while the small- to medium-sized rocks are briefly carried up into suspension before crashing back down into the bedload. Drawing by Mark Wolfe.**

The evidence strongly suggests that the gravels were deposited during a period of tremendous tectonic activity but while the mountains were still submerged beneath the Floodwaters (Oard, 2001a; 2001b; Psalm 104:5–9). Erosion would have diminished greatly in emergent areas. This implies the rapid vertical uplift of the mountains, probably accompanied by the subsidence of the ocean basins (Oard, in press). Since the gravels and the subsequent channelized erosion would mark the end of the Recessive Stage of the Flood, these events are a good indication of the Flood/post-Flood boundary, regardless of their uniformitarian "age." In many cases, this boundary would be equivalent to the late Cenozoic.

These long-transported coarse gravels are but one criterion that indicates that the Flood/post-Flood boundary is in the late Cenozoic, likely the very latest Cenozoic in most areas (Oard, 2007).

## Summary

The widespread, thick, coarse Nenana Gravel adds to the growing list of such gravels that were transported long distances during the late stages of the Flood. No uniformitarian hypothesis has yet come close to explaining the features of these deposits. But, the details of these gravels are easily explained by the Recessional Stage of the Flood (Walker, 1994). Sheet flow eroded the land, forming planation surfaces over broad areas and at multiple levels. Gravel lag deposits were laid down on these surfaces, after having been transported hundreds of miles from their source. Sometimes, the gravel filled deep paleovalleys, such as are found east and northeast of Jackson, Wyoming. Ongoing uplift carried rounded rocks to the tops of mountains, such as the Teton Mountains of northwest Wyoming and the Wallowa Mountains of northeast Oregon.

As more and more mountains and plateaus rose above the Floodwater, channelized flow rapidly carved valleys, canyons, and water gaps. It also eroded the planation surfaces and their gravel caps, leaving scattered remnants of the gravels, often at high elevations on top of plateaus and ridges. The gravels and erosional surfaces are powerful evidence of the work of the global Flood.

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