Deposits Remaining from the Genesis Flood: Rim Gravels in Arizona

Michael J. Oard and Peter Klevberg*

Abstract

Well-rounded coarse gravel provides clues to the depositional process. The coarse gravel of the Mogollon Rim in central and northern Arizona, called Rim Gravel, was examined at two widely separated and representative locations. Further characteristics of the coarse gravel was obtained from the literature. The coarse gravel occupies the highest terrain in the region and is very coarse in east-central Arizona. It is deduced that this coarse gravel was deposited as a sheet and eroded into remnants during the Recessional Stage of the Genesis Flood. We conclude that the Rim Gravel provides evidence that the Flood/post-Flood (D/P) boundary corresponds to the stratigraphic location of rocks termed "late Cenozoic" in the uniformitarian geological column in this part of the western United States. This interpretation is relevant to theories for the formation of many notable geomorphic features, including the Grand Canyon of the Colorado River.

Introduction

Gravel, cobbles, and boulders contain information on the depositional process. They are lumped together and called coarse gravel. Sometimes paleocurrent indicators are present, such as clast imbrication and cross-beds. The degree of rounding of the coarse gravel determines the amount of action by water. Well-rounded coarse gravel is an indicator of significant transport by water during some time in its history. The larger the clasts in the deposit usually the stronger the current needed to transport the coarse gravel. If the coarse gravel is lithified within a matrix, it is called a conglomerate. There are clast-supported and matrix-supported coarse gravels. In the former, the rocks are touching each other with the matrix filling the voids, while in the latter the rocks are almost entirely surrounded by matrix.

Many (if not most) deposits probably have complex histories, and this is likely the case for the Rim Gravel. For example, material when first eroded may be transported via mass wasting (a debris flow, landslide, slump, etc.). As transport continued, and with the addition of water, the material could have been carried in traction at the bottom of the flowing water. The rounding of coarse gravel would more likely occur during this process rather than from mass wasting. It is also possible that the material was eroded by water, rounded, and then mixed in with fine-grained sediment to become matrix supported at deposition. The fine-grained sediment between clasts could have resulted from the breaking up of subjacent material *in situ* or the erosion of finer-grained upstream substrate during the transport process. Regardless, rounded coarse gravel is an indicator of the action of water.

Uniformitarian scientists would normally interpret rounded rocks as the result of a river or beach process. When they observe rounded rocks, they have a tendency to interpret them as fluvial (Miall, 1996). Generally, one does not encounter littoral (along beaches) environmental interpretations of rounded coarse gravels. Creationist geologists also expect much rounding of rock during the Deluge.

---

* Michael J. Oard, 34 W. Clara Ct., Bozeman, MT 59718
Peter Klevberg, 512 Seventh Avenue North, Great Falls, MT 59401
Accepted for publication: June 22, 2004

So, the latter need to carefully examine the characteristics of the coarse gravel to be able to distinguish between a Flood-laid coarse gravel and one laid down in the postdiluvian (post-Flood) period.

One of the distinguishing processes between river deposits and diluvial deposits could be the locations of the coarse gravel deposits. The most intriguing locations are the well-rounded coarse gravels found atop plateaus and mountain ranges, especially in situations where the lithologies do not outcrop in the landform. Uniformitarian geologists would simply conclude that the coarse gravel was the remnant of an ancient river, but they rarely analyze their deduction in depth. This is where the diluvialist should examine other properties of the coarse gravel, such as its lithology, areal extent, geomorphology, and texture, to see if the deposit matches products of modern fluvial processes.

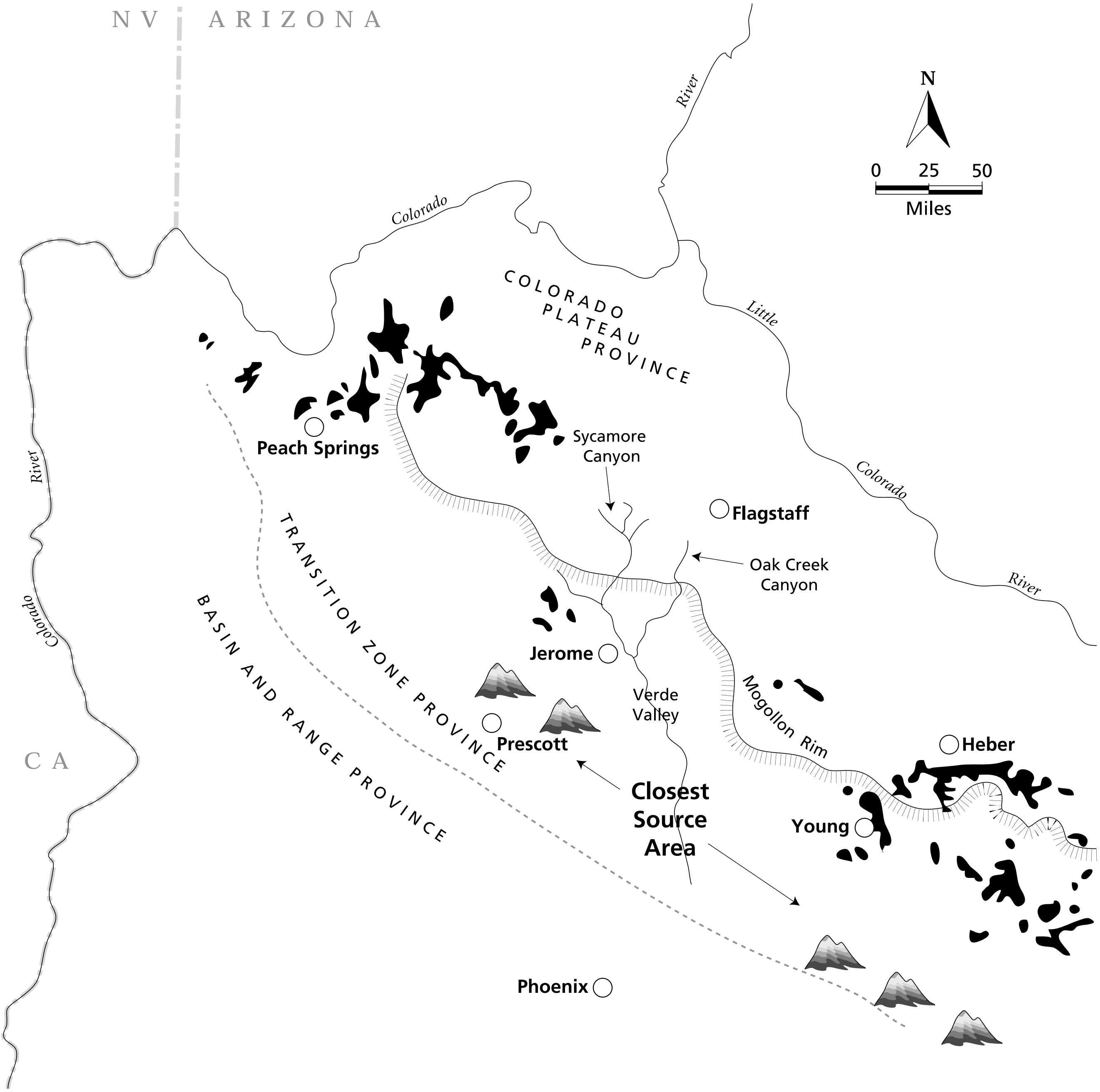

Figure 1. Location of Rim Gravel in Arizona in black (redrawn by Mark Wolfe after Elston and Young, 1991, Figure 1). Physiographic zones of Arizona are also shown. Nearest sources for the Rim Gravel along the northwest and east-central location Mogollon Rim pointed out, but this does not necessarily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

This paper reports on coarse gravel from the southwest rim of the Colorado Plateau in Arizona. This rim is called the Mogollon Rim (McKee, 1951; Young and McKee, 1978) and represents the boundary between the Colorado Plateau and the Transition Zone of mountains and valleys to the southwest. Figure 1 shows the three physiographic zones of Arizona. This rim is a general northwest-southeast escarpment that extends from northwest Arizona into east-central Arizona (Figure 2). It is the edge of a broad plateau-like feature to the northeast. The coarse gravels on and near the Rim are called Rim Gravels (Peirce et al., 1979). This article represents a literature search and a reconnaissance field description from two locations suitably representative but far apart in northwest and east-central Arizona.

Observations of Rim Gravel

Rim Gravel was observed at two widely spaced locations along and near the Mogollon Rim. These locations represent the largest deposits of Rim Gravel. The first location described is in northwest Arizona northeast of Peach Springs on the eastern Hualapai Indian Reservation. The second location is in east-central Arizona southwest of the town of Heber (see Figure 1 for locations). The appendix provides a description of the coarse gravel at these two locations.

Characteristics of Rim Gravel

Uniformitarian scientists have known about the Rim Gravel for at least 80 years (Koons, 1948a). Since this time, there have been many observations and reports on the Rim Gravel. However, there are conflicting interpretations on the ages and origins of the deposits (Holm, 2001). We examined as many data as were available to us from the literature and the field study in this section.

Geomorphologic Setting

The Rim Gravels in northern and central Arizona occupy a unique location on and near the surface of the Earth. They are often found on the highest terrain of the Mogollon Rim, generally on ridge crests at elevations of 2,100 to 2,400 meters (6,900 to 7,900 feet) (Scarborough, 1989). A number of geologists have noted that the Rim Gravels lie on top of an erosion surface that usually truncates the "Paleozoic" rocks of the Mogollon Rim area (Peirce et al., 1979; Young, 1979; Elston and Young, 1991). The erosion surface has beveled both hard and soft rocks the same, at least in the Sycamore Canyon area (Price, 1950).

This erosion surface has been later dissected in spots to form canyons and valleys. The Rim Gravel likely was reworked from the Mogollon Rim and now occupies the valleys and canyons as well as pediments and lava-capped mesas on the Colorado Plateau (Holm, 2001). Some Rim Gravels have been covered by lava flows that are common in the region (McKee and McKee, 1972). For example, basalt covers an outcrop of gravel in Oak Creek Canyon (Figure 3), a deep canyon perpendicular to the Mogollon Rim (Figure 1) where the city of Sedona is located (Holm and Cloud, 1990). These other gravels have been given a bewildering number of names. There is a question of whether they should be considered true Rim Gravels (Peirce et al., 1979). For the sake of simplicity, we focus mainly on the coarse gravel at and near the top of the Mogollon Rim.

Lithologies

The lithologies of the rocks vary considerably. There is a significant proportion of exotic quartzite in the coarse gravels from the Mogollon Rim. Exotic clasts do not outcrop in the vicinity but are transported from long distance. There is also a large percentage of local "Paleozoic" rocks, especially

Figure 2. Mogollon Rim in background east northeast across the Verde Valley from the Black Hills west of the old mining town of Jerome, northeast of Prescott.

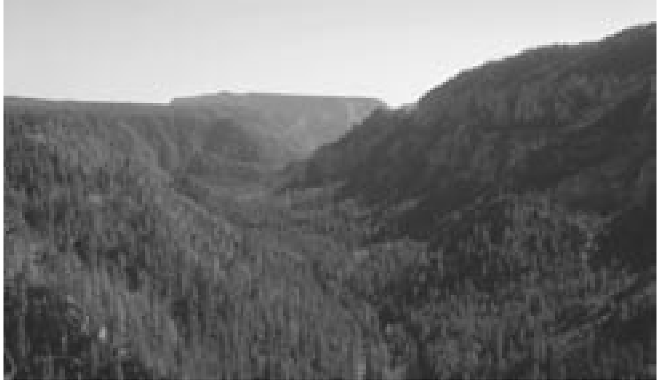

Figure 3. Oak Creek Canyon just south of the Mogollon Rim (view south). The east side of canyon covered by a basalt flow with coarse gravel below. West side has been faulted upward over 100 meters (330 feet).

sandstone. It is claimed that there are no local basalt boulders in the Rim Gravels, but only exotic basalts of K-Ar ages older than the gravels (Elston and Young, 1991), which may depend upon the exact definition of Rim Gravel. It is also a suspect conclusion unless geochemical data of statistically adequate number and not just "ages" disprove a connection with basalt flows in the region. Basalt boulders were not observed in the two field areas included in this study. Basalt boulders are present in Sycamore and Oak Creek Canyons cut on the southwest edge of the Mogollon Rim (McKee and McKee, 1972) (see Figure 1 for locations). However, these canyon gravels should probably be excluded from the definition of Rim Gravels. A lack of basalt boulders in the Rim Gravels on top of the Mogollon Rim would imply that the agency that spread the coarse gravel occurred before the widespread volcanism and surficial basalt flows of the region. Inclusion of a few such clasts in the Rim Gravel would imply the contemporaneity of the extrusion and deposition of lava, since the gravel preceded extensive extrusion, yet the extrusion occurred in an environment where boulders could be ripped off and rounded and incorporated into the gravels before the basalt had a chance to flow over and cap them. Further research would be necessary to determine which inference is likely correct. The volcanism is attributed to uplift of the Colorado Plateau and Basin and Range extension in southwest Arizona by uniformitarian geologists (Young and McKee, 1978).

Extent

The coarse gravel is present in many places in northern and central Arizona, especially along and near the Mogollon Rim (Figure 1). In some areas of northwest and east central Arizona the coarse gravel is considered widespread (Koons, 1948b; Lucchitta, 1979; 1989; Peirce et al., 1979; Elston and Young, 1991). There are even locations north of the Grand Canyon (Lucchitta, 1989; Elston and Young, 1991), indicating that the Rim Gravels were deposited before the Grand Canyon was eroded. Koons (1964) estimated that the coarse gravel was up to 76 meters (249 feet) within the extensive surficial outcrops east of the Hualapai Indian Reservation. The coarse gravels are up to 62 meters (203 feet) thick in other locations (Peirce et al., 1979). Based on all these occurrences, it is believed that the Rim Gravels were much thicker and more continuous at one time and have been much eroded since deposition, mainly during "Cenozoic" uplift. Elston and Young (1991) state:

> To obtain the existing stratigraphic and topographic distribution of Rim gravels across the Colorado Plateau and adjacent Transition Zone, the gravels must have once formed a thick, virtually continuous regional blanket that buried much, if not all, of the Mogollon Rim, the irregular erosion surface south of the rim, and the relatively smooth erosion surface developed on resistant strata north of the rim. (p. 12,396)

Thus the outcrops represent erosional remnants after a great amount of erosion (Elston and Young, 1991).

Paleocurrent Indicators

One of the most amazing characteristics of the Rim Gravels is that paleocurrent indicators show directions from the topographically lower south or west (Peirce et al., 1979; Elston and Young, 1991). These paleocurrent directions are especially based on the location of probable source areas, cross-beds, clast imbrication, and orientation of some of the canyons and valleys (McKee and McKee, 1972). Paleocurrent directions in some of the canyon and valley gravels line up with the northeast orientation of some canyons or valleys (Young, 1966; Young and Brennan, 1974).

Source Areas

Some geologists once believed the quartzites were eroded from the Shinurump Conglomerate, at least for the coarse gravels in Sycamore Canyon (Price, 1950). However, the clast size in the Shinurump Conglomerate is too small, and the lithologies do not match (Cooley, 1962). The closest source for quartzite and other igneous and metamorphic exotic rocks of the Rim Gravel in the northwest Mogollon Rim is around the Prescott area, about 80 kilometers (50 miles) to the south (Koons, 1948a; 1964). The closest source for the east central Rim Gravel is not too distant to the south. However, the source of the rocks could be from a number of locations to the south and west where the exotic lithologies outcrop extensively (Conway and Silver, 1989; Anderson, 1989; Wrucke, 1989; Williams et al., 1992; 1999). A very minor amount of rotten granitoids may indicate that the source was not too far away, if they were weathered prior to transport. If weathering occurred after transport, they may have actually been very distant or a small portion of the initial sediment supply.

It is interesting that the altitude of the land south and west of the Mogollon Rim is much lower, and apparently, this difference is not due to significant faulting near the Mogollon Rim, since the rim is considered erosional (Holm, 2001; Williams et al., 1999). While faults with minor vertical offsets are present in the Verde Valley area, Elston and Young (1991) state:

> The northern margin of the Transition Zone in central Arizona is an essentially unfaulted, south facing erosional escarpment known as the Mogollon Rim . . . . Faulting is not responsible for most of this escarpment. (p. 12,393)

Such low elevations south and west of the Mogollon Rim, where the coarse gravel likely originated, indicate

Table I. Characteristics of Rim Gravel

Characteristic	Observations
Geomorphologic setting	Covers Mogollon Rim erosion surface
Lithologies	Large percentage of exotic clasts; most clasts quartzite and other hard rock types, but Rim Gravel also includes clasts from subjacent strata
Probable source areas	Some clasts correspond with outcrops south and west of Mogollon Rim
Extent	Appears to have been originally continuous from northwest to east-central Arizona
Paleocurrent indicators	Predominant paleocurrent directions reportedly from south and west

that the land used to be higher and that tremendous erosion occurred south of the Rim during the uniformitarian "Cenozoic" Era (Dumitru et al., 1994). This postulated higher terrain south of the Mogollon Rim has resulted in the concept of the Mogollon Highlands that are now eroded to mountains and valleys (Cooley and Davidson, 1963; Scarborough, 1989).

Characteristics of the Rim Gravel are summarized in Table I.

Paleohydrologic Analysis

Paleohydrology is the application of fluid mechanics principles to questions of past fluid motion, including sediment transport. Hydraulic engineering principles are used to determine parameters pertinent to the depositional environment. It is therefore limited to providing minima (occasionally maxima) that may be used to test various historical scenarios that geologists may devise. If a particular story posits flow depths and current speeds too small to transport observed clasts (but not clasts formed *in situ*) over a given paleoslope, then the story does not hold water. Methods used in estimating minimum depths and current speeds have been described elsewhere (Klevberg, 1998; Klevberg and Oard, 1998).

Paleoslope Estimates

Based on paleocurrent directions and the configuration of erosion surfaces, paleoslope can be estimated. It is quite variable in the study area, being least northwest of Sycamore Canyon and steeper in the southeast near the towns of Young and Heber (Figure 1). The gradient was estimated from topographic maps beginning at the current edge of the Mogollon Rim. Clast size follows this same trend, being least on the gentler slopes of the western Colorado Plateau Province and steeper back of the Mogollon Rim on the southern edge of the plateau, where the paleoslope is a reasonably steep 0.015 (1½ percent).

Bedload Transport Hypothesis

The rounding of clasts observed in the Rim Gravel is consonant with bedload transport. For the estimated paleoslope and observed clast sizes, bedload transport could occur at modest flow depths, low Reynolds numbers, and high Froude numbers. Low Reynolds numbers—in this case less than about 500—indicate laminar flow, though laminar flow can occur in the transition zone above 2,000 (Roberson and Crowe, 1985). A Froude number greater than 1.0 indicates hypercritical or "rapid" flow. A rushing mountain stream will have a Froude number greater than 1.0, while a river with a smooth surface will have a Froude number less than 1.0. These values are based on integrated average current speeds, which typically coincides with the current speed at an elevation approximately 60 percent of the flow depth measured from the stream bottom.

Calculations were performed using the Keulegan and Chezy equations (Klevberg and Oard, 1998). These were checked by using Manning's equation to determine the n value for the stream bottom to achieve the velocities calculated using the Chezy equation. The resulting Manning n values are approximately 0.025, which is about average for earth canals and slightly lower than for an "average" gravel riverbed (Giles, 1962). If sheet flow rather than channelized (e.g. braided stream) flow occurred, the value of n would be somewhat less than average due to fewer bank and bar related obstacles.

Table II. Rim Gravel Paleohydraulic Estimates

Clast Diameter (mm)	1,500	500	1,500
Slope*	0.014915	0.007458	0.007458
Minimum Shear Stress (N/m^2)	725	240	725
Minimum Depth (m)	4.96	3.28	9.91
Minimum Current Speed (m/s)	21.5	11.5	20.0
Minimum Unit Flow (m^3/s per m width)	106	37.8	198
Froude Number	3.08	2.03	2.03
Reynolds Number	2.15E03	7.64E02	4.01E03

*First column represents maximum observed paleoslope; second and third column values are based on arbitrarily halved value for slope, which is still in excess of minimum slope in northwest part of study area and assumes sinuosity = 1 (i.e. conservative assumptions).

Estimates of minimum current properties are shown in Table II. The first column is a straightforward calculation based on the largest observed clast size and steepest paleoslope. Since these clasts show evidence of transport, it is the maximum clast size, not the average, that determines the minimum bed shear stress (Flores and Alvarez, 1997; Klevberg, 1998; Klevberg and Oard, 1998). This column represents sandstone eroded from the subjacent strata. The second column is based on the largest exotic clast observed. The second and third columns are based on an assumed paleoslope half as steep as the steepest observed paleoslope to achieve a more "average" paleocurrent estimate (accounting for lesser slopes elsewhere and potential sinuosity) for the entire study area. The second column results may more accurately reflect the minimum current required to transport the Rim Gravel. These calculations provide values for several parameters that are important in testing genetic inferences for the Rim Gravel.

- Estimated minimum depths range from 3.3 meters (11 feet) to 9.9 meters (32.5 feet). Actual depths may have been greater.
- Estimated minimum current speeds range from 11.5 m/s (26 mph) to 21.5 m/s (48 mph). Actual peak current speeds may have been greater. These are far in excess of the recommended maximum allowable current speed for channels excavated in hard rock, which is 3 to 4.5 m/s (6.7 to 10 mph) (Julien, 1995), indicating that very rapid erosion would have taken place. Peak current speeds in excess of 30 m/s (67 mph) may result in cavitation and extremely rapid destruction of rock masses (Holroyd, 1990a,b).
- Estimated discharge per meter width range from 38 to 198 m^3/s per meter width (410 to 2,130 ft^3/s per foot width). Actual peak unit discharge may have been greater. The estimated unit flows exceed historic peak flood unit flows for the Colorado River at Bright Angel. Unit discharge estimates indicate a very different environment of deposition for the Rim Gravels from current environments.
- Paleocurrents were supercritical (Fr>1.0). To reduce the Froude number to 1.0 (critical flow) would require a flow depth of 4.6 kilometers (2.86 miles)! Flow, therefore, was almost certainly rapid, not tranquil.
- Estimated minimum Reynolds numbers are near the boundary between laminar and transitional flow. If actual peak depths and current speeds exceed the minimums estimated here, Reynolds numbers would have been higher, and flow would have been turbulent.

Minimum paleocurrents would have been very energetic, capable of eroding hard rock, planing off obstructions, rounding clasts, and transporting large amounts of sediment.

Significance of Percussion Marks

Percussion marks were observed on many quartzite cobbles and boulders in the Rim Gravel. Percussion marks are not observed forming on clasts in modern channels where bedload occurs as described above. Even extremely energetic stream rapids seldom produce percussion marks, though a small percentage can be produced by waterfalls or hurricanes under the right conditions (Berthault, 2004, personal communication). The formation of percussion marks under static loading has been disputed (Klein, 1963). Percussion marks appear limited to relatively smooth clasts of hard and vitreous, cryptocrystalline or microcrystalline lithologies (i.e. hard, brittle, strong, homogeneous materials) that collide at relative velocities of at least several meters per second (Berthault, 2004, personal communication). Transport in suspension, in which clasts are briefly carried upward in extremely energetic streams, is required in a fluvial environment for the clasts to interact violently enough to produce percussion marks (Klevberg and Oard, 1998).

The presence of percussion marks in the Rim Gravels indicates that clasts transported from upstream of extant outcrops experienced currents in excess of those required for bedload transport. Subsequent bedload transport (assuming mere bedload transport occurred) was insufficient to physically weather percussion marks off clast surfaces. Data are insufficient to determine whether currents could be expected to have exceeded 30 m/s (67 mph). Cavitation is also hindered by a rough gravel bed and entrainment of air (Holroyd, 1990b). Percussion marks alone are sufficient to indicate a highly energetic and erosive environment.

Channel Width

No evidence for distinct channels was evident in the Rim Gravel. Dissected channel deposits, lag bars, bank collapse structures, or other indicators of paleochannels were not observed. The typical uniformitarian approach to this problem is to invoke braided streams, which is a possibility diluvialists need to investigate. Braided streams are observed today in glacial and desert environments where a sudden decrease in stream gradient occurs, reducing sediment carrying capacity and resulting in deposition of sediment. Braided streams, obviously, have channels that divide and reconnect repeatedly, forming a wide and shallow stream filled with bars. Bars may migrate, and sediment is constantly sorted, with coarse material deposited first and fine sediment on the lee sides where current speeds are less. This structure can be seen if one excavates through the deposits. With no evidence for channels observed in the Rim Gravels, we have avoided this problem by estimating unit flows.

Preliminary estimates of unit flow (m^3/s flow per meter width) for the Colorado River at Bright Angel based on U.S. Geological Survey data and channel dimension estimates provide a maximum historic flood unit flow rate of approximately 40 m^3/s (1,410 ft^3/s per foot width), which is comparable to the *minimum* value shown in Table II. So the braided stream idea is feasible, right? No! We see no such channel evidence, and the immense area of the Colorado drainage basin is funneled through the narrow inner gorge of Grand Canyon at Bright Angel. The conditions necessary for formation of the Rim Gravel do not compare favorably with present processes.

Uniformitarian Age

Uniformitarian geoscientists, while sometimes struggling with the physical implications of the scientific data, often do not hesitate to assign ages to coarse, tabular, surficial gravel deposits. (Such deposits, which often cover planation surfaces, have no accepted scientific name or "shorthand" term as yet.) Because the uniformitarian geologic column is not a scientific construct but a speculative natural history paradigm (Froede, 1995; Klevberg, 1999; 2000a,b; Reed, 1998; 2000; 2001; Reed et al., 1996; Woodmorappe, 1999c) which was formulated largely prior to widespread field work (Taylor, 1992; Woodmorappe, 1996), it comes as no surprise that efforts to work within the confines of the geological column often result in disagreement not only between scientists, but also between theories and data (Froede, 1998; Froede and Reed, 1999; Klevberg, 2000b; Reed and Froede, 2000; 2003; Woodmorappe, 1999a). The Rim Gravel is no exception.

Rim gravels have been assigned various uniformitarian ages, as well as divergent interpretations and variable geological settings within the uniformitarian system (Young, 1979). Studies present conflicting interpretations about the ages and origins of the deposits (Holm, 2001). One early author dated the Rim Gravels in the Sycamore Canyon as "Triassic," which was later changed to "Miocene" or "Pliocene," late "Cenozoic," in the mid 20th century (Price, 1950). Some authors similarly dated the coarse gravels as late "Cenozoic" (McKee, 1951; McKee and McKee, 1972).

Recent reports, however, have mostly relegated the dates of deposition of the Rim Gravel to the "early Cenozoic", or even the "late Cretaceous" (Young, 1979; Scarborough, 1989; Elston and Young, 1991; Holm, 2001). The U.S. Geological Survey (Condit et al., 1993) classifies the Rim Gravel as "Oligocene," from the "Tertiary Period" of the "Cenozoic Era," which would make it mid "Cenozoic." Valley erosion with subsequent deposition of coarse gravel is believed to have occurred mainly in the mid to late "Cenozoic" with the gravels reworked from higher terrain (Holm, 2001). Thus, the older gravels are on top of the higher terrain, and the younger gravels lie in the valleys and canyons (Young, 1979).

Diluvial Interpretation—Rim Gravel from Recessional Stage of Flood?

The paleohydrologic constraints that the Rim Gravels provide us are very significant to natural history studies of the American Southwest, both for those who hold to uniformitarian doctrine and catastrophists (including creationists). Uniformitarian and catastrophist interpretations are contrasted in Table III.

Table III. Contrasting Interpretations of Rim Gravel Characteristics

Characteristic	Uniformitarian Explanation	Catastrophist Explanation
Thickness	Channelized deposition	Sheet deposition
Coarse particle size	Episodic fluvial transport	Torrential velocities
Clast support	Bar development and sorting	High competence or current winnowing
Matrix support	Debris flows or episodically low current speeds	Characteristic of source or capacity limited
Exotic clasts	Slope retreat or episodic fluvial transport	Energetic, long-distance transport
Local clasts	Local erosion and deposition	Energetic currents resulted in local erosion
Few or no basalt clasts	Gravels before eruptions	Gravels right before eruptions
Geomorphologic setting	A large east-west valley bottom	A large erosion surface
Subjacent erosion surface	Channelized erosion by water (peneplanation)	Sheet erosion by water (catastrophic planation)
Unusual lithologies	Fluvial transport and reworking over time	Energetic, long-distance transport
Probable source areas	South and west	South and west
Lateral extent	Once continuous	Once continuous
Paleocurrent indicators	South and west	South and west, very energetic

Uniformitarian Issues

It is difficult to fit the Rim Gravels into the uniformitarian framework for the following reasons:

- Deposition of the coarse, tabular, surficial gravel was clearly regional and catastrophic.
- An enormous amount of earth material has apparently been removed, especially south of the Mogollon Rim, since deposition of the Rim Gravel, resulting in a relative reversal of topography.
- Much volcanism occurred which was at least partly contemporary to the deposition of Rim Gravel. Evidence for even one hiatus between these rapid processes has not been observed.
- The catastrophic deposition of coarse gravel and large-scale regional volcanism appear related to Basin and Range tectonism, constraining the chronology of those events.

First, the size and location of the exotic coarse gravels on the highest terrain, which represents remnants of an erosion surface, implies powerful currents sweeping downhill from the south and west. The concept of the Mogollon Highlands seems sound. The relatively common percussion marks indicate that currents, not *in situ* or mass wasting processes, transported the rocks at around a few tens of meters per second (40 mph or more) during some stage in the clasts' history (Klevberg and Oard, 1998). It is predominantly the more resistant rocks that ended up as a boulder lag on the current Mogollon Rim, while the softer lithologies were either swept away or contributed to the matrix surrounding the boulders (both clast supported and matrix supported gravels are observed in the Rim Gravel). The likelihood that the Rim Gravel was first deposited as a sheet during an erosional event, after a great amount of deposition of other sediments, implies deposition during the Abative or Sheet Flow Phase during the Recessional Stage of the Deluge (Walker, 1994) (Figure 4).

Second, tremendous erosion occurred during and subsequent to the deposition of the Rim Gravels (Billingsley et al., 2000). The "Mogollon Highlands" were eroded a few thousand meters (6,000 feet or more) and lowered *below* what is now the Mogollon Rim. Little subsequent lowering of the Rim likely occurred during this phase, but the

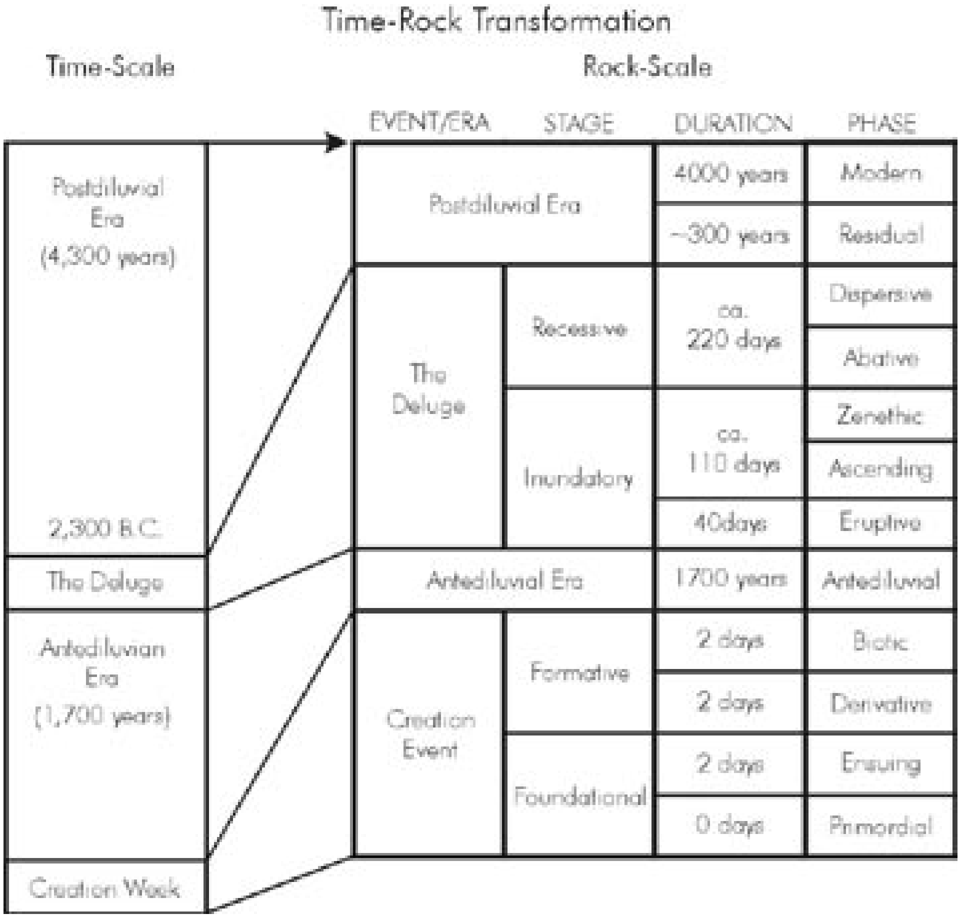

Figure 4. Walker's geological timescale and classification system for the Noahic Flood (after Walker, 1994).

coarse gravel was eroded away, leaving remnants. So, we essentially go along with the uniformitarian deduction of the erosion of the "Mogollon Highlands." The currents that deposited the Rim Gravel were from the south and west, but they became more from the north and east with time as the Mogollon Rim generally became the highest terrain, and base level became the Pacific Ocean. Therefore, there was a reversal of drainage. During this time in the biblical Flood, the water would have become more channelized, resulting in much greater erosion south of the Mogollon Rim. The channelized flow spreading off the highest land as the water level of the Deluge dropped would cut canyons and valleys, rework some of the Rim Gravel into the valleys and onto pediments, and mix the coarse gravel with local lithologies. This is the Dispersive or Channelized Phase in Walker's (1994) classification, the last event of the Flood (Figure 4).

Third, much volcanism occurred, sometimes extruding basalt on top of the Rim gravels. Some of this volcanism occurred during the Sheet Flow Phase, capping the Rim Gravels near the top of the Mogollon Rim, after practically all of the coarse gravel was laid on and near the Mogollon Rim. Volcanism must have continued into the Channelized Phase of the Deluge, covering up those gravels reworked into valleys and canyons, such as at Sycamore and Oak Creek Canyons. Volcanism probably continued into the immediate postdiluvian period.

Fourth, all this activity must have occurred during tremendous tectonic activity while the region was still submerged below the Floodwater and while the area was emerging from the Floodwater (Oard, 2001a,b; Psalm 104:5–9). This implies rapid vertical uplift of the southwestern United States, probably accompanied by the falling Pacific Ocean bottom. The Floodwater, at first moving as a sheet during the Abative Phase, would become more channelized as more and more terrain became exposed. The volcanism occurred during the uplift of the Colorado Plateau and the extension of the Basin and Range, as uniformitarian scientists surmise.

The coarse, tabular, surficial gravel capping an erosion surface is difficult to accommodate in a uniformitarian scenario because the once continuous cover over a wide area is not a stable feature or one seen forming in modern environments. Yet many remnants cover large areas to this day. In the east-central part of the Mogollon Rim, the coarse gravel often forms a flat surface on the highest terrain over a large area. It is difficult for uniformitarian scientists to appeal to terrain reversal due to the armoring of the coarse gravel because some of the gravel is matrix supported. In the hypothetical concept of terrain reversal, it seems that the gravel should end up as a lag and be clast supported. Lag deposits should provide a rough outline of paleochannels, yet this does not appear to be the case. So, the coarse gravels give every indication of being caused by a great catastrophe. But was this catastrophe the Genesis Flood or events in postdiluvian time?

Issues for Catastrophists

Catastrophists come in very different forms: evolutionists, diluvialists, and neocuvierists.[1] Catastrophists may acknowledge the evidence for catastrophic deposition of the Rim Gravels while completely disagreeing on the natural history in which the catastrophe or catastrophes occurred. While the Rim Gravels do not appear to be braided stream deposits, neither are they readily explained by the catastrophic emptying of pluvial lakes *a la* the dam breach theory for the formation of the Grand Canyon. This is evident from the unit flow estimates and the high elevation of the coarse gravels. Not only would such a reservoir have to fill and empty many times to create such a vast gravel deposit (and where are the channel boundaries?), but the paleocurrent directions are wrong. A postdiluvial interpretation of the Rim Gravels strains credulity. While the popular dam breach theory for Grand Canyon faces great technical difficulties (Oard, 2001b), these do not hold a candle to the difficulties facing anyone attempting to explain the Rim Gravel as a postdiluvial phenomenon. It is inconceivable that such deposition of Rim Gravel, tremendous erosion, huge tectonic uplift, and great volcanism could occur after the Deluge. What kind of postdiluvial catastrophic scenario would account for all this activity? Just the rounding of so much quartzite implies the action of large volumes of water, indicating the whole region was under water in the early "Cenozoic"—assuming there is any validity to the sequence of the uniformitarian geological column. We believe that the gravel represents a diluvial deposit from the Recessional Stage of the Flood, according to Walker's (1994) biblical geological timescale (Figure 4).

Preliminary Stratigraphic Interpretation

No thorough diluvial analysis of regional stratigraphy has been conducted as yet, and studies to date have been at the reconnaissance level. Uniformitarian scientists have described some of the relative dating relationships (mixing them, of course, with dubious radiometric "data"—see Woodmorappe, 1999b). In general, they identify the Rim Gravel as a relatively early deposit for the Mogollon Rim area, contemporary with lower Paulden, Cherry, and Beavertail Formations. These conglomerate units are interpreted as slope base or valley fill sediments (Holm, 2001); the presence of basalt clasts indicates no significant hiatus before emplacement of the Hickey and House Mountain Basalts. A similar situation exists with the stratigraphically higher Perkinsville and Verde Formations, and the overlying "Rim Basalts." The presence of Rim Basalts over Rim Gravel in some locales provides an obvious means of relative dating, as do flows that ran over the Mogollon Rim, but relative dating of the various flows must still be worked out. Present published information is largely a confusion of scientific data with speculations and inferences derived from uniformitarian presuppositions.

Froede et al. (1998) interpreted the Hickey Basalt and subsequent volcanics as postdiluvial ("Ice Age Time Frame" and "Upper Ice Age/Lower Present Age Division," respectively). These interpretations were described by the authors as tentative, and they may be subject to reconsideration based on new evidence (Froede, 2000), in which case a diluvial interpretation may be preferable. In either case, the preliminary stratigraphic interpretation agrees with the diluvial interpretation of the Rim Gravel provided here. We believe the paleohydrologic constraints of the Rim Gravel make it an excellent chronostratigraphic marker for earth history studies by diluvialists.

Implications

The Rim Gravel is considered one key to understanding the persistent uniformitarian problems of the Colorado Plateau, including the erosional history of the Colorado Plateau, the origin of the Grand Canyon, and the origin of the Mogollon Rim (Elston and Young, 1991; Holm, 2001). We believe deposition of the Rim Gravel is key to interpretation of the diluvial history of the area.

The lead author, who thinks the uniformitarian stratigraphic column represents a *general* geologic sequence, believes the Rim Gravel provides a means of locating the end of the Genesis Flood in the rock record. The deposition of the Rim Gravel is mostly dated as early "Cenozoic" in the uniformitarian geological timescale. The subsequent erosion of the area would occur more towards the middle "Cenozoic." So, the Floodwater must have still covered much of the area clear into the mid "Cenozoic," leaving the late "Cenozoic" to finish the more channelized erosion. Thus it appears that if a creationist assumes the validity of the stratigraphic sequence of the uniformitarian geological

---

[1] While some may consider *neocuvierist* a pejorative term, this is not necessarily the case, and not our intention here. There is no better term we are aware of for the view espousing multiple global (or at least continental or regional) catastrophes, only one of which was the biblical Flood. While Georges Cuvier thought the Deluge was the last of these, many *neo*cuvierists differ from him in positing postdiluvial catastrophes. Diluvialists, in contrast, consider such catastrophes as orders of magnitude less important than the Deluge.

time scale, the diluvian/postdiluvian (Flood/post-Flood or D/P) boundary is in the late "Cenozoic" in this region. (It is important to recognize that "Cenozoic" is used by evolutionists to designate rocks nearer the Earth's surface or up section and are therefore more likely than many other rocks, e.g. "Devonian" or "Pre-Cambrian," to coincide with the D/P boundary.) Diluvialists who (like the other authors) are column agnostics or doubtful of such universal claims may still recognize in the Rim Gravel a significant relative dating mechanism for the D/P boundary. Any post Rim Gravel feature, such as the Grand Canyon, cannot therefore be earlier than this point in earth history.

While the Rim Gravel has great significance to historical geology, it is not an isolated example. We, along with John Hergenrather, have been studying exotic, well-rounded cobbles and boulders, mostly of well-rounded quartzite, across the Pacific Northwest, Montana, Wyoming, southern Alberta, and southern Saskatchewan (Oard, 1996; 2000; 2001a; Klevberg and Oard, 1998; Oard and Klevberg, 1998). We observe these far-traveled rocks many hundreds of kilometers from their nearest source. They are not only found in valleys and on plains, but also are located on mountaintops, such as the Wallowa Mountains of northeast Oregon, the Gravelly Range of southwest Montana, the northern Teton Mountains, and the mountains of central Oregon. We have managed to deduce that these gravels represent objective and powerful evidence for rapid currents of wide and deep extent flowing both east and west off the Rocky Mountains (Klevberg and Oard, 1998). We are aware of other exotic gravels in Utah and southwest Wyoming (Schmitt, 1985; DeCelles, 1988; Elston and Young, 1991; DeCelles and Cavazza, 1999). So, it appears that the Rim Gravels of Arizona are part of the same diluvial events that occurred over the whole western United States.

All these coarse gravels are dated from the "late Cretaceous" and "Cenozoic" within the uniformitarian system. The quartzite also lies upon late "Cenozoic" lavas of the Columbia River Basalts (Oard, 1996). Thus, if one follows the sequence of the uniformitarian geologic column, the pattern based on exotic quartzite and other coarse gravels indicating the Flood/post-Flood boundary is consistent over the western United States. Alternatively, most of the coarse gravels near the D/P boundary have been lumped into the "late Cretaceous" and "Cenozoic" categories by uniformitarian scientists. It may be worthwhile to study the reasons why uniformitarian scientists have classified these deposits thus in their system (cf. Klevberg, 1999; 2000a,b; Reed and Froede 2003; Woodmorappe, 1999c). From either vantage, the significance of these coarse gravel deposits for historical geology is great.

Summary

Coarse gravel on top of the Mogollon Rim in central and northern Arizona, called the Rim Gravel, has great significance for questions of historical geology in the American Southwest. We examined two widely separated and representative locations near the northwest Rim and along the east-central Rim. The coarse gravel occupies an erosion surface on the highest terrain in the region and is believed to have once been continuous all along the Rim. A large percentage of the coarse gravel is exotic quartzites, sometimes with percussion marks. Based on literature sources, paleocurrent data indicate the coarse gravel was transported from the south and west, which currently is at a much lower elevation than the Mogollon Rim. Based on paleohydrological analysis, we calculate that the coarse gravel was transported by sheet flow moving at velocities of at least a few tens of meters per second (40 mph or greater).

Although the uniformitarian age of the gravel is generally believed to have been early "Cenozoic," it can be surmised that the gravel and the "Mogollon Highlands" to the south were eroded probably in the mid "Cenozoic." The more channelized erosion of the area probably would be assigned to the late "Cenozoic." This is premised, of course, on the assumption that these uniformitarian classifications have any real meaning at all.

We infer that this coarse gravel was deposited as a sheet during the early Recessional Stage of the Genesis Flood. The area then underwent erosion of the deposited gravel and substrate during uplift of the area, generally during the Channelized Phase of the Deluge. We conclude that the Rim Gravel provides evidence that the Flood/post-Flood (D/P) boundary largely corresponds to the stratigraphic location of rocks termed "late Cenozoic" in the uniformitarian geological column in this part of the western United States. Since the Grand Canyon of the Colorado River cuts through the Rim Gravel, this feature must post-date the deposition of the Rim Gravel at least slightly.

Appendix

The first location examined during field reconnaissance was in northwest Arizona along Arizona Highway 18 in the eastern Hualapai Indian Reservation, northeast of Peach Springs (Figure 1). Valley gravels are common along Arizona Highway 18 (Figure 5). These gravels would be considered the Robbers Roost gravel of Koons (1948b). The coarse gravel is mostly sandstone from local "Paleozoic" deposits. The gravel deposits observed were mostly clast supported, generally cemented, and poorly sorted with small sand or sandstone interbeds or lenses. True Rim Gravel was found covering the highest point along Highway 18

Figure 5. Robbers Roost gravel along Arizona Highway 18 about 12 kilometers (8 miles) northeast of U. S. Highway 66. Rock hammer in center of picture provides scale.

Figure 6. Rim Gravel on Arizona Highway 18 from the eastern Hualapai Indian Reservation about 50 kilometers (31 miles) northeast of Peach Springs, Arizona.

Figure 7. Well-rounded quartzite clast with percussion marks from Rim Gravel shown in Figure 4.

about 50 kilometers (31 miles) northeast of Peach Springs (Figure 6). This gravel represents an extensive deposit on the Coconino Plateau in the eastern Hualapai Indian Reservation and farther eastward. The unlithified coarse gravel observed by the lead author contained about 30 to 40% exotic well-rounded quartzite. The largest clast was about 30 centimeters (12 inches) in diameter. Some of the boulders possessed percussion marks (Figure 7) indicative of a very energetic depositional environment (Klevberg and Oard, 1998).

The coarse gravel on the east-central Mogollon Rim is most impressive. The gravel is thick and very coarse (Elston and Young, 1991). On ridges near the Mogollon Rim, the coarse gravel forms a flat surface (Figure 8). The deposit extends southward down the valley leading to the town of Young (see Figure 1 for location). The deposit exhibits clast-supported fabric in some places, and matrix support in others (Figure 9). Observed clasts were around 50 to 70% exotic quartzite, 15 to 25% local sandstones, less than 2% granitoids (Figure 10) with rare conglomerate, quartz, chert, gneiss and other igneous and metamorphic lithologies. Some of the granitoids and gneisses were well weathered and rotten. The quartzites observed were well rounded, large, and contained percussion marks (Figure 11). The largest quartzite observed had an A-axis of about 60 centimeters (24 inches) and a B-axis of around 50 centimeters (20 inches) with abundant percussion marks (Figure 12). The A-axis is the long axis while the B-axis is the intermediate axis of the clast. The sandstone boulders were even larger, mostly up to 1 meter (3.3 feet) A-axis. One subrounded sandstone boulder lay on top of the very coarse gravel (Figure 13) with a 2 meter (6.6 feet) A-axis (Figure 14). (It is possible this large clast was deposited at this location when the road was built, taken very likely when the road cut was excavated.) The size of the clasts decreased from

Figure 8. Coarse gravel on a ridge just north of Mogollon Rim forming a flat surface. Picture taken about 4 kilometers (2.5 miles) southwest of Arizona Highway 260, southwest of Heber, Arizona.

Figure 9. Matrix-supported Rim Gravel at the top of the Mogollon Rim at the junction of forest roads 512 and 291, southwest of Heber, Arizona.

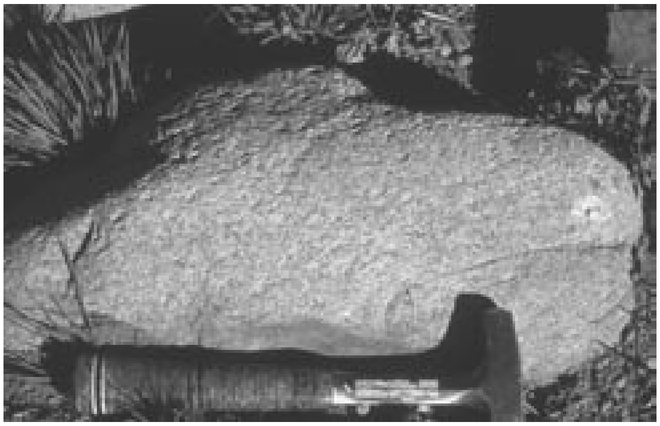

Figure 10. Granitoid clast with an A-axis of 45 centimeters from just south of the Mogollon Rim, 7 kilometers (4.5 miles) south of Arizona Highway 260 on Forest Service Road 512, southwest of Heber, Arizona.

the top of the Mogollon Rim south down the valley toward Young. One reason the clasts are so large in the east-central Mogollon Rim compared with the northwest Rim could be due to the closer source for the former.

Several gravel samples collected during this investigation contained rocks exhibiting mineralization or evidence

Figure 11. Quartzite with abundant percussion marks from just south of the Mogollon Rim, 7 kilometers (4.5 miles) south of Arizona Highway 260 on Forest Service Road 512, southwest of Heber, Arizona.

Figure 12. Well-rounded quartzite with abundant percussion marks and an A-axis of about 60 centimeters (24 inches) and a B-axis of about 50 centimeters (20 inches) from about 1 kilometer (0.6 miles) south of the junction of forest roads 512 and 291, southwest of Heber, Arizona.

Figure 13. Outcrop of very coarse, clast-supported gravel with very large sandstone boulders up to 2 meters (6 feet) A-axis on top (shown in Figure 14). Location is 7 kilometers (4.5 miles) south of Arizona Highway 260 on forest road 512, southwest of Heber, Arizona.

of hydrothermal alteration. Particularly prominent were hematite, limonite, malachite and lesser amounts of other copper minerals. Significant mineralization is present in the vicinity of Jerome, Arizona (Figure 1). While no active mining is underway in Jerome, local historical postings state that large-scale mining of the copper deposits occurred from 1876 to 1953. Based on the lithologies from the Rim Gravel, mineralized outcrops were exposed long before 1876.

Glossary

Braided stream: a stream form characterized by anastomosing channels separated by bars and generally found where a sudden decrease in gradient occurs.

Clast: an individual pebble, cobble, or boulder.

Coarse gravel: gravel containing significant amounts of cobbles and boulders.

Cross-beds: fabric patterns in detrital sedimentary rocks or unconsolidated sediments formed by laminations at an angle to the bedding direction, often observed forming today as advancing (prograding) delta fronts.

Exotic: of a lithology not found subjacent to the deposit, implying transport from a distant source.

Froude number: the square root of the interial-gravity force

Figure 14. Close-up view of 2 meters (6 feet) A-axis boulder from Figure 11. Boulder is subrounded and composed of local sandstone.

ratio; critical flow occurs at a Froude number of one, representing the minimum energy but an unstable condition, Froude numbers greater than one are rapid, and Froude numbers less than one are tranquil.

Granitoids: Any quartzofeldspathic phaneritic plutonic rock, including granite, diorite, quartz monzonite, and tonalite.

Imbrication: stacking of somewhat flattened shapes in a shingle fashion; relatively flat (nonequant) rocks in streambeds are usually imbricated dipping upstream.

Matrix: the material surrounding clasts and occupying the void spaces between them.

Percussion marks: crescentic fractures in the surface of a microcrystalline or cryptocrystalline rock, somwhat cone-shaped in section.

Quartzite: a rock composed primarily or completely of silica (SiO_2) in which fracturing occurs across grains (if grains are evident) rather than between them.

Reynolds number: the ratio of inertial to viscous forces; low Reynolds numbers indicate laminar flow, high Reynolds numbers turbulent flow.

Acknowledgments

We thank the Van Andel Creation Research Center for support and lodging for the lead author during this research. John Meyer was kind enough to take two days from his busy schedule to accompany him to the Hualapai Indian Reservation. We thank Tom Vail for providing the width of the river at Bright Angel. The field research was paid for by a grant from the Creation Research Society. We appreciate the technical assistance of Guy Berthault and the translation assistance of Richard Teachout and Donna Carlaw.

References

Anderson, J. L. 1989. Proterozoic anorogenic granites of the Southwestern United States. In Jenney, J. P. and Reynolds, S. J. (Editors). *Geologic Evolution of Arizona, Arizona Geological Society Digest* 17. pp. 211–238. Arizona Geological Society, Tucson, AZ.

Berthault, G. 2004. Personal communication regarding paleohydrology, in particular a paper attributed to H. Bertouille (2004), *Marques de Percussion en coup d'ongle sur les galets* [Point impacts and angles in formation of percussion marks]. (Reference unavailable.).

Billingsley, G. H., K. J. Wenrich, and P. W. Huntoon. 2000. Breccia-pipe and geologic map of the southwest part of the Hualapai Indian Reservation and vicinity, Arizona. *U.S. Geological Survey Geologic Investigation Series* I–2643 pamphlet.

Condit, C. D., L .S. Crumpler, and J. C. Aubele. 1993. Lithologic, age group, magnetopolarity, and geochemical maps of the Springerville Volcanic Field, east-central Arizona. Map I–2431 with notes. U.S. Geological Survey, Denver, CO.

Cooley, M. E., 1962. Geomorphology and the age of volcanic rocks in northeastern Arizona. *Arizona Geological Society Digest* 5:97–115.

Cooley, M. E., and E. S. Davidson. 1963. The Mogollon Highlands: their influence on Mesozoic and Cenozoic erosion and sedimentation. *Arizona Geological Society Digest* 6:7–35.

Conway, C. M., and L. T. Silver. 1989. Early Proterozoic rocks (1710-1615 Ma) in central and southeastern Arizona. In Jenney, J. P. and Reynolds, S. J. (Editors). *Geologic Evolution of Arizona, Arizona Geological Society Digest* 17. pp. 165–186. Arizona Geological Society, Tucson, AZ.

DeCelles, P. G. 1988. Lithologic provenance modeling applied to the Late Cretaceous synorogenic Echo Canyon Conglomerate, Utah, a case of multiple source areas. *Geology* 16:1039–1043.

DeCelles, P. G. and W. Cavazza. 1999. A comparison of fluvial megafans in the Cordilleran (Upper Cretaceous) and modern Himalayan foreland basin systems. *Geological Society of America Bulletin* 111:1315–1334.

Dumitru, T. A., I. R. Duddy, and P. F. Green. 1994. Mesozoic-Cenozoic burial, uplift, and erosion history of the west-central Colorado Plateau. *Geology* 22:499–502.

Elston, D. P., and R. A. Young. 1991. Cretaceous-Eocene (Laramide) landscape development and Oligocene-Pliocene drainage reorganization of transition zone and Colorado Plateau, AZ. *Journal of Geophysical Research* 96(B7):12,389–12,406.

Flores, M.G., and J.A.M. Álvarez. 1997. *Inicio de movimiento y acorazamiento* [Initiation of movement and streambed armoring]. *Manual de ingeniería de ríos* [Manual of river/channel engineering], pp. 70–92. Comisión Nacional del Agua, Mexico City, Mexico.

Froede, C. R., Jr. 1995. A proposal for a creationist geological timescale. *CRSQ* 32:90–94.

———.1998. *Field Studies in Catastrophic Geology*. Creation Research Society Monograph No 7, St. Joseph, MO.

———. 2000. Submarine volcanism, Part I–subaqueous basalt eruptions and lava flows. *CRSQ* 37:22–35.

Froede, C. R., Jr., and J. K. Reed. 1999. Assessing creationist stratigraphy with evidence from the Gulf of Mexico. *CRSQ* 36:51–60.

Froede, C. R., Jr., G. F. Howe, J. K. Reed, and J. R. Meyer. 1998. An overview of various igneous rock outcrops near the Van Andel Creation Research Center interpreted within a young-earth flood model. *CRSQ* 35:126–133.

Giles, R. V. 1962. *Schaum's Outline of Thoery and Problems of Fluid Mechanics and Hydraulics*, (2nd edition). McGraw-Hill Book Company, New York, NY.

Holm, R. F. 2001. Cenozoic paleogeography of the central Mogollon Rim-southern Colorado Plateau region, Arizona, revealed by Tertiary gravel deposits, Oligocene to Pleistocene lava flows, and incised streams. *Geological Society of America Bulletin* 113:1,467–1,485.

Holm, R. F., and R. A. Cloud. 1990. Regional significance of recurrent faulting and intracanyon volcanism at Oak Creek Canyon, southern Colorado Plateau, Arizona. *Geology* 18:1,014–1,017.

Holroyd, E. W., III. 1990a. An introduction to the possible role of cavitation in the erosion of water channels. *CRSQ* 27:23–32.

———, 1990b. Some simulations of the possible role of cavitation in catastrophic floods. *CRSQ* 27:49–55.

Julien, P. Y. 1995. *Erosion and Sedimentation*. Cambridge University Press, New York, NY.

Klein, G.dV. 1963. Boulder surface markings in Quaco Formation (upper triassic), St. Martin's, New Brunswick, Canada. *Journal of Sedimentary Petrology* 33:49–52.

Klevberg, P. 1998. The Big Sky Paving gravel deposit, Cascade County, Montana. *CRSQ* 34:225–235.

———. 1999. The philosophy of sequence stratigraphy, Part I–philosophic background. *CRSQ* 36:72–80.

———. 2000a. The philosophy of sequence stratigraphy, Part II–application to stratigraphy. *CRSQ* 38:36–46.

———. 2000b. The philosophy of sequence stratigraphy–Part III: application to sequence stratigraphy. *CRSQ* 37:94–104.

Klevberg, P., and M. J. Oard. 1998. Paleohydrology of the Cypress Hills Formation and Flaxville gravel. In Walsh, R. E. (editor), *Proceedings of the Fourth International Conference on Creationism*, pp. 361–378, Creation Science Fellowship, Pittsburgh, PA.

Koons, D. 1948a. High-level gravels of western Grand Canyon. *Science* 107:475–476.

———.1948b. Geology of the eastern Hualapai Reservation. *Museum of Northern Arizona Bulletin (Plateau)* 20(4):53–60.

———. 1964. Structure of the eastern Hualapai [sic] Indian Reservation, Arizona. *Arizona Geological Society Digest* 7:97–114.

Lucchitta, I. 1979. Late Cenozoic uplift of the southwestern Colorado Plateau and adjacent lower Colorado River region. *Tectonophysics* 61:63–95.

———. 1989. History of the Grand Canyon and of the Colorado River in Arizona. In Jenney, J. P. and Reynolds, S. J. (Editors). *Geologic Evolution of Arizona, Arizona Geological Society Digest 17*. pp. 701–715. Arizona Geological Society, Tucson, AZ.

McKee, E. D. 1951. Sedimentary basins of Arizona and adjoining areas. *Geological Society of America Bulletin* 62:481–506.

McKee, E. D., and E. H. McKee. 1972. Pliocene uplift of the Grand Canyon region—time of drainage adjustment. *Geological Society of America Bulletin* 83:1923–1932,

Miall, A. D. 1996. *The Geology of Fluvial Deposits—Sedimentary Facies, Basin Analysis, and Petroleum Geology*. Springer, New York, NY.

Oard, M. J. 1996. Where is the Flood/post-Flood boundary in the rock record? *Creation Ex Nihilo Technical Journal* 10(2):258–278.

———. 2000. Antiquity of landforms: objective evidence that dating methods are wrong. *Creation Ex Nihilo Technical Journal* 14(1):35–39.

———. 2001a. Vertical tectonics and the drainage of Floodwater: a model for the Middle and Late Diluvian Period – Part I. *CRSQ* 38(1):3–17.

———. 2001b. Vertical tectonics and the drainage of Floodwater: a model for the Middle and Late Diluvian Period – Part II. *CRSQ* 38(2):79–95.

Oard, M. J., and P. Klevberg. 1998. A Diluvial interpretation of the Cypress Hills Formation, Flaxville gravels, and related deposits. In Walsh, R. E. (Editor). *Proceedings of the Fourth International Conference on Creationism*. pp. 421–436. Creation Science Fellowship, Pittsburgh, PA.

Peirce, H. W., P. E. Damon, and M. Shafiqullah. 1979. An Oligocene (?) Colorado Plateau edge in Arizona. *Tectonophysics* 61:1–24.

Price, W. E. 1950. Cenozoic gravels on the rim of Sycamore Canyon, Arizona. *Geological Society of America Bulletin* 61:501–508.

Reed, J. K. 1998. Demythologizing uniformitarian history. *CRSQ* 35:156–165.

———. 2000. Historiography and natural history. *CRSQ* 37:160–175.

———. 2001. *Natural History in the Christian Worldview*. Creation Research Society Books Monograph No. 11, St. Joseph, MO.

Reed, J. K., and C. R. Froede, Jr. 2000. Bible-based flood geology: two different approaches to resolving earth history–a reply to

Tyler and Garner. *CRSQ* 37:61–66.

———. 2003. The uniformitarian stratigraphic column–shortcut or pitfall for creation geology? *CRSQ* 40:90–98.

Reed, J. K., C. R. Froede, Jr., and C. B. Bennett. 1996. The role of geologic energy in interpreting the stratigraphic record. *CRSQ* 33:97–101.

Roberson, J. A., and C. T. Crowe. 1985. *Engineering Fluid Mechanics* (3rd edition). Houghton Mifflin Company, Boston, MA.

Scarborough, R. 1989. Cenozoic erosion and sedimentation in Arizona. In Jenney, J. P. and Reynolds, S. J. (Editors). *Geologic Evolution of Arizona, Arizona Geological Society Digest 17*. pp. 515–537. Arizona Geological Society, Tucson, AZ.

Schmitt, J. G. 1985. Synorogenic sedimentation of Upper Cretaceous Frontier Formation conglomerates and associated strata, Wyoming-Idaho-Utah thrust belt. *The Mountain Geologist* 22 (1):5–15.

Taylor, I. 1992. *In the Minds of Men: Darwin and the New World Order*. TFE Publishing, Toronto, Canada.

Walker, T. 1994. A Biblical geological model. In Walsh, R. E. (Editor). *Proceedings of the Third International Conference on Creationism*. Technical Symposium Sessions. pp. 581–592. Creation Science Fellowship, Pittsburgh, PA.

Williams, E. L., J. R. Meyer, and G. W. Wolfrom. 1992. Erosion of Grand Canyon Part II—Review of river capture, piping and ancestral river hypotheses and the possible formation of vast lakes. *CRSQ* 28:138–145.

Willams, E. L., G. F. Howe, and J. R. Meyer. 1999. An introduction to the geology of Verde Valley, a different perspective. *CRSQ* 36:81–88.

Woodmorappe, J. 1996. Clarifications related to the 'reality' of the geologic column. *Creation Ex Nihilo Technical Journal* 10:279–290.

———. 1999a. *Studies in Flood Geology*. Institute for Creation Research, El Cajon, CA.

———. 1999b. *The Mythology of Modern Dating Methods*. Institute for Creation Research, El Cajon, CA.

———. 1999c. The essential nonexistence of the evolutionary-uniformitarian geologic column: a quantitative assessment. In Woodmorappe, J. (editor), *Studies in Flood Geology*, pp. 103–130. Institute for Creation Research, El Cajon, CA.

Wrucke, C. T. 1989. The middle Proterozoic Apache Group, Troy quartzite, and associated diabase of Arizona. In Jenney, J. P. and Reynolds, S. J. (Editors). *Geologic Evolution of Arizona, Arizona Geological Society Digest 17*. pp. 239–258. Arizona Geological Society, Tucson, AZ.

Young, R. A. 1966. *Cenozoic Geology along the Edge of the Colorado Plateau in Northwestern Arizona*. PhD Thesis, Washington University, St. Louis, MO.

———. 1979. Laramide deformation, erosion and plutonism along the southwest margin of the Colorado Plateau. *Tectonophysics* 61:25–47.

Young, R. A., and W. J. Brennan. 1974. Peach Springs Tuff: its bearing on structural evolution of the Colorado Plateau and development of Cenozoic drainage in Mohave County, Arizona. *Geological Society of America Bulletin* 85:83–90.

Young, R. A., and E. H. McKee. 1978. Early and middle Cenozoic drainage and erosion in west-central Arizona. *Geological Society of America Bulletin* 89:1745–1750.