Appendix 14

Paleohydrologic Analysis of Rim Gravel

Paleohydrology is the application of fluid mechanics to questions of past fluid motion, including sediment transport. Peter Klevberg of Great Falls, Montana, used hydraulic engineering principles to determine parameters pertinent to the depositional environment of the Rim Gravel. It is therefore limited mainly to providing *minimum* estimates that may be used to test various historical scenarios geologists may dream up. If a particular story posits flow depths and current speeds too small to transport observed rocks over a given paleoslope, then the story isn't possible. Methods used in estimating minimum depths and current speeds have been described in the creationist technical literature.[1,2,3]

Paleoslope Estimates

The paleoslope can be estimated using paleocurrent directions and the configuration of erosion surfaces. It is quite variable in the Rim Gravel study area. The area northwest of Sycamore Canyon has the least slope and to the southeast near the towns of Young and Heber, the slope is much steeper. The slope was estimated from topographic maps beginning at the current edge of the Mogollon Rim. Rock 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 (1.5%).

Bedload Transport Hypothesis

The rounding of the rocks seen in the Rim Gravel is consonant with bedload transport. For the estimated paleoslope and observed rock 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, smooth flow, though laminar flow can happen in the transition zone above a Reynolds number of 2,000.[4] A Froude number greater than 1.0 indicates hypercritical or "rapid, turbulent" 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.

Velocity calculations were performed using the Keulegan and Chezy equations that relate current velocity to various parameters of the bed.[2] These were checked by using Manning's equation to determine the *n* value for the stream bottom to achieve the velocities

[1] Klevberg, P., 1998. The Big Sky Paving gravel deposit, Cascade County, Montana. *Creation Research Society Quarterly* 34:225–235.

[2] 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*, technical symposium sessions, Creation Science Fellowship, Pittsburgh, PA, pp. 361–378.

[3] Oard, M.J. and P. Klevberg, 2005. Deposits remaining from the Genesis Flood: Rim Gravels in Arizona. *Creation Research Society Quarterly* 42(1):1–17.

[4] Roberson, J.A. and C.T. Crowe, 1985. *Engineering Fluid Mechanics*, third edition. Houghton Mifflin Company, Boston, MA, p. 314.

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 bed river.[5] 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.

Estimates of minimum current properties are shown in Table A14.1. The second column is a straightforward calculation based on the largest observed exotic rock size and steepest paleoslope. This represents sandstone eroded from the sedimentary rocks below the Rim Gravel. The third and fourth columns are based on an assumed paleoslope half as steep as the steepest observed paleoslope to achieve a more "average" paleocurrent (accounting for lesser slopes elsewhere and potential sinuosity) for the entire study area. The third 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 speculative inferences for the Rim Gravel.

Current Properties	**Max. Slope**	**Avg. Slope**	**Min. Current**
Rock diameter (cm)	150	50	150
Slope	0.014915	0.007458	0.007458
Minimum shear Stress (N/m2)	725	240	725
Minimum depth (m)	4.96	3.28	9.91
Minimum Current Speed (m/sec)	21.5	11.5	20.0
Minimum Unit Flow (m3/s per m width)	106	37.8	198
Froude Number	3.08	2.03	2.03
Reynolds Number	2.15×10^3	7.64×10^2	4.01×10^3

Table A14.1. Rim Gravel paleohydraulic estimates. The second column represents maximum inferred paleoslope, the third and fourth column values are based on an arbitrarily halved value for slope, which is still in excess of the minimum slope in the northwest part of the Rim Gravel area and assumes a sinuosity of 1 (no sinuosity) for the current, a conservative assumption.

The minimum current speed in the calculations is 26 mph (11.5 m/sec or 42 kph) for a conservative estimate of the paleoslope, while the maximum is around 47 mph (21 m/sec or 76 kph). Remember, in these estimates the current speed is a minimum estimate based on the variable parameters in the calculation. The speeds are on the order of the fastest flash floods on Earth today that race down steep mountain valleys. Minimum paleocurrents would have been very energetic, capable of eroding hard rock, planing off obstructions, rounding rocks, and transporting large amounts of sediment. Estimated minimum depths range from 11 feet (3.3 m) to 32.5 feet (9.9 m). Actual depths may have been much greater.

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[5] Giles, R.V., 1962. *Schaum's Outline of Theory and Problems of Fluid Mechanics and Hydraulics*, 2nd edition, McGraw-Hill Book company, New York, NY, p. 252.

Estimated discharge per a foot width range from 410 to 2,130 cubic feet per second per foot width (38 to 198 cubic meters per second per meter 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 flow pattern and depositional environment for the Rim Gravels than present environments.

Paleocurrents were supercritical (Froude number >1.0) and therefore the flow was rapid and turbulent. To reduce the Froude number to 1.0 (critical flow) would require a flow depth of 4.6 kilometers (2.86 miles)! Estimated minimum Reynolds numbers are near the boundary between laminar and transitional flow.