earth should have received 36,000 impact craters greater than 30 km in diameter, with about 100 over 1,000 km and a few with diameters of 4,000 to 5,000 km.[17] Such a great bombardment would pulverize a larger portion of the earth's surface and may have started the Flood. The implications of such bombardment are tremendous and I don't think creationist have yet dealt with this issue. The reason that we do not see direct evidence of such bombardment is very likely because vertical tectonics, erosion and re-deposition would have greatly modified the original craters during the Flood. All these microdiamonds and ultra high-pressure minerals, plus island arcs, could be remnants of a huge asteroid bombardment at the time of the Flood.

References

1. Armitage, M.H. and Snelling, A.A., Radiohalos and diamonds: are diamonds really for ever? in: Snelling, A.A. (Ed.), *Proceedings of the Sixth International Conference on Creationism*, Creation Science Fellowship and Institute for Creation Research, Pittsburgh, PA and Dallas, TX, pp. 323–334, 2008.
2. Oard, M.J., The uniformitarian challenge of ultrahigh-pressure minerals, *Journal of Creation* **20**(1):5–6, 2006.
3. Liou, J.G., Ernst, W.G. and Ogasawara, Y., Petrochemical and tectonic processes of UHP/HP terranes I: Preface, *International Geology Review* **44**:765–769, 2002.
4. Cartigny, P. *et al.*, Early Proterozoic ultrahigh pressure metamorphism: evidence from microdiamonds, *Science* **304**:853–855, 2004.
5. Dobrzhinetskaya, L.F. *et al.*, Microdiamonds in high-grade metamorphic rocks of the Western Gneiss region, Norway, *Geology* **23**:597–600, 1995.
6. Platt, J.P., Exhumation of high-pressure rocks: a review of concepts and processes, *Terra Nova* **5**:121, 1993.
7. Yang, J.-S. *et al.*, Diamond- and Coesite-bearing chromitites from the Luobusa ophiolite, Tibet, *Geology* **35**:875–878, 2007.
8. Oard, M.J., What is the meaning of ophiolites? *Journal of Creation* **22**(3):13–15, 2008.
9. Green II, H.W., Psychology of a changing paradigm: 40+ years of high-pressure metamorphism, *International Geology Review* **47**:439–456, 2005.
10. Mizukami, T. *et al.*, Forearc diamond from Japan, *Geology* **36**:219–222, 2008.
11. Oard, M.J., Subduction unlikely—plate tectonics improbable; in: Reed, J.K. (Ed.), *Plate Tectonics: A Different View*, Creation Research Society Books, Chino Valley, AZ, pp. 93–145, 2000.
12. Mizukami *et al.*, ref. 10, p. 219.
13. Mizukami *et al.*, ref. 10, p. 221.
14. Frank, F.C., Curvature of island arcs, *Nature* **220**:363, 1968; Hsui, A.T. and Youngquist, S., A dynamic model of the curvature of the Mariana Trench, *Nature* **318**:455–457, 1985; Shahabpour, J., Relationships among the tectonic components of the island arcs and their plate tectonic implications, *Journal of Geodynamics* **23**(2):79–93, 1997.
15. Samec, R.G., Is the Moon's orbit "ringing" from an asteroid collision event which triggered the Flood? in: Snelling, A.A. (Ed.), *Proceedings of the Sixth International Conference on Creationism*, Creation Science Fellowship and Institute for Creation Research, Pittsburgh, PA and Dallas, TX, pp. 255–261, 2008.
16. Samec, R.G., On the origin of lunar maria, *Journal of Creation* **22**(3):101–108, 2008.
17. Oard, M.J., How many impact craters should there be on Earth? *Journal of Creation* (in press).
18. Cormier, V.F., Tectonics near the junction of the Aleutian and Kuril-Kamchatka Arcs and a mechanism for Middle Tertiary magmatism in the Kamchatka Basin, *Geological Society of America Bulletin* **86**:443–453, 1975.
19. Clift, P.D. and Vannucchi, P., Controls on tectonic accretion versus erosion in subduction zones: implications for the origin and recycling of the continental crust, *Review of Geophysics* **42**, RG2001/2004.

Eolian erosion exposé

Emil Silvestru

Wind (eolian) erosion is usually mentioned in the scientific literature as wind picking up sand particles (deflation) and "sandblasting" the bedrock (corrasion).[1,2] The most visible results are sand deposits (dunes and associated forms) and strange "mushroom" rocks.

Little is however said or taught about the possibility of wind excavating large hollows in massive rocks. The most obvious features that come to mind are *tafoni* (singular *tafone*) which is defined as

> "A hollow, produced by localized weathering on a steep face. Rock breakdown typically takes place by granular disintegration or by flaking, and the hollow shows a tendency to grow upwards and backwards."[3]

Although most authors seem to emphasize localized weathering, mineral constituents inside the host rocks and local fracture concentration as cause for their formation, some have at least considered the role of wind in the overall excavation process.[4]

Wind "eats" rock

I believe that wind plays a more significant role in the formation of tafoni. During microclimate research in a salt mine near the city of Turda, Transylvania, Romania, I witnessed the formation of many "megascallops"—large (up do a meter long and 30 cm diameter at the wider end) scallop or spoon-like excavations—in rocksalt resulting from the opening new air shafts. The cause was the sudden increase in fresh air flow from the surface through the shaft. The fresh humid air being unsaturated in salt aerosols, unlike the normal, near-stagnant mine atmosphere would be able to dissolve the rocksalt in areas where turbulence ensured a longer air-rocksalt contact. These were generally in the upper corners of the mining galleries and on one location dozens of parallel megascallops formed in less than 10 years. There were no significant chemical inhomogeneities in the rocksalt to explain such features by selective dissolution. Microclimate measurements as well as smoke experiments have confirmed the major role of air turbulence in creating these features.

The presence of tafoni on Mars[5] further emphasizes the role of wind in "tafonisation".

Water can too

Similar scalloping morphologies caused by air currents also occur in ice as exemplified by the superbly scalloped walls of Arches Cave in the Khumbu Glacier (Mt. Everest, Nepal; figure 1).[6] They also occur when wind blows over compacted snow.[7] In these cases the mechanism is sublimation of homogenous crystalline matter.

Dissolutional scalloping and fluting is common in limestone, gypsum and salt caves. Subcritical turbulent flow of unsaturated water has been proven to be the mechanism responsible for scalloping in these situations.[7] (Figure 2).

A common mechanism

There are many morphological similarities between tafoni (figure 3) and these rocksalt excavations and I suggest that air turbulence plays a significant role in the formation of tafoni. The origin of tafoni is undoubtedly polygenic, with variable porosity and matrix mineralogy acting as initiators of tafonisation. A more porous area in sandstone for example will tend to accumulate more pore water and if freezing occurs, cryoclasty will tend to cause granular disintegration. Once a tiny excavation forms, air flow will become more turbulent and deflation will occur, with a tendency for the excavation to deepen along turbulence (eddy) pathways; the larger the resulting excavation, the more airborne particles become available for corrasion. Studies have shown that tafoni tend to deepen rapidly as they expand (positive feedback)[5]. If the wind is consistent and persistent, large tafoni can form in a matter of years.

Some authors[5] have pointed out that case hardening occurs on the outer roof areas of tafoni the result of persistent eddies that would further the specific tafoni excavation.

Figure 1. Scallops in Resonance Cave, Vancouver Island, British Columbia, Canada. The speleothems mark the transition from flooded regime (when scallops formed) to free-surface flow. The cave is excavated in Triassic Quatzino Limestone.

Figure 2. Tafoni in Cretaceous sandstone at Stone Garden near Tumbler Ridge, British Columbia, Canada. The vertical jointing does not affect/control tafonization. There seems to be no case hardening nor is there any overhanging "brow".

From tafoni to arch

What would happen if tafoni formed in narrow inhomogeneous sandstone ridges ("rock fins")? If the polygenetic conditions are consistent and persistent enough, they may very well perforate the ridge from one side to the other creating arches like the ones in the Arches National Park in Utah. Once a perforation like that occurred, the turbulent airflow would increase, as well as preferential, contour cryoclasty as now the open rim will provide more porosity for water retention. Collapse will significantly enlarge arches until certain, temporary equilibrium is reached.

Cave (karst) scalloping and pothole distribution reveals that these features almost exclusively form on the walls and bedrock of conduits, never in the concavity of sharp bends where water flow impact is frontal. The reason is that coherent and persistant turbulence (vital for scalloping and potholing) occurs where parallel flow is affected by rockwall rugosity. Similarly, one would expect that tafoni preferentially form on the sides of narrow canyons, and statistically they do. In the Castle Rocks State Park, Idaho, tafoni form mostly in the main cluster of spires, rather than in isolated inselbergs.[5]

If winds were consistent for longer periods in the past, such an origin for many of the arches might be possible. I acknowledge that I have not visited the site and am relying entirely on photographic and video sources as well as field data elsewhere. Very strong and persistent seasonal winds were present during the deglaciation period in the Late Pleistocene even at mid-latitudes.[8]

When?

Oard[9] attributes the arches and natural bridges in Utah to Late Flood

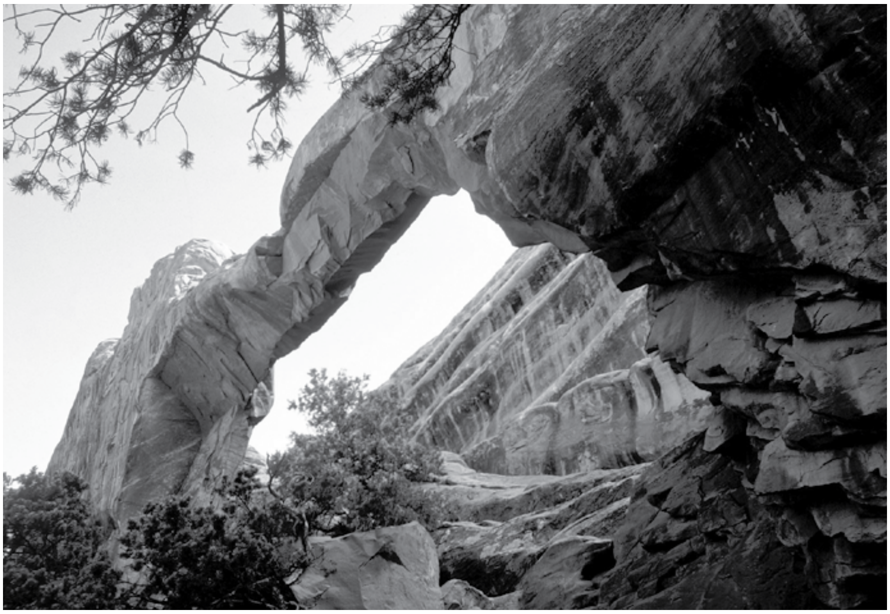

Figure 3. Wall Arch was one of the largest natural arches in Arches National Park, Utah, before it collapsed in August 2008.

mechanisms. Natural bridges are different from arches in that they span an existing or dry stream which is believed to have undercut them. They are often excavated in relatively homogenous rocks unlike arches which always have a harder rock forming the roof and a softer one below. According to Oard, the arches would have formed during either the Sheet-flow or Channelize-flow Phase of the Retreating Stage of the Flood, while natural bridges probably formed during the Channelized Phase.[10] Oard's assumption is that somehow, as incised valleys formed during the Retreating Phase, undercutting of less resistant rock under a more resistant layer. However, this does not really answer the objection Oard himself quotes from the literature:

> "Arch formation cannot be due solely to weathering and erosion, however, because these processes are not restricted to the sides of arches in rock fins. There must be some factor that locally enhances the effects of erosion within a rather small part of the rock fin to produce an arch. How erosion is localized within the rock fin to form an arch is enigmatic."[11]

I suspect that there is nothing enigmatic about such localization once persistent seasonal air turbulence is inferred. Oard's explanation is most likely valid in the case of natural bridges and probably for the formation of rock fins during rapid downcutting of incised valleys. In fact most rock fins represent meander necks, narrow ridges of rock separating the two sides of a hairpin meander in an incised valley. I think that these arches formed towards the end of the Ice Age; during rapid deglaciation. Those were times when winds were very strong and persistent, especially since most mid-latitude areas were completely deforested, allowing for extensive eolian erosion as is current on Mars.[12] In fact climate patterns were most likely very different from the present ones as the thermohaline circulation system was massively disrupted by the sudden input of huge amounts of fresh meltwater coming from the rapidly-melting ice sheets.[13]

Conclusion

The role of early post-Flood climate in geomorphology has not been investigated to any extent by young-earth creation scientists, although it may in fact have played a significant role in sculpting at least some of the landmarks of every continent. Under such circumstances, any present attempt—including this one—cannot but be speculative in nature. I believe that post-Flood paleoclimate reconstructions are needed and they could be assisted if not complimented by geomorphic investigation. Furthermore, such reconstructions may prove useful for future faunal and floral distribution creationist studies, including anthropology.

References

1. Selley, R.C., *Applied Sedimentology,* 2nd ed., Academic Press, San Diego, CA, p. 23, 2000.
2. Reading, H.G. (Ed.), *Sedimentary Environments*, Blackwell Science, Oxford, p. 125, 2002.
3. <www.highbeam.com/doc/1O15-tafone.html>.
4. Rodriguez-Navarro, C., Doehne, E. and Sebastian, E., Origins of honeycomb weathering: the role of salts and wind, *GSA Bulletin* **111**(8);1250–1255, August 1999; <*http://bulletin.geoscienceworld.org/cgi/content/abstract/111/8/1250*>.
5. Hacker, A., Controls of Tafoni Development in Castle Rocks, Idaho, <http://keckgeology.org/files/pdf/symvol/16th/idaho/hackernew.pdf>, 28 April 2009.
6. Benn, D. and Gulley, J., Under Thin Air: the 2005 Ngozumpa Glacier Cave research Project, *NSS News* **64**(10):16, 2006.
7. Ford, D.D. and Williams, P., *Karst Geomorphology and Hydrology*, Chapman Hall, London, p. 305, 1992.
8. Oard, M., *An Ice Age Caused by the Genesis Flood*, Institute for Creation Research, El Cajon, CA, pp. 109–119, 1990.
9. Oard, M., Many arches and natural bridges likely from the Flood, *Journal of Creation* **23**(1):115–118, 2009.
10. Oard, M., *Flood by Design: Receding Water Shapes the Earth's Surface*, Master Books, Green Forest, AR, 2008.
11. Cruickshank, K.M. and Aydin, A., Role of fracture localization in arch formation, Arches National Park, Utah, *GSA Bulletin* **106**: 879, 1996.
12. Reading, ref. 2, p. 125.
13. Broecker, W.S. *et al.*, Routing of meltwater from Laurentide Ice Sheet during the Younger Dryas cold episode, *Nature* **341**:318–321, 28 Sept. 1989.