PSI NEWSLETTER

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Impact at Cumberland Gap: Where Natural and National History Collide

By Steve Kortenkamp

Asteroids and comets likely played important roles in the origin and evolution of life on Earth. In primordial times they were vessels for delivery of water and organic material to our barren young planet. Paradoxically, once life arose they became instruments of mass extinctions. However, in addition to their rather grandiose involvement with genesis, impacts of asteroids and comets have also affected events in modern times, including significant milestones in American history. One particular impact that occurred hundreds of millions of years ago was in just the right location to aid Daniel Boone and early American settlers in their westward journey across the Appalachian Mountains.

DANIEL BOONE ESCORTING SETTLERS THROUGH THE CUMBERLAND GAP, 1852, by renowned artist George Caleb Bingham, Washington University Gallery of Art, St. Louis, MO.

The Appalachians are the weathered and worn remains of mountains that date to the formation of the supercontinent Pangaea 300 million years ago. They stretch 1500 miles along the Atlantic seaboard of North America, from Quebec down into Alabama. Despite their relatively modest topography, the Appalachians once presented a formidable obstacle to early inhabitants of our country. European explorers often described maddening attempts to navigate through the natural maze of steep ridges and dead-end valleys. By some accounts only three naturally occurring, easily navigable, east-west routes exist through the mountain range. The most famous of these passages is at Cumberland Gap, where Virginia, Tennessee, and Kentucky all meet.

The mountain passage at Cumberland Gap has a rich heritage that dates to prehistoric times. It served as a major migratory route for herds of bison and elk, then for native Cherokee and Shawnee Indians, and also small parties of early American hunters and traders. In 1769, legendary frontiersman Daniel Boone made his first traverse of Cumberland Gap. He was awestruck by the bountiful lands to the west and soon sought to move his family there.

Boone and his contemporaries are credited with recognizing the significance of Cumberland Gap for the wholesale westward movement of settlers into what was then called Kaintucke. In 1775, just before the out-

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break of our Revolutionary War, Boone was commissioned to clear a trail through Cumberland Gap. Originally called Boone's Trace, the route evolved into what is now referred to as the Wilderness Road. Up until this time the original American colonies had been effectively hemmed in by the Appalachians. Completion of Boone's Trace released a torrent of settlers itching for the land and freedom of the western frontier. By 1792, over 100,000 people had followed Boone on foot across the Appalachians, compelling the Union to admit Kentucky as the first extra-colonial western state.

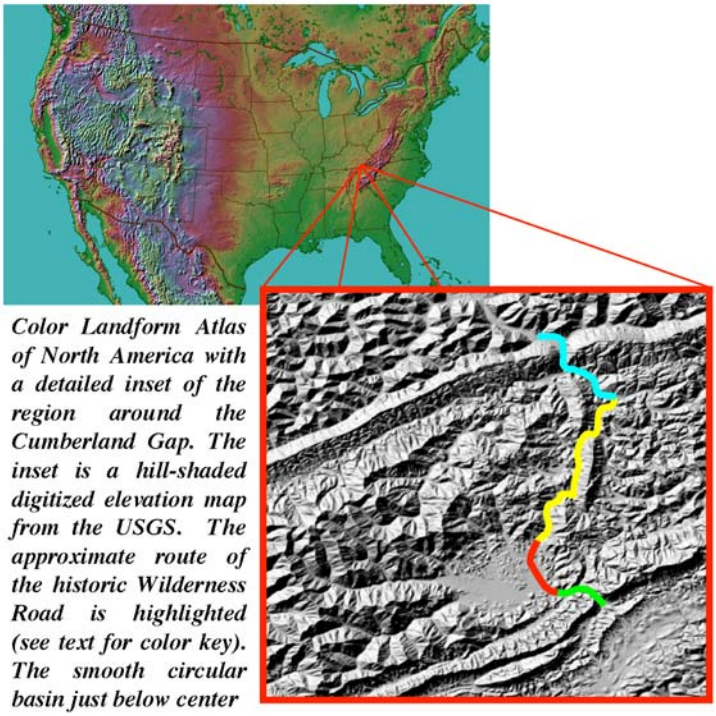
Unbeknownst to Boone and the settlers who followed him, as well as the Indians and animals that came before, was the cosmic influence on their route. Their journey across the Appalachians was made possible, or at least considerably less tortuous, thanks to the presence of an ancient impact crater. This crater is easily identified in the detailed inset of the Cumberland Gap region on the diagram to the right. The gentle basin left by the impact lies in stark contrast to the rugged terrain of the surrounding region.

The twelve-mile-long route through the Appalachians at Cumberland Gap owes its existence to four geologic elements. The colored line in the inset of the diagram to the right traces Boone's Wilderness Road and helps to identify these four ingredients. Traversing the gap from Virginia to Kentucky these features are: (green) a gap in the Cumberland mountain ridge, (red) a three-mile diameter impact crater just west of the Cumberland ridge, (yellow) a valley formed partly by the Yellow Creek, and (blue) an eroded gap in the Pine mountain ridge where the Cumberland River flows through.

The historical significance of Cumberland Gap is likely dependent on the mutual presence of all four of its geologic elements. Without the two mountain gaps the route would be nonexistent. Absent the impact crater or the creek valley, the route may not have been easily navigable for pack horses, much less the wagon trains that began traversing it in 1796.

In the early to mid 19th century additional routes west gained in popularity, including steamboat travel either down the Ohio River or up the Mississippi. However, the primary overland route to the interior of the country remained the passage at Cumberland Gap. By 1810, over 300,000 settlers had migrated west through the impact crater at Cumberland Gap. Within the next decade the Union had swelled to include eight more western states. Several notable families migrated through Cumberland Gap; among them was the Clark family with children George Rogers and William (of Lewis & Clark fame) as well as the parents and grandparents of Abraham Lincoln.

Today the impact crater at Cumberland Gap is home to the town of Middlesboro, Kentucky. Remnants of the uplifted central peak of the crater are visible on the grounds of the city's golf course. The rock shown in the image above right was found at the country club. The feather-like striations visible in the rock are the telltale pattern of a so-called shatter cone, a type of rock fragment naturally formed only during impact events. The existence of shatter cones helped confirm the impact origin of the Middlesboro basin.



Color Landform Atlas of North America with a detailed inset of the region around the Cumberland Gap. The inset is a hill-shaded digitized elevation map from the USGS. The approximate route of the historic Wilderness Road is highlighted (see text for color key). The smooth circular basin just below center of the inset is the impact crater that today is home to the town of Middlesboro, Kentucky. The Color Landform Atlas was produced by Ray Sterner at the Johns Hopkins University Applied Physics Lab (fermi.jhuapl.edu/states/states.html) and is licensed to North Star Science and Technology (www.landforms.biz).

Shatter cone rock fragment, left, at the Middlesboro impact crater. Image is from Milam et al., 2004, Lunar and Planetary Science Conference.

The unique confluence of natural and national history at Cumberland Gap has only recently been officially recognized. In September 2003, the Kentucky Society of Professional Geologists designated Middlesboro as a Distinguished Geologic Site. This distinction is attracting scientists and tourists and helping to revive the economy of the region around Cumberland Gap.

Like many areas of Appalachia, Middlesboro is a mining town. It is the only place known in the world where coal is mined from within an impact crater. The complicated system of faults and undulating layers of rock inside the crater requires special techniques to extract the coal. Geologists speculate that these same techniques could be useful for mining resources on the moon and asteroids. This hints at the possibility that the Middlesboro crater may influence our future just as it has had an impact on American history. In any case, it is fascinating to imagine that such an important component of our history was aided by the fortuitous impact of a relatively small asteroid millions of years before humans had evolved as a species.

Steve Kortenkamp is a research scientist at PSI and may be reached at kortenka@psi.edu for further information.

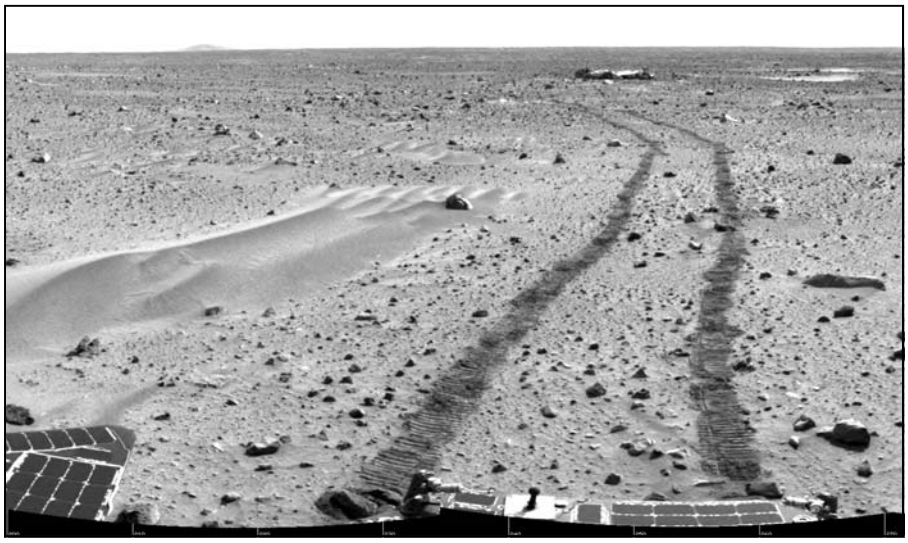
Images of the Month: Two Landscapes on Mars *By William K. Hartmann*

One of the joys of working with the images coming back from the two Mars rovers, *Spirit* and *Opportunity*, is that you can download wide-angle panoramas from either rover, select your own favorite part of the scene, like a photographer pointing a camera, crop out that scene, and make your own "snapshot." A little processing in Adobe Photoshop helps, as I find the posted images tend to be dark and low-contrast.

This is a perfect activity for teachers and students since it teaches about Mars as well as the principles of nature photography and image processing. Find these images on the web at **http://marsrovers.jpl.nasa.gov/gallery/press/.**

The images to the right show two places on Mars we have come to know and love, and the tremendous difference in their terrain types. The top image is a *we were there* shot, showing the tracks left by the Spirit rover on the floor of Gusev crater. This is very typical Martian terrain, similar to the two Viking landing sites visited in 1976 and Pathfinder's site in 1997: sandy terrain, scattered boulders, and scattered dunes.

The second image shows a striking vista at Opportunity's Terra Meridiani site — a totally different landscape of windblown, rippled sand, with no boulders, and with a few pits or disturbances which may be where debris blown out of large impact craters fell to the ground and made secondary craters. On the horizon in the distance is Endurance crater, which was reached by Opportunity in early May.

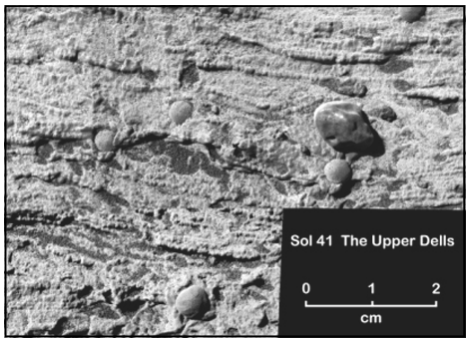


Spirit rover leaves tracks across the floor of Gusev crater; the landing platform is in the distance. (Image credit: NASA/JPL 2/17/04).

The plains of Terra Meridiani, as seen from Opportunity rover, are unlike any other surface we've seen at the other four landing sites. The smooth plain is covered with sandy material mixed with hematite-rich BB-sized spherules. (Image credit: NASA/JPL/Cornell)

The biggest excitement in the landings is the evidence that the Terra Meridiani site may be an ancient lake floor. Data from Mars Global Surveyor indicated this plain has a very unusual deposit of hematite, possibly left by water (see Melissa Lane's article in the Winter 2002 PSI Newsletter). Our own pre-landing work at PSI, published in Icarus (2001, 149:37-53), indicates that this site was an ancient surface that was covered over by sediments or debris, and then was recently (5 to 20 million years ago?) uncovered, or exhumed in geologists' parlance, by erosive processes. Recent discoveries by the Opportunity rover show that the rocks in the area were saturated by water (or under standing water?) and contain typically 20 to 40% sulfate minerals.

The small image to the right shows the most dramatic evidence for water in Terra Meridiani. This close-up of rock outcrops shows very fine layering. Moreover, the layering is wavy and the layers cut each other off in a pattern recognized by geologists as typical of thin sediments deposited by flowing water. The hematite, according to Spirit rover instruments, is concentrated in the small spherules. The plain in the middle image is littered with these spherules, and they seem to have eroded out of the sediment layers and been left behind as the weak sediments broke down and were removed, probably by wind.



Close-up view of Terra Meridiani rock layers and hematite spherules.

These images are only a tiny sampling of what is available on the Mars rover web sites. The official 90-day missions, for which the rovers were designed, have ended, but the rovers are working well and mission extensions have been approved for five months. Spirit rover, for example, is still chugging away toward distant hills in Gusev crater, where old sediment layers may be exposed. From Mars, as always, there is much more to

Photo Gallery

Twins in Pasadena

Karl and Mi Jeong Hibbitts with their adorable twin boys, Taegon Robert and Jaegon William, just days after they were born, March 19, 2004.

And look how big they are by May 13— and how cute!

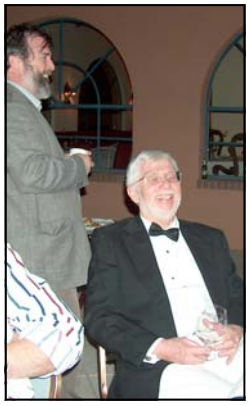
On a beautiful April evening in Tucson, we celebrated Don Davis' career as Director of PSI, 1978-2004. Below are some photographs of that marvelous evening at Janos restaurant.

Don Davis is surrounded by friends and family at the dinner in his honor. From left, Andy O'Dell (NAU, emeritus), Don and his daughter Jennifer Giblin (whose visit from New York was a wonderful surprise for Don), and Steve Larson (UA).

Karen Wood, left, and Diana Wheeler (Don's wife) enjoy the balmy night air on the patio at Janos.

Party-goers gathered on the patio at sunset; from left, Frank Chuang, David Crown, Les Bleamaster and Steve Kortenkamp (all PSI-Tucson).

Enjoying the festivities, from left, Gayle and Bill Hartmann (Bill is a co-founder of PSI), Kerry Swindle, M.D., Bill Boynton (UA) and Dorian Voorhees (UA).



Just who is relishing the handover most — outgoing director Don Davis, right, or incoming director, Mark Sykes?

Among the many at the gathering from the UA were, from left, in foreground, Robert Strom, David Kring, Tim Swindle, and Larry Lebofsky (back to camera).

Attending the celebration are, from left, Marilyn Guengerich (Mark Sykes' wife), Maggie Gilman, Don Hunten (UA) and Ann Sprague (UA).

Richard Green (NOAO) and his wife Joan, chat with PSI's Chuck Wood (back to camera) during the celebration dinner.

Eileen Ryan, formerly with PSI, traveled from New Mexico Tech to attend the party for Don.

A beautiful evening under the stars where everyone had a grand time dining alfresco at Janos and celebrating Don's 26 years at the helm of PSI.

Kelly Yoder, left, and Mark Everett (both PSI-AZ) visit with Janet Whitener (PSI-CA) at the party.

Special thanks to the many generous people who helped sponsor this memorable evening honoring Don Davis.

Director's Notes

June 2004

Having just finished my first month as Director of PSI, I can now fully appreciate the breadth and depth of the work that Don Davis has shouldered for more than two decades! There are accounting systems to understand, federal regulations to internalize, documents to generate, leases to negotiate, communications with funding agencies, and preparations for auditors, while occasionally sneaking in a little science. I have also come to appreciate our excellent staff in Tucson and California, who keep our operations running smoothly.

PSI has grown rapidly in recent years and continues to grow. In the past two months we have added five new scientists who will be expanding PSI activities in groundbased planetary astronomy, early solar system formation, astrobiology, and planetary geophysics. PSI has provided and will continue to provide a supportive environment for young scientists working to establish their research careers. Established scientists are also finding PSI's collegial environment attractive. One consequence of this is that our recently purchased Tucson office is now full and we are negotiating to lease additional space nearby. Our Pasadena office will also be expanding, and the number of our off-site scientists is increasing.

PSI is moving aggressively into spacebased infrared observations using the Spitzer Space Telescope. We were just awarded the largest time allocation for that facility in its first guest observer competition. This program will study the origins of the interplanetary dust complex between the orbits of Earth and Jupiter. Additional Spitzer projects for which PSI scientists have been awarded time include the study of asteroids, comets trails, and the outer satellites of Jupiter and Saturn. Spitzer is the last of the "Great Observatories", making very sensitive observations of thermal radiation; it is expected to operate for the next five years.

PSI is a vibrant research institution with a great future before it. We have an excellent mix of researchers at all levels of their careers and a stimulating diversity of expertise in groundbased and spacebased observations, theory, lab and field work, and many NASA spacecraft missions. PSI is involved in all major solar system exploration initiatives including the Moon-Mars Initiative, and PSI scientists are participating in the formulation of our national space policy. This is an exciting and fun place to be.

My plans for the future include the establishment of a building fund to pay off our mortgage and acquire the facilities we need to sustain and expand PSI's good work. Despite our continued successes in increasing PSI grants and contracts, the free and clear ownership of our building will provide institutional stability that cannot be achieved by grants alone. It will give PSI greater flexibility to invest its resources in its scientists and achieve preeminence in the exploration of the solar system.

Mark V. Sykes
Director

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The ***Friends of PSI*** are people like you — folks interested in the excitement and knowledge brought about by astronomy and planetary science. The scientists at the Planetary Science Institute pursue fundamental research in planetary science, geology, and astronomy. PSI is also involved in many educational activities including school field trip programs, popular articles and lectures, research internships for undergraduates, and training and mentoring young researchers at the graduate and postdoctoral levels.

Friends receive a quarterly newsletter detailing the activities of PSI's science and education programs. Additionally, the newsletter contains new scientific discoveries at PSI, as well as features on PSI scientists and their activities.

So join us today with your yearly membership contribution, or become a supporting or sustaining member by joining at one of the tax-deductible categories listed below.

- ***Meteorite Member*** ($35): Receive the newsletter plus personal invitations to "members only" Institute events.
- ***Asteroid Member*** ($200): All of the above plus your choice of one of the following: A multicolor print of an original painting by W. K. Hartmann, or a signed copy of *A Traveler's Guide to Mars*, Bill's beautiful and fascinating overview of modern Mars research, illustrated by detailed photographs from the Mars Global Surveyor mission.
- ***Planet Member*** ($750): All of the above plus an exclusive invitation to an annual private dinner and highlights of astronomy talk with Institute scientists.
- ***Star Member*** ($5,000): All of the above plus an invitation to a night of observing at the Skywatcher's Inn, hosted by PSI scientists. This outing includes naked eye and telescopic viewing of the night sky at a prime dark-sky observatory near Benson, AZ.
- Or you can become a ***Supporting Member*** ($10,000 or more) or a ***Sustaining Member*** ($20,000 or more) and receive all of the above as well as provide additional funds to be used by PSI scientists in research and educational activities.

To make your tax-deductible donation, please complete the form on page 6 and send to our Tucson office.

Thank you!

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