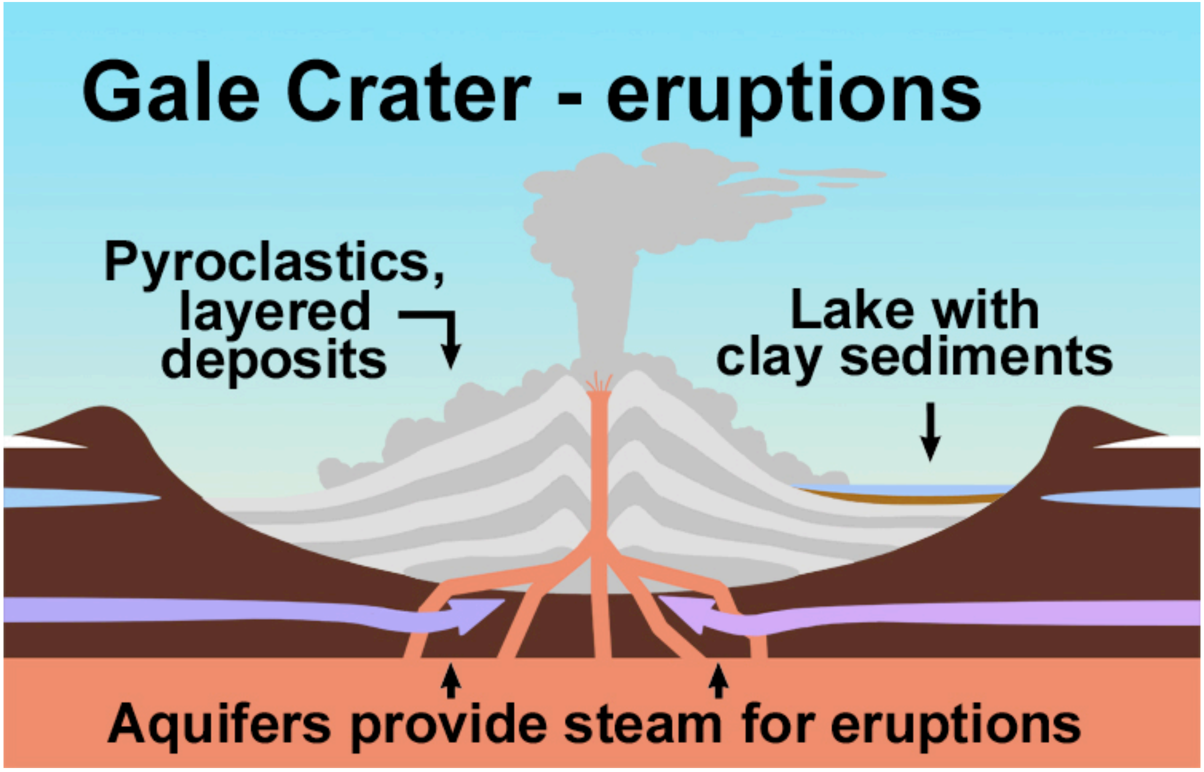

THE VOLCANIC LANDSCAPE OF GALE CRATER ON MARS

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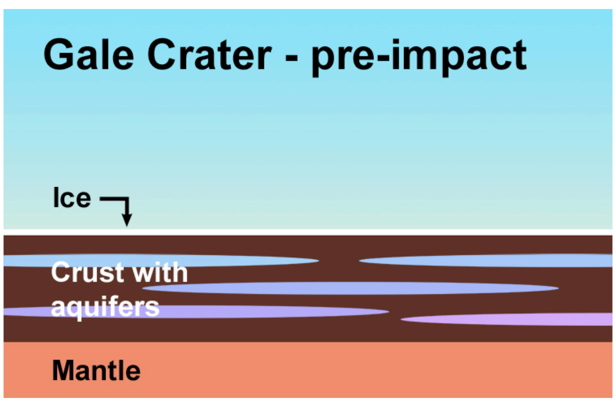
As the Mars rover Curiosity explores the landscape of Gale Crater, a 96 mile (154 km) wide hole in the planet with an imposing 3.4 mile (18 km) high central peak in its middle, a scientific conundrum has been reported by the investigators who are operating the rover's science instruments. Everywhere they look with the rover's camera eyes, they see landforms that suggest wind and water laid down the rock layers that make up the landscape. But when they analyze the chemistry of the rock layers, they find that water could not have been involved, because water would have altered the chemistry of the sand and dust particles it carried.

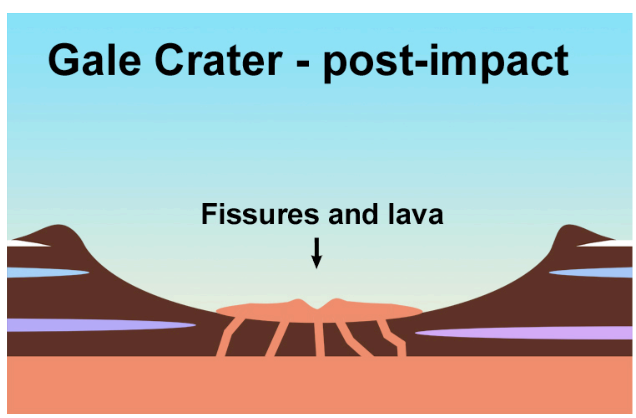
One principle investigator has stated the problem succinctly: the rock layers have the appearance of sedimentary rocks put in place by windblown dunes or river sandbars—but they have the chemistry of pure basaltic, volcanic, lava.

In my view, these investigators may have been misled somewhat by their primary mission goals, which include a directive to "follow the water" and to look for environments where life could have existed. Because such environments must include ample amounts of liquid water, it seems possible the investigators are distracted from seeing other possibilities in the landforms they are investigating, especially volcanic landforms lacking water and therefore non-conducive to life.

It seems quite reasonable that investigators trying to fit their data to life-compatible scenarios might overlook alternative, harsher conditions that could explain their raw data much more precisely than they have done in their published reports. This presentation will address their data, and offer an alternative model for the evolution of the landscape of Gale Crater—namely, via volcanism.

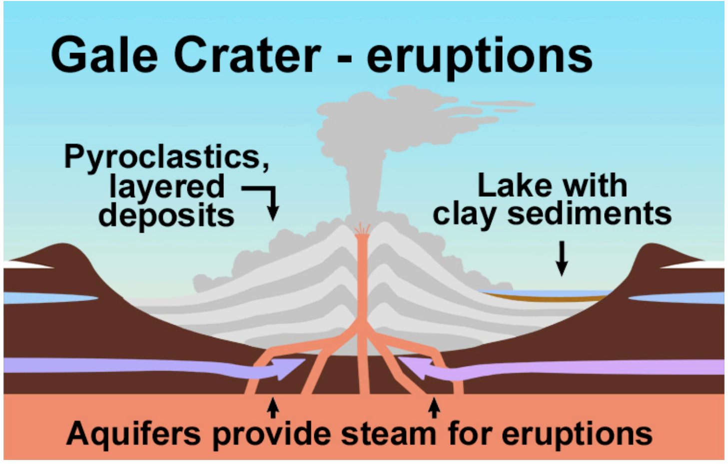


Both models start from the same point of departure: about 3.6 billion years ago, an asteroid struck Mars with enough force to put that 96 mile hole in the ground and send a powerful shock wave deep into the crust. All agree that this event started a series of subsequent developments that led to today's landscape at Gale Crater. The point of divergence comes when one either takes the wind-and-water rationale the rover team has adopted, or uses volcanism as the primary mechanism.



Pyroclastic deposits from volcanic eruptions come in a tremendous variety of forms. Because it is not my intent to review these, it is sufficient to select the one that best fits the data obtained from Curiosity's cameras and chemistry experiments, which show that most rocks examined so far have a mineral composition quite close to basalt, the most common form of volcanic rock on Mars and Earth. Hand lens imaging and microscopic imaging have shown the rocks to be generally grainy, as opposed to glassy or vesiculated (a bubbled form common to many basaltic rocks on earth). Importantly, not all earthly pyroclastic deposits have significant amounts of glassy materials in them. Some can be quite granular at a fine scale, as is seen in the Mt. St. Helens ash sample collected by Dr. M. A. Wilson of the College of Geology, Wooster University, Ohio. That sample has abundant crystalline rock particles in it, derived from the basalt of the volcano by the ultra-violent conditions of a Plinian explosion and pyroclastic flow. Dr. Wilson's sample contains minimal amounts of glassy shards. Instead it includes some rounded particles of glassy material mixed in with the crystalline particles.

Perhaps such pyroclastic materials form the bulk of the outcrops on the bottom of Gale Crater and the slopes of Mount Sharp, the central peak. What remains then, is to explain how those landforms were created from this pulverized material. If the apparently windblown and waterborne formations were not actually emplaced by wind and water, then how did they come about?



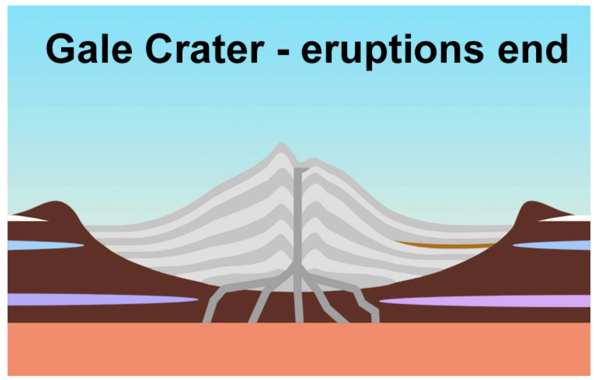
Again, Mt. St. Helens and other earthly volcanoes provide appropriate examples. The deposits on their sides, or laid down farther from their central vents, provide examples of all the outcrops encountered by Curiosity. Investigators working with the rover's imaging systems have reported layered deposits, which they have characterized as possible riverbed or lakebed deposits, and sloping layered deposits they characterize as possible dunes, or the advancing edges of river deltas. However, these deposition histories are not the only ones that fit the landforms seen.

The alternative to these wind- and water-driven mechanisms is the stratovolcano, a mountain like St. Helens, built of layer after layer of pyroclastic flows. In Mt. St. Helens' historic eruption, the most prominent phenomenon of all was the explosion of rock and dust from the volcano's caldera. Propelled by a devastating blast of gas, dust and rock fragments spread over the surrounding landscape for miles, traveling in incandescently-hot clouds of stupendous proportions.

Pyroclastic flows are driven by steam, carbon dioxide, and other gasses trapped under the volcano at extreme pressures and temperatures. The sudden release of pressure as the volcano explodes exerts violent forces that pulverize rocks and disperse fluid lavas into finely divided particles. The initial pyroclastic cloud of dust and rock comprises a mixture of large and small fragments, but as the flow moves downhill under the pull of gravity, this assortment of fragments begins to separate. Large rocks and boulders fall out early, while dust and smaller rocks (called lapilli) continue to move downhill.

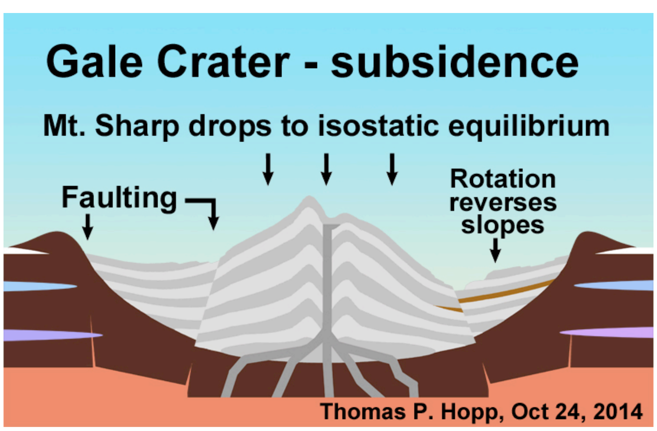
This sorting-out of particle sizes has much to say about some of the layered deposits seen so far by Curiosity. Most common there are layers made of particles so fine that the rock appears featureless, even when examined up close with the "hand-lens" magnifier on the rover's robotic arm. Other deposits appear fine-grained as well, but contain within them scattered dots of larger materials, on the order of a quarter-inch across. These look like the small lapilli that earthbound geologists have noted in some of our planet's pyroclastic deposits. Finally, in just a few locations, rover geologists have reported layers of larger stones, in the range of one-half-inch to an inch in diameter. These latter deposits they describe as "conglomerate" rocks, geologic terminology for a rock layer that itself is comprised of many individual rocks solidified into one mass. However, within pyroclastic flows, such groups of larger, heavier fragments of stone are simply included within the continuum of things grouped under the term "lapilli."

Key here is the notion that the farther a pyroclastic flow goes, the more it loses its larger rocks and comes to consist solely of fine ash. Alternatively, it is also true that the larger and more energetic an eruption is, the farther it will spread its larger rock fragments. So volcanoes, like rivers, can spread layers of rocks or fine powders, and deposit them in the same places, or separately.



The forgoing examples and discussions offer an alternative to the water- and wind-driven mechanisms proposed by the rover scientists to explain the different layered deposits they have been exploring. Simply put, multiple eruptions of pyroclastic flows, large and small, could have created all the landforms seen so far by Curiosity.

Rover scientists have noted variations within outcrops that appear like layers of wind-blown sand, and this forms the basis of one argument that the entire edifice of Mt. Sharp was piled up by the wind. However, in my pyroclastic model, these dune-like layers could have been blown by the gasses that carried the dust, with gusts caused by local variations in the landscape. Such wind-like variations have been described for pyroclastic ash accumulations on Earth.



While my volcanic concept requires no liquid water for emplacement of any landform seen so far, it does not exclude it. So far, there have been several, rare instances of deposits with a quite different chemical signature than basalt, namely clay minerals. Clays occur where basaltic materials are in contact with liquid water for long periods of time, and are altered by chemical reaction with the water. Therefore, if the Mt. Sharp volcano lay dormant for substantial amounts of time, then water from rain or underground aquifers might have filled parts of the crater floor, much the way Spirit Lake has formed beside Mt. St. Helens. Such lakes, although intermittent, would have left behind muddy layers of sediment deposited on their bottoms, which subsequently would have been buried by additional pyroclastic flows from Mt. Sharp. Therefore, while a volcanic model explains the major proportion of the landforms seen at Gale Crater, there is no reason to exclude some limited role for water in the landscape.

In summary, a model is presented in which Gale Crater's Mount Sharp is a meteor-impact-derived strato-volcano, built by pyroclastic eruptions. This model explains the geological features encountered by the rover Curiosity without the need to invoke significant action by wind or liquid water.

This and other scientific observations and theories are published in occasional papers by the author. For more information about Thomas P. Hopp, PhD, and to see his other publications, visit:

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