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Press Release

Scientists Propose New Concept of Terrestrial Planet Formation

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Scientists have long been intrigued by the surfaces of terrestrial bodies other than Earth which reveal deep similarities beneath their superficially differing volcanic and tectonic histories.

A team of scientists from NASA, Hampton University and The University of Hong Kong propose a new way of understanding the cooling and transfer of heat from terrestrial planetary interiors and how that affects the generation of the volcanic terrains that dominate the rocky planets. Based on the present dynamics of Jupiter's tidally heated moon, Io, the scientists hypothesize that the geological histories of the solar system's terrestrial bodies, specifically Mercury, Venus, Moon and Mars, are consistent with a mode of early planetary evolution involving heat-pipes. They further propose that heat-pipe cooling is a universal process that may explain the common features seen on the surfaces of terrestrial planets.

The team's findings are discussed in a paper recently published in *Earth and Planetary Science Letters*.

"We believe that the concept of a heat-pipe mode of planet formation is important and will help explain the evolution of all rocky planets," said Dr. Justin Simon, NASA Planetary Scientist, Center for Isotope Cosmochemistry and Geochronology in the Astromaterials Research and Exploration Science Division at NASA's Johnson Space Center in Houston, Texas and one of the coauthors of the paper. "If shown to be correct, it will be discussed along with the theories of plate tectonics, planetary 'magma oceans' and the 'giant impact theory for the origin of the moon.'"

The scientists hypothesize heat-pipe cooling was involved in the evolution of all terrestrial planets including early Earth and represents the transition from the magma ocean to the rigid-lid or plate tectonic modes of planetary evolution. Heat-pipes transport heat from the interior to the surface via mantle melting and magma ascent. The resulting eruptions lead to global volcanic resurfacing by which older volcanic layers are progressively buried and pushed downward to form thick, cold and strong mechanical lithospheres.

The authors review the observations relevant to the formation of the surfaces of each of the terrestrial planets and current models that have been proposed to explain them. They then discuss the major outstanding problems and show how the heat-pipe hypothesis can resolve these in a consistent way across all planets.

"The terrestrial bodies in our solar system look different enough that the classical view is that they all formed differently, at least in terms of making their outer shells. If our analysis holds merit, it points in the direction of a universal model for the early development of terrestrial planets, across our solar system and beyond," said Dr. Alexander Webb, Associate Professor, The University of Hong Kong.

The authors note that Mercury was globally resurfaced early in its evolution by volcanic eruptions emplacing smooth plains with few identifiable eruption centers. The authors conclude that the geological observations

of the planet point to an episode of heat-pipes operating for somewhat less than the first billion years of Mercury's evolution. The surface of Venus is also dominated by lavas with broad plains made up of numerous flows spanning hundreds of kilometers at low slope with few identifiable source structures. Venus does not display sufficient volcanic flux to currently experience active heat-pipe cooling, but the authors conclude that the thick, stagnant lithospheric lid is a relict of heat-pipe operation that ceased rapidly several hundred million years ago.

Among the most important surface features on Mars are its large volcanos, ancient cratered terrains and the crustal dichotomy between the elevated southern hemisphere and the depressed northern hemisphere. It remains unclear which processes were responsible for the formation of the dichotomy, but the authors conclude that a strong ancient lithosphere created by heat-pipe volcanism would have aided in the preservation of this ancient feature. Similarly, the Moon stands out as having a shape that is dramatically out of hydrostatic equilibrium, but preserving a disequilibrium shape requires a strong, early-formed lithosphere. The authors argue that a strong lithosphere is precisely the expected behavior of a body experiencing heat-pipe cooling.

The team brought together geological, geochemical and geochronological evidence from the terrestrial bodies in our solar system to show that heat-pipes may have provided the primary mechanism of crustal formation and resurfacing. The heat-pipe hypothesis provides a uniform explanation for common features of the known terrestrial planets that have not undergone plate tectonics and should be considered an important aspect of their evolution.

“The development of this theory is a great example of how exploration of our planetary neighbors, in this case [Jupiter's moon] Io, has led to a deeper understanding of Earth as well as rocky planets across the galaxy,” said Dr. William Moore, professor of atmospheric and planetary sciences, Hampton University, USA.

Heat-pipes should also occur on rocky exoplanets orbiting other stars. A planet twice the mass of Earth should take more than twice as long to cool, because the surface area does not grow as fast as the mass. For large exoplanets, the lifetime of the heat-pipe mode may exceed the lifetime of Sun-like parent stars and thus any subsequent plate-tectonic phase may never be observed. This study forces us to rethink our expectations of what types of surfaces and atmospheres to expect as we expand our exploration of other solar systems.

To view the paper, go to:

<http://www.sciencedirect.com/science/article/pii/S0012821X17303242>

Image download: <http://www.scifac.hku.hk/news/media?page=1>

Captions:

Image 1. Io with a volcanic plume at the top



Image 2. Dr Alex Webb, Associate Professor at Department of Earth Sciences (on the left) and his graduate student ZUO Jiawei conferring in the field.



Image 3. Dr Alex Webb in the field of Isua, Greenland, studying 3.8 billion year old rocks that may have been produced via heat-pipe processes on Earth.



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