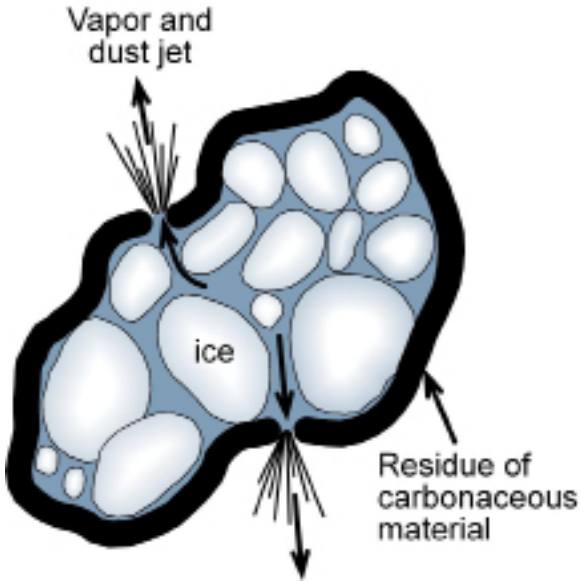
Origins of Earth's Water



Origin of Earth's Water

Students often ask the most basic of questions...to which the teacher has no clear response.

In an effort to help out, the following is a short discussion that willl provide insight but still not clear answer. The reason for can clearly be related to the nature of the science of Earth's water changing as more and more information becomes available. Therefore, we begin with the basic question: "What is the origin of Earth's liquid water?".

During its proto-planet stage, Earth was constantly bombarded by cometary fragments, asteroids, and planetoid. Recent data is beginning to identify all of these bodies are water sources.

Until the era of robotic space flight the origin of Earth's water had a simple answer-- water-rich comets colliding with Earth during its formative proto-planet stage that ended about 4.6 billion years ago. This concept was based on data obtained from 1950's era optical telescopic spectroscopy that revealed comets were essentially "dirty snowballs" composed of frozen water. The combination of frozen water and the astronomical model that proposed the huge numbers of impacts during Earth's formative stages led to the conclusion that comets were the primary source of Earth's water. It was further assumed that Earth's extreme temperatures required this added water to exist only as water vapor.

Asteroids are irregularly shaped objects. Some suggest they are remnants of planets that never coalesced into a solid body. Other think they are small rocky bodies that were never incorporated into a planet and are basically left over objects. Most asteroids orbit the Sun between Mars and Jupiter. The largest asteroids are called planetoids. Comets are distinguished from asteroids and planetoids because thy have an icy component that becomes an unstable atmosphere when heated during close approaches to the Sun. A collision between protoplanet Earth and an large planetoid called Theia, about 4.4 billion years ago, is currently considered the best explanation for the existence of the Moon.

Any liquid water that would try to fall to the surface would instantly be evaporated by the high surface temperatures of the cooling early Earth. Finally, it was assumed that the cooling of the Earth to temperatures that would allow for the existence of liquid surface water probably required at least a billion years of so. As the early crust formed and expanded, and volcanism raged, the planetary surface temperature was undoubtedly above water's boiling point. Thus, any condensation (rain) falling from that ancient atmosphere immediately vaporized, encasing Earth in a thick layer of clouds. It must have been an eerie scene: the underside of the dark cloud cover illuminated by the glow of erupting volcanoes and molten rock.

Recent robotic space missions, including a soft landing on a comet, have produce data that may falsify, at least partially, some or all of these ideas. One idea remains clearly accepted--nearly all of the water, the stuff that covers over 70% of Earth's surface and perpetuates our very lives, came from some place else. Carl Sagan was right, we are indeed the product of star stuff!

A comet has a nucleus, an water ice coma surrounding the nucleus, and a tail which forms from outgassing dust or gas caused by both solar wind pressure and heating of the coma during close passed to the Sun.

The following articles will go a long way towards helping you, or your students, appreciate how new exploration is changing the thinking on the origin of Earth's water:

http://www.space.com/27969-earth-water-from-asteroids-not-comets.html

http://rosetta.jpl.nasa.gov/news/getting-know-rosetta%E2%80%99s-comet-0

http://www.nasa.gov/jpl/rosetta-comet-water-different-than-earth-water/#.VlzdajZdE2w

http://www.dailymail.co.uk/sciencetech/article-3316880/How-Earth-blue-planet-Lava-deep-mantle-suggests-world-formed-water-it.html

At this point, maybe a better, and more productive, way to phrase the inquiry is to ask how liquid surface water came to exist? During the transition from proto-planet to planet Earth, planet-wide volcanism produced enormous out-gassing events, ash clouds, near surface magmas, and surface lava flows. Most of this molten material, when it cooled, became various kinds of granitic and basaltic rocks. This step was crucial because, being relatively less dense than other rocks and molten material inside Earth, the granite and basalt literally floated upward to form Earth's first crust. Studies on zircon crystals dated at 4.4 billion years old suggest that had to have existed within some type of water-rich crustal material only160 million years after Earth's origin. This type of evidence requires us to consider the idea that some form of crustal landscape existed much earlier than originally thought and that such locations could have housed liquid water is the rocks surface temperature was below water's boiling point.

Today, observations and measurements have established the fact that one of the largest products of a volcanic eruption is water vapor in the form of steam. When you ask students this question, they invariably respond with ash and lava. Applying uniformitarianism, we can say that Earth's widespread and massive volcanic activity, as it evolved into planet Earth, out-gassed enormous amounts of steam that came from water contained within the cosmic stuff that made up proto-planet Earth. Recent studies, such as the zircon research, now suggest that liquid water, not necessarily large bodies, may have existed as early as 4.2 billion years ago upon some early piece of cooled crust.

The question remains, when did liquid water first exist on Earth's surface? Studies of oxygen ratios in four billion year old zircon crystals suggest they were exposed to liquid water (*https://www.sciencedaily.com/releases/2001/01/010111074038.htm*). This idea requires further explanation of how Earth shed enough internal heat in such a brief span of geologic time to permit atmospheric water vapor condensation in the form of rain and the accumulation of said rainfall into bodies of standing water. However, the idea does indicate that landscape change due to physical and chemical weathering has been going on much longer than expected.

Two narratives found at http://www.wvgs.wvnet.edu/www/geoeduc/geoeduc.htm provide more information on plate tectonics and the connection between volcanism and the formation of Earth's granitic and basaltic crust. The articles are part of the Conceptual Understanding Series for West Virginia Teachers. One is called Plate Tectonics and the other is called Igneous Rocks.

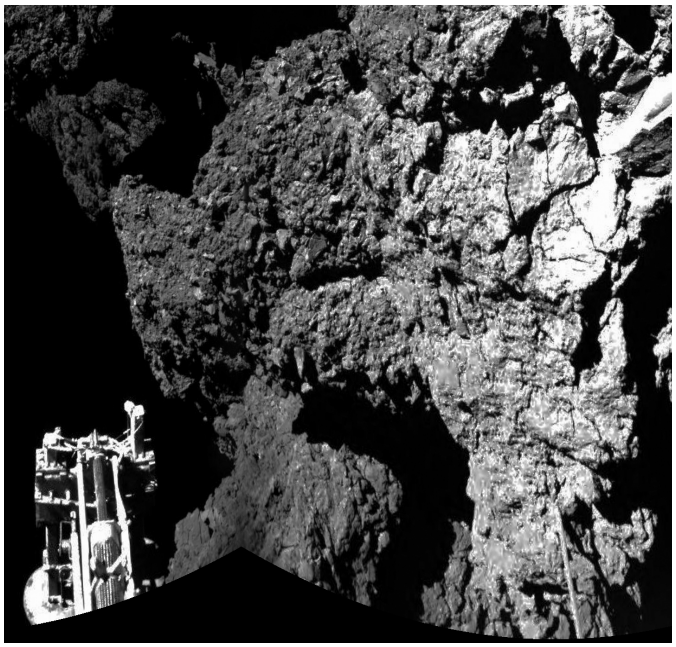


Figure 1. This picture far out form the Sun does not conform to most students mental construct of what a comet looks like. The visible tail, the comet's most distinctive feature, only develops during close approaches to the Sun. (NASA image)

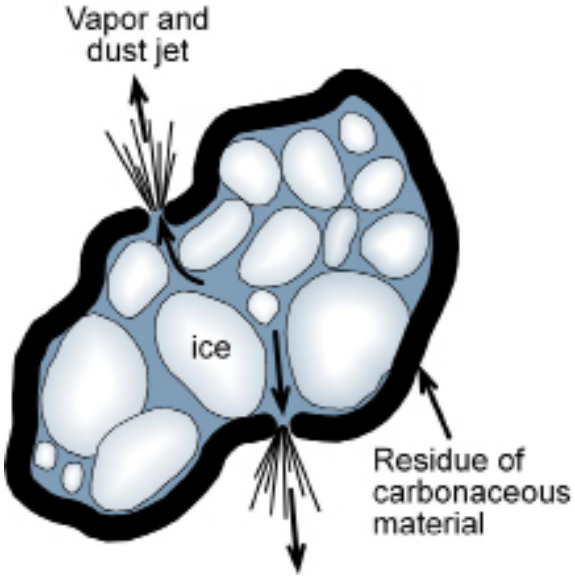


Figure 2. A new version of the inside of a comet provides a more complex structure than previously considered.