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Volcanoes of the solar system

Ice covered planets could have volcanoes too, says S.Ananthanarayanan.

The principle is that hot interiors need to find a way to emerge if they have no other way to cool.

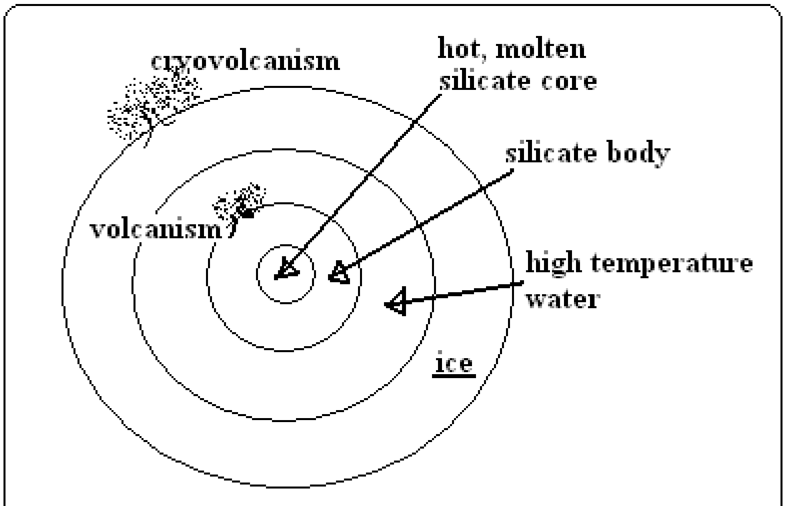
Examples of a cooling spherical body could be a hard boiled egg or a boiled potato. The surface cools rapidly and gives the impression of being ready to eat. But the centre is still hot as ever, as one who takes a bite would discover. The reason is that the material of the egg or the potato is a poor conductor of heat and the surface can cool despite the centre still being hot. And for the same reason, the centre would take a long time to cool.

It is the same with planets, like the Earth, Mars and many of the planets and moons of the Solar System. The age of most of these bodies is about 4.65 billion years. They have been steadily radiating heat into space a long time and higher the surface temperatures the more the heat they lose. But centres, or cores, of all of them are under huge pressures and some have thermonuclear processes that generate heat. The gravitational stresses created by neighbouring stars or satellites are another source of disturbance, seen as ocean tides on the surface, but which generate heat in the more rigid internal regions.

Volcanism

The interiors are thus at very high temperatures, consisting of molten rock under pressure. The surrounding mass of silicates, or even ice in the case of the cooler planets, is a bad conductor and cannot relieve the pressure at the centre. Cooling must then take place through fissures or faults in the envelope, in volcanic action. What pours out on the surface of the Earth or Mars, or Jupiter's satellite, Io, is molten silicate matter, known as ***magma***. This kind of transport of hot liquid interiors to the surface is called ***advection***, and is one of the main methods of the formation of the crust of planets. The shape and dimensions of the volcanic ejection can also vary, ranging from 20 km high, as in ***Olympus Mons***, on the surface of Mars, to mounds less of than 100 metres, seen son the Earth.

This is in the case of silicate dominated bodies like the Earth, the Moon or Mars. In the case of ice dominated objects, like Saturn's moons, the advected liquid is molten ice, which is to say, liquid water, and it could even be steam or overheated water vapour. This process, of advective eruption in cold bodies, is called ***cryovolcanism***. Cryovolcanism is currently active in Saturn's moon, ***Enceladus***, is believed to be going on in ***Titan*** and may have happened in ***Tethys*** and ***Dione***. Neptune's satellite ***Triton*** discharges jets of nitrogen and it has large, flat areas which may be evidence of eruptions of water in the past. Jupiter's satellites ***Ganymede*** and ***Europa*** are covered with ice and they show surface fractures through which some of the water may have emerged from deeper within. In fact, the ice covered satellite ***Europa*** hides an ocean of water, at the bottom of which there is a silica-rich planet body, large enough to have heat sources, both from radioactive reactions as well as because of tidal action. Hence, in the case of Europa, there may be conventional volcanism in the silicate body and cryovolcanism in the water-ice envelope. This is something, for an object just a little smaller than the Earth!



Structure of Jupiter's satellite, Europa

Variety

The outer layers of the earth consist of plates, that seem to have formed at different times and are still siding over one another, to settle down. It is this movement of parts of the surface that has led to the formation of continents, the raising of mountains and, over short times intervals, the incidence of earthquakes. The existence of these sliding plates may be because of the formation of crust through volcanic activity at different times.

On the earth, there is clear correlation between different types of volcanism and the structure of the parts of the earth. Deep in the water, near the centre of oceans, we find ridges of volcanoes that erupt to create new plates of crust. These are made up of metal-rich and silica-poor ***basalts***, which arise from the underlying mantle, as it melts and decompresses when the crust above adjusts itself. At other places we find another kind of volcano, which comes into being when the basaltic ocean floor crust melts due to heating from below and flows back into the mantle (a process called ***subduction***). The magma of these volcanoes, thanks to the water and sediments, are metal-poor and silicate-rich. Yet another kind of volcano is not related to the movement of plates but is still similar to the basaltic magma that arises from mantle melting under moving crustal plates.

In the planets

It is agreed that the kind of volcanic activity in other, silicate-rich planets is mostly of the third kind, which is not related to plate movement. Venus, Mars and Io have scattered and localized volcanic activity, not the ridges seen along plate edges, as on Earth. The Moon also shows scattered activity, whose lava flowed freely and did not create clear volcanic mounds. Mercury has similar volcanic structure. The conditions on earth are perhaps due to its particular size and water content. Venus is almost the same size but does not seem to have had water like the Earth. Mars, in its early history, had ample water, but is less than as found on the Earth.

Our information about other planets is by telescope observations, including observations from man-made satellites in orbit around the planets. There are limitations – only radar can penetrate the atmosphere of Venus, while good resolution is possible with Mars. We also rely on spectroscopic analyses and also some in situ chemical analyses by probes landed on Venus and Mars, for instance. We have Apollo mission samples of lava from the moon and the same thing is planned for Mars. But there has been great improvement in the theoretical understanding of the processes and this has implications for understanding the processed going on in the Earth.