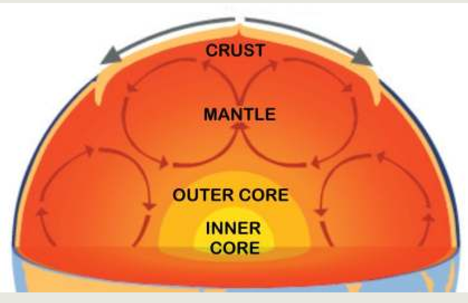
VOLCANOES

Mount Mayon, Phillipines

Compiled by U. Schreiber



Simplified sketch of the Earth's structure

Volcanoes are one of the most awe-inspiring natural phenomena known to Man. Defined as openings, or ruptures, in a planet's crust, which allow hot, molten rock, ash and gases to escape from its interior in various more or less violent stages, volcanoes are not confined to Earth, but have been identified on a number of other worlds throughout the solar system - although most of these "off-Earth" volcanoes have been long extinct. As destructive as volcanic activity can be to life and property, it is also one of the most important, constructive geological processes, constantly rebuilding the ocean floor, and forming a crucial element in the Earth's ongoing regeneration.

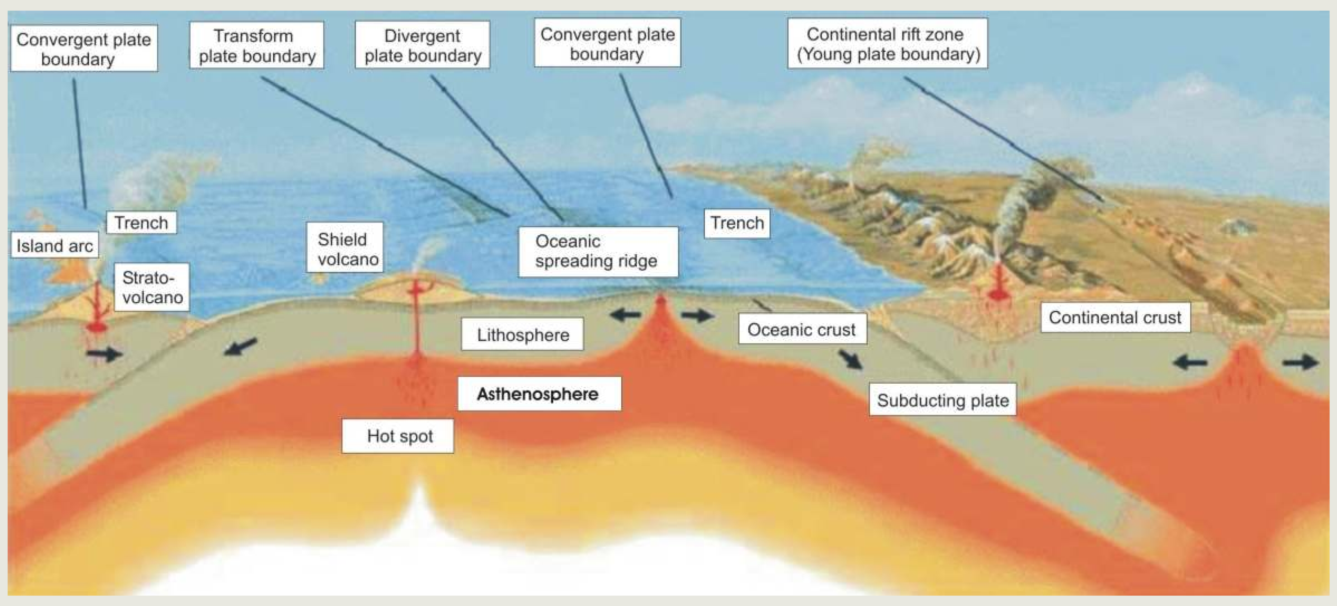
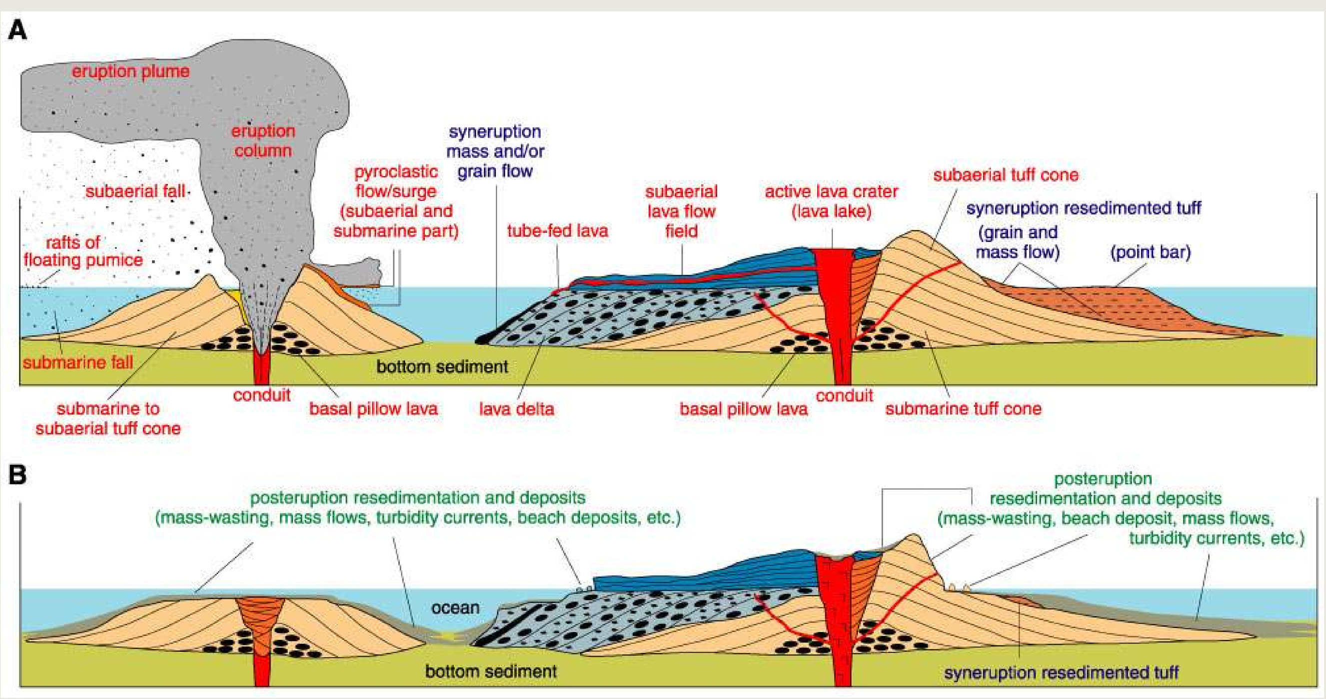


Plate tectonics and its relationship to volcanic activity

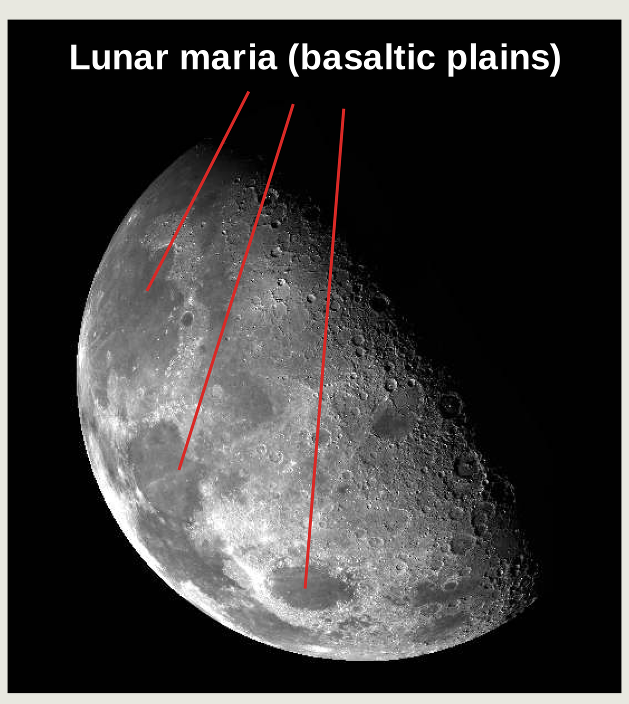


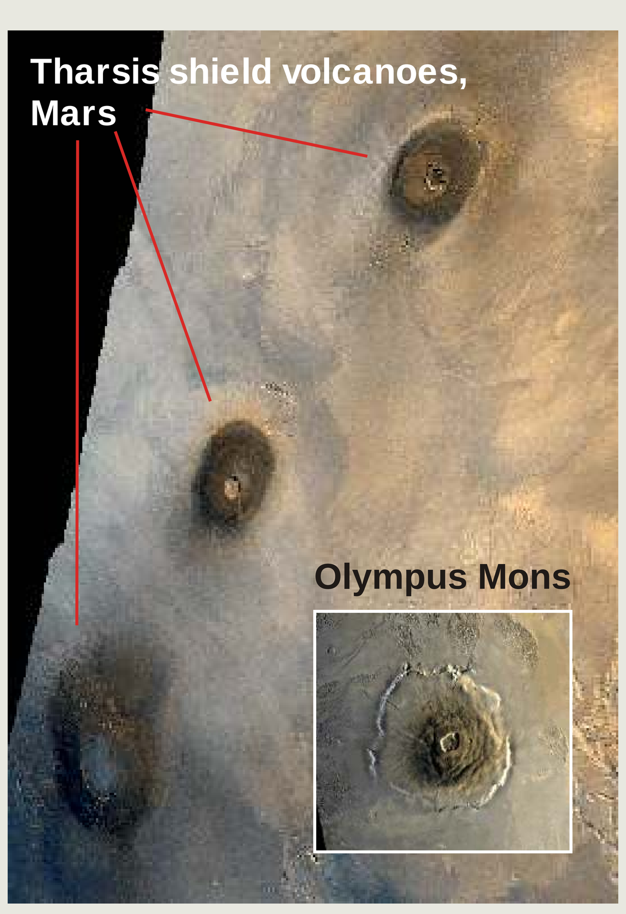
Cross-sections through a volcanoes different stages

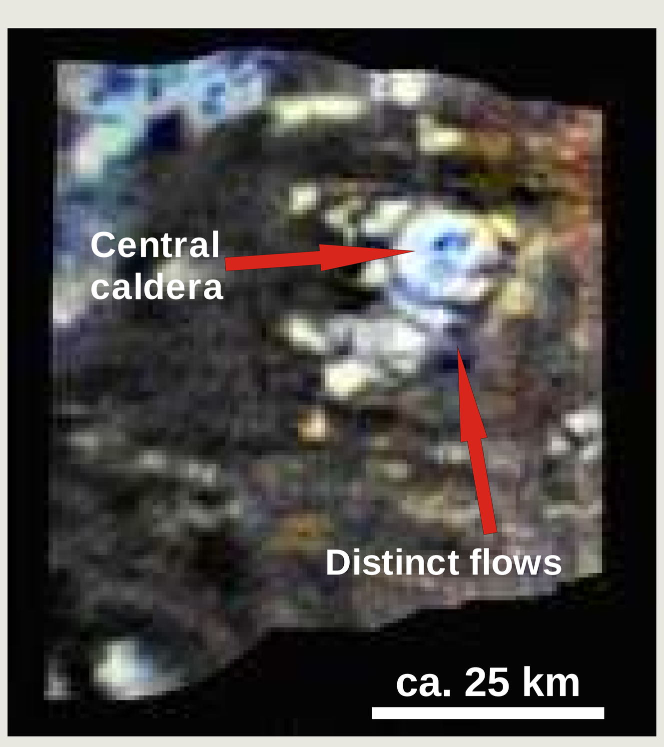
Mechanics of a Volcano

Liquified by high pressures and temperatures deep in the Earth's interior, magma rises upward through the crust as it has a lesser density than the surrounding solid rock (similar to a gas balloon rising upward through air), its heat melting more material during its ascent. Below the surface it collects in *magma chambers* until its upward thrust exceeds the containing pressure of the overlying rock, or a crack opens up in the crust. At this stage molten rock (now called *lava*) spews out onto surface, leaving the emptied out magma chamber to collapse and form a *caldera*. The shape and structure of a volcano, as well as the intensity of the volcanic eruption and its destructive potential, is dependent on a number of factors, primarily the composition of the molten rock.

Chemically lavas ranges from felsic (>63% silica) to ultramafic (<45% silica), which decides their physical behaviour. While silica-poor lava is less viscous and just tends to flow out of the vent, silica-rich magma - because of its more sluggish nature - often contains trapped gases, causing explosive eruptions that produce high amounts of ash and pyroclastics. Composition and discharge rate also affect lava texture, forming either smooth *pahoehoe* flows (low discharge rates/gentle slopes), or blocky *aa* flows (high discharge rates/steep slopes). Magma that extrudes under water, e.g. at a mid-ocean ridge, forms pillow lavas.







Shield volcanoes make up only a small portion of Mars' volcanic record (left); possible cryovolcano on Titan (top)

TYPES OF VOLCANISM

On Earth, volcanoes are mostly associated with tectonic plates boundaries, i.e. the stresses and strains generated by the movement of lithospheric plates relative to each other. Volcanoes sitting on a mid-ocean ridge (e.g. Iceland) are caused by the pulling apart of ***divergent tectonic plates***, while the volcanoes lining the Pacific Ocean ("Pacific Rim of Fire") are associated with ***convergent tectonic plates*** coming together. Apart from plate boundaries, volcanoes can also form where there is stretching and thinning of the Earth's crust (***non-hotspot intraplate volcanism***), for instance in the African Rift Valley, or as a result of *mantle plumes* - updomings of the hot liquid mantle, which underlies the solid crust. Terrestrial examples for such ***hotspot intraplate volcanism*** are the Hawaiian Islands, but this type of volcanism is also found on other rocky planets and moons too small to generate enough internal heat energy to drive plate tectonics. Incidentally, there the lack of plate tectonics causes such hotspots to remain stationary for much longer times, thus allowing volcanoes to keep growing until their *magma reservoirs* are depleted (e.g. Martian shield volcanoes).

Pahoehoe (left) versus Aa lava (right)

Metamorphosed pillow lava

Fresh pillow lava

Size comparison between the highest mountains on Earth, Mars and Venus (Maxwell Mountains); note that Mt Everest is not a volcano

Ash plume erupting from stratovolcano Mt. Cleveland, Alaska (as seen from the International Space Station)

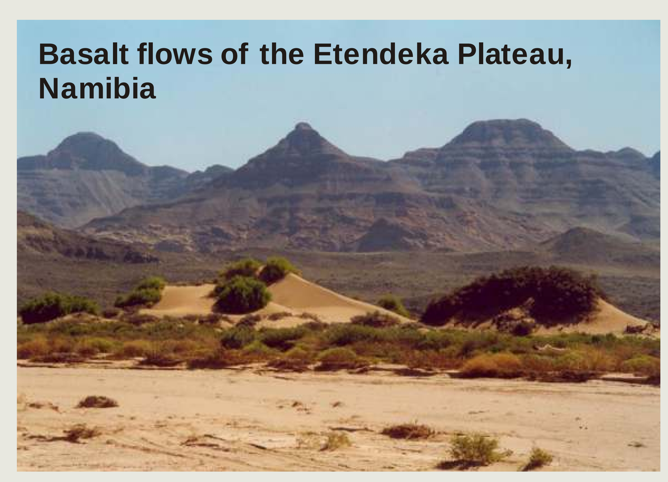
Cinder cone "Sunset Crater", Arizona

Shield volcano Skjaldbreidur, Iceland

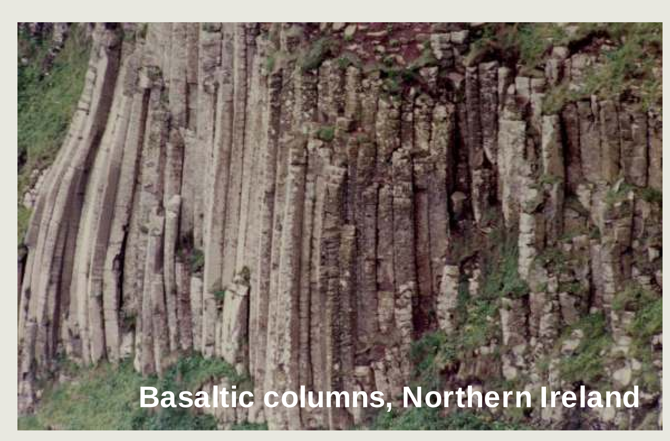
VOLCANIC FEATURES

As the factors interacting in volcanic activity are varied and manifold, so are its products. The type of volcano that comes closest to the common perception of a conical mountain, spewing lava and gases from a crater at its summit, are ***stratovolcanoes*** and ***cinder cones***, which produce ash and lava in alternating layers ("strata"), or predominantly ash and other pyroclastic material, respectively. In contrast, ***shield volcanoes*** - so called because of their shield-like profiles - are formed by the eruption of ***low-viscosity*** lava that can flow great distances from the vent but rarely explodes violently, while ***lava domes*** are built by sometimes explosive eruptions of ***highly viscous*** lava that generally does not flow far from the vent. ***Volcanic fissures*** are characterized by a curtain of lava spewing to a small height out of a crack in the ground, and the heat of ***hydrovolcanic eruptions*** near oceans or wet areas, flashes the water it comes into contact with into a column of steam.

While the aforementioned volcanic types have largely localized effects a ***supervolcano,*** consisting of a huge caldera up to several hundred kilometres across, can cause devastation on a continental scale. Such eruptions, although their explosivity varies, could radically alter the landscape and severely affect global climate for years due to the sheer volume of the ejected material (e.g. the last eruption of the Yellowstone Caldera, USA, produced ~1000 km^3 of rhyolitic lavas and ash some 640.000 years ago). Even more extensive were the flood basalt extrusions during the Cretaceous that formed the Etendeka / Parana Plateaus of Namibia and Brazil, respectively, with an estimated extruded volume of ca. 200.000 km^3... which is not particularly large as such events go!



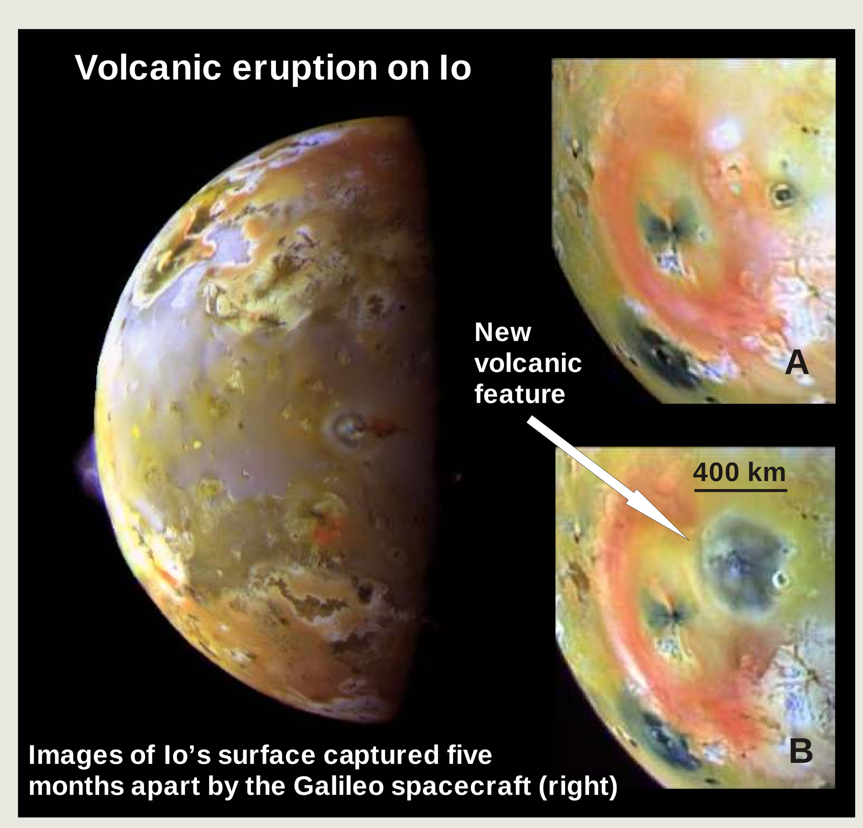
Basalt flows of the Etendeka Plateau, Namibia



Basaltic columns, Northern Ireland

VOLCANOES ON OTHER WORLDS

Volcanism has played an important part on other planetary bodies, too, although the driving forces may be different from those operating on Earth. While hotspot volcanism probably created the giant shield volcanoes on Mars, little is as yet known about the volcanic cones and mare-like volcanic plains, to name but a few of the red planet's volcanic features. Much more ubiquitous - if rather uniform - volcanism is evident on Earth's other neighbour, Venus, most of whose surface is covered by lava flows. Extensive plains of basaltic lavas (visible as dark patches on the Moon's glowing face) also cover much of the lunar surface, with smaller lunar domes of more silicious material centering upon localized vents. However, lunar volcanic rocks have an average age of some 3.5 billion years (about the same age as the oldest terrestrial rocks), and although on Mars and Venus volcanism appears to have lasted longer than that, no present volcanic activity has been observed on either of these worlds. The only planetary body with confirmed active volcanism - apart from Earth - is Jupiter's innermost moon Io. While the processes that formed volcanic features on Venus, Mars and Earth's Moon remain largely speculative, Io's volcanoes, which resurface it continually, probably are driven by the gravitational forces exerted by Jupiter's mass. Similar tidal processes are thought to be responsible for possible cryo (ice) volcanism on Saturn's largest moon Titan. Instead of molten rock, volcanoes of this type erupt volatiles like water, ammonia and methane, which condense immediately after eruption in the very low surrounding temperatures (-180^{o}C).



Images of Io's surface captured five months apart by the Galileo spacecraft (right)