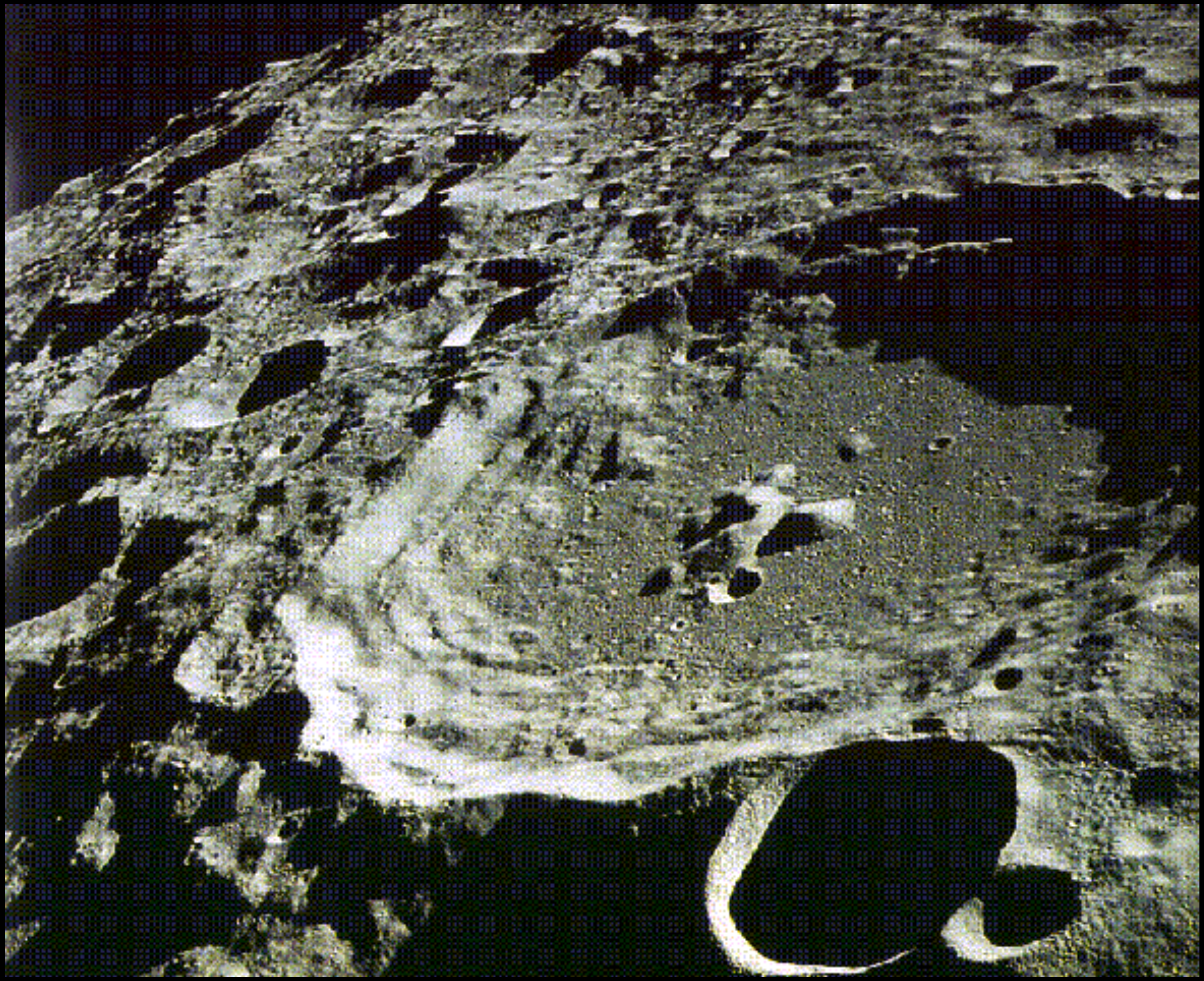
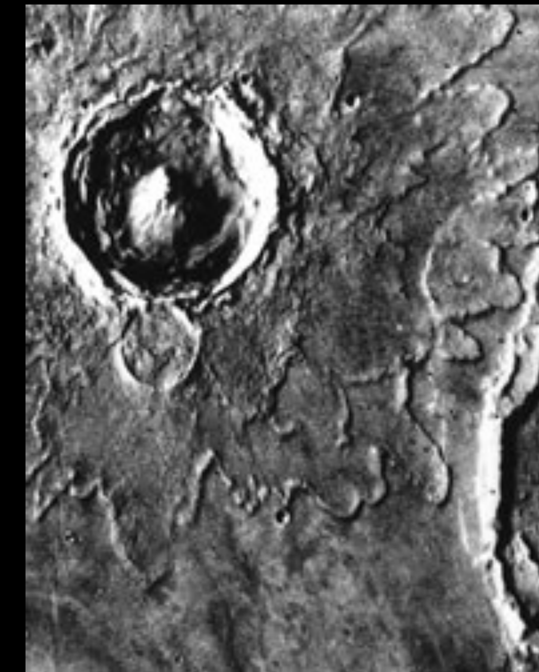
The evolution of a planetary surface is dominated by the following processes:

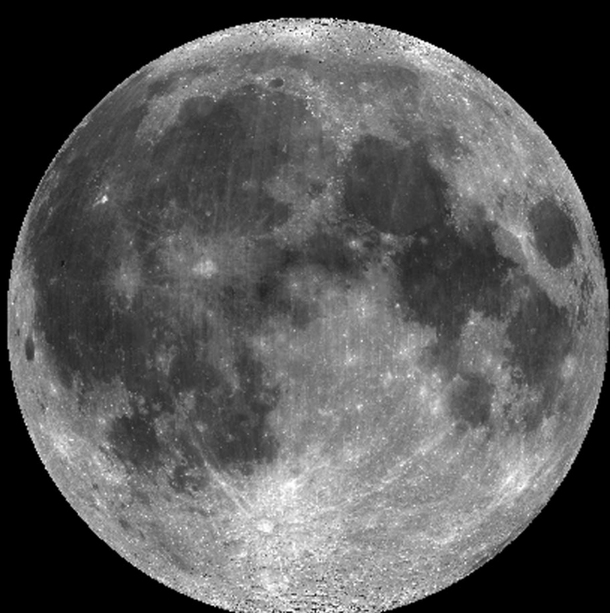


impact cratering

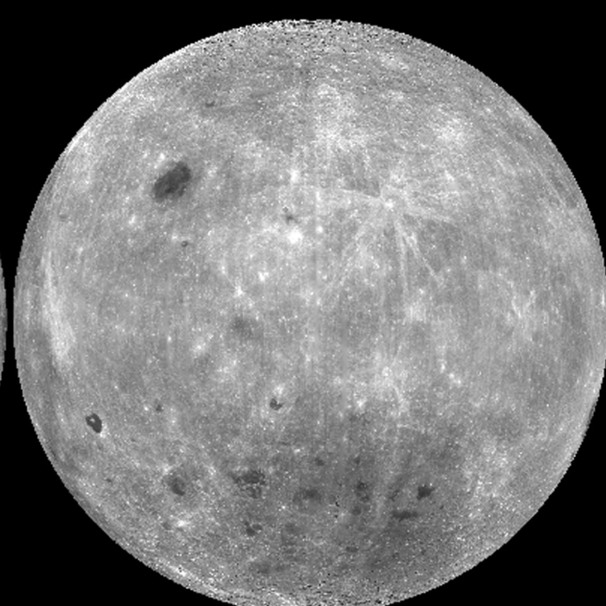
This image shows a simple crater on Mars that has no central peak or terraces around its edges. The crater is 2 kilometers (about 1 mile) wide. An extensive blanket of ejecta covers the area around the rim.



A complex crater in the northern region of Mars. This crater is about 20 kilometers (12 miles) across and has a large central peak and terraces around its rim. The ejecta blanket has lobes, which may indicate wet material was ejected, suggesting that subsurface water or melted ice was mixed into the debris.



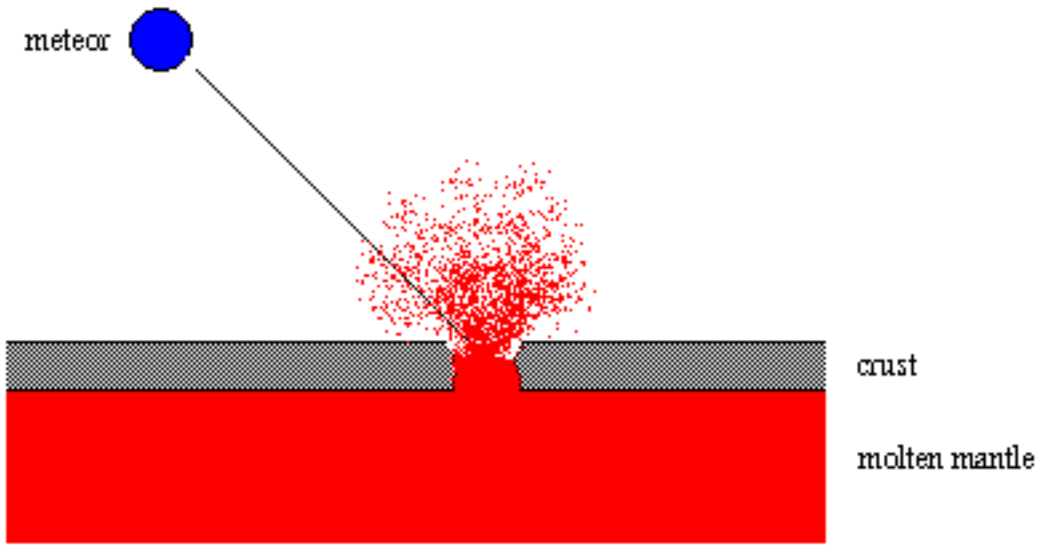
Near Side



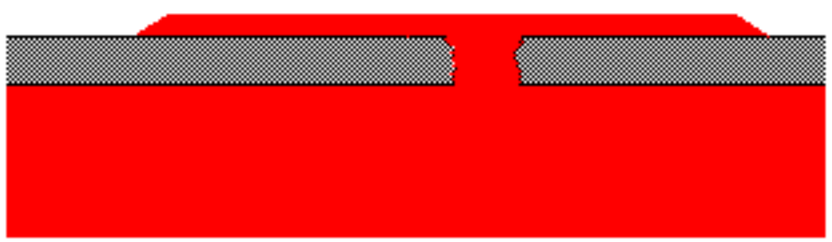
Far Side

Impact basins are very large impact structures that are more than 300 kilometers (185 miles) in diameter. The largest impact basin on the Moon is 2500 kilometers (1550 miles) in diameter and more than 12 kilometers (7 miles) deep. Large impact basins are also found on other planets, including Mars and Mercury.

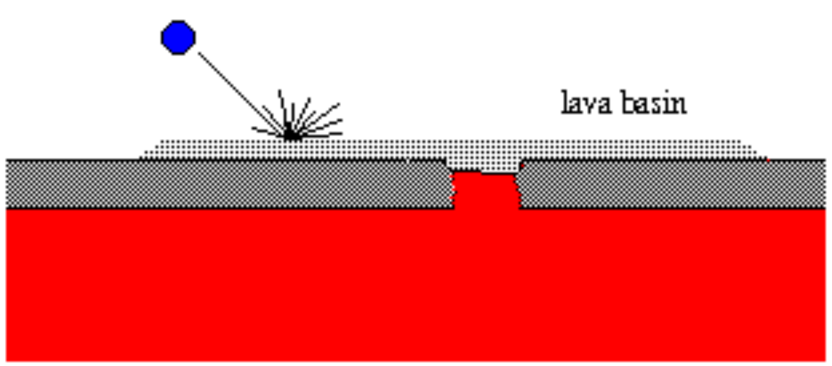
The large circular dark areas in the image are impact basins, created as huge impactors struck the Moon. Lava later flowed across the low floors of the basins, giving them a darker, smoother appearance than the surrounding, brighter highlands. The dark basins can be seen by the naked eye



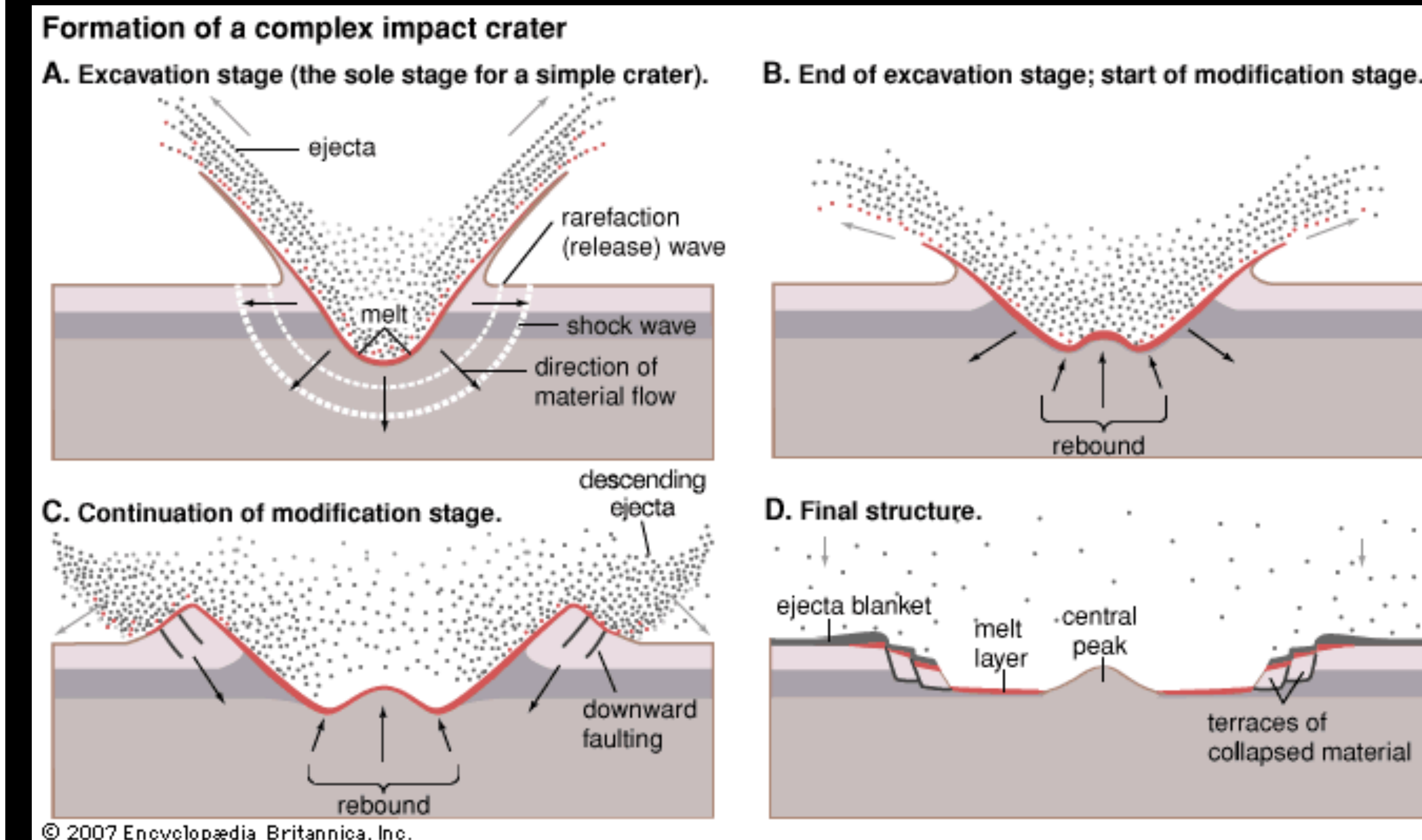
large impacts penetrate crust into mantle



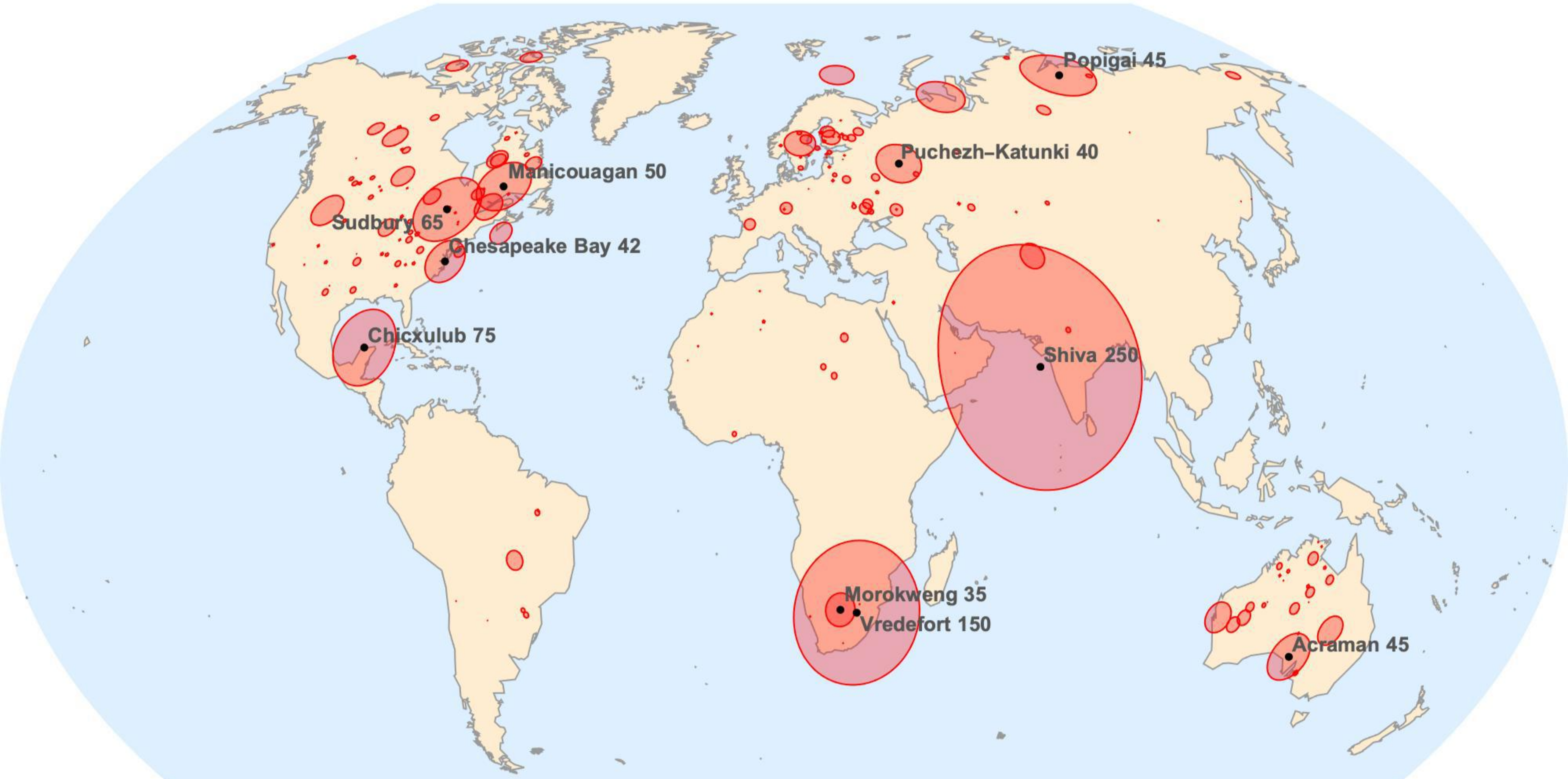
lava released to flow over surface and erase earlier cratering



lava cools to form basin, which is lightly cratered by later impacts



All Earth's Impact Craters At 10x Geo−Magnification



Data and tools: *Wolfram Language*. Made by *Vitaliy Kaurov*. Details: **wolfr.am/craters10x**

Impact craters are a challenge to visualize naturally on a world map. Their radii span 5 orders of magnitude: from a few meters to a few 100 km. But even the largest ones are much smaller than the Earth, which makes most of the craters invisible and mutually incomparable if plotted at actual size. Here the craters radii are multiplied by 10 and corresponding proper geo-disks are drawn on the Earth's surface around the craters centers in Winkel tripel geo-projection (hence, the disks appear deformed). In this way one can visually compare the craters sizes to known continental features sizes, and then roughly shrink them back in mind by 10 times. This also helps to mutually compare the craters sizes. The largest 10 craters are labeled by their names and actual radii values in km. The Winkel tripel projection (NGS standard) is minimizing three kinds of map distortion: area, direction, and distance. It is also instructive to see how even a standard map projection distorts the 3D geometry of the planet surface.

tectonic activity

Tectonic Activity:

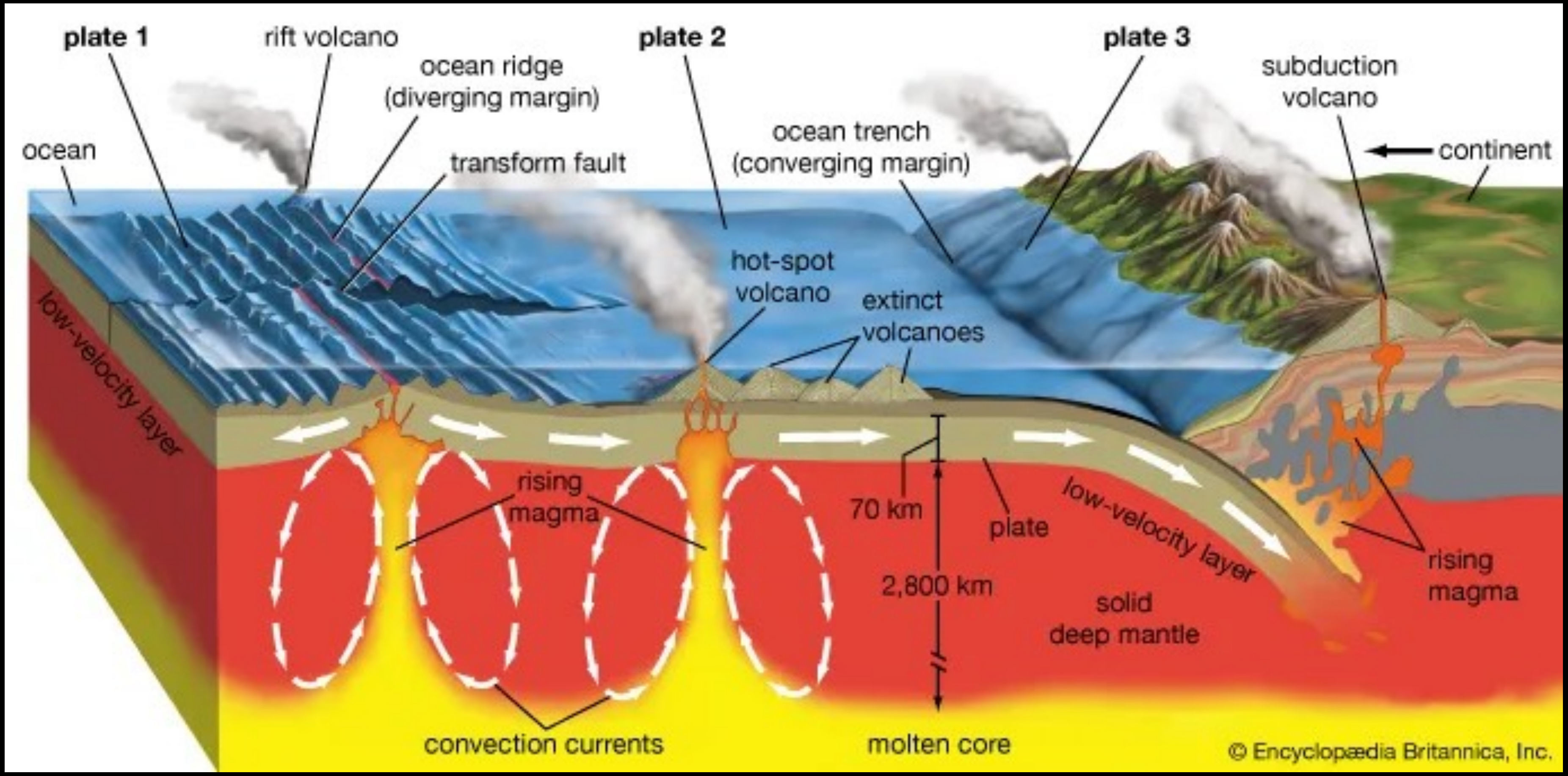
The amount of tectonic activity on a planet is controlled by the amount of heat stored in the planets interior after formation. The larger the amount of heat, the more energy stored that is transferred to the surface in the form of geological activity.

The amount of heat stored in a planet's interior comes from three sources:

1) the energy of formation of the planet
2) heat generated by the decay of radioactive elements.
3) tidal friction (for worlds around Jovian planets)

Formation energy or leftover heat is due to the fact that the debris and gas that the planet forms from coalesces into a ball. The potential energy from gravity of this infalling material is converted to kinetic energy (heat) as the debris falls together. Thus, the higher the mass of the planet, the greater the amount of energy deposited on it during formation, the greater the heat and, therefore, the greater the amount of tectonic activity.

The amount of heat from radioactive materials is also proportional to the mass of the planet. Again, more mass = more radioactive material = more heat from radioactive decay.
e motion.



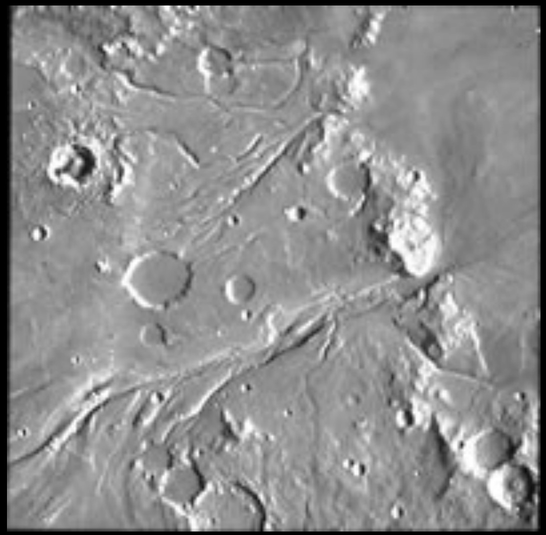
Tectonic activity displays itself in the following ways:

plate motion
volcanoes
mountain/terrain formation
crustal fractures

The more diverse the surface geography of a planet, the more involved is the tectonic activity. For example, the Earth is one of the most tectonically active planets in the Solar System and has extensive systems of plate boundaries, active volcanoes, mountain ranges and canyons. Mars (small, low in mass) on the other hand has very few mountain ranges or active volcanoes. The fact that the volcanoes on Mars are large implies that Mars was once active, in its distant past but with limited plate motion.

erosion

Note that this list is also in temporal order since impact cratering occurs first, followed by tectonic activity and then erosion. Also note that all the planets receive the same amount of impacts from remnant debris in the early Solar System. But that the amount of tectonic activity and erosion varies from planet to planet.



Erosion:

Erosion can be cause by the following processes:

atmospheric erosion (wind, weather)
tectonic activity (crustal movement/recycling, volcanoes)
gravity (slumping)

Depending on the mass of the atmosphere, this list is in order of strength. Atmospheric erosion has short timescales, on order of hundreds of thousands of years. Tectonic activity can take on order of millions of years. Gravity slumping is only visible on airless worlds with timescales of billions of years.

Note that large features, such as impact basins or extremely large impact craters can not be eroded away even after 100's of millions of years. Such large features on the Earth were eroded by tectonic activity, i.e. the crust was recycled by plate motion such that those ancient impact basins are gone.

Evolution of Earth vs. Moon

Initial formation -> both Earth and Moon form as molten balls that cool and solidify — 4.8 billion years ago

gravitational settling of elements — 4.6 billion years ago

light

heavy

core

Moon

no tectonic activity (too little mass)

Earth

tectonics mix crust and mantle

era of impact cratering — 3.9 billion years ago

large impacts shatter crust
basin flooding = maria — 3.6 billion years ago

Moon

later light cratering

cool core, no outgassing

Earth

atmosphere protects surface from later impacts (burn-up)

hotter core -> continued tectonic activity

outgassing -> atmosphere, erosion