Heat budgets for planets

[Q] We know that the Earth was hotter once than it is now. What are some sources of heat in the Earth's interior?

[A] • Residual heat of formation: gravitational potential energy released as planetisimals accreted onto the forming planet

• Radioactive decay: radioactive elements produced in nucleosynthesis in stars and distributed into interstellar medium by supernovae will become part of solar system. As Earth differentiates they sink to center & release energy as they decay. More @ early times.....

• Differentiation will release more potential energy as heavier elements sink to center

- tidal heating
- heating from meteor impacts

How does the heat get out?

3 possibilities: convection, conduction or radiation

- Conduction is most important in the lithosphere (crust)
- Convection is important in the mantle (asthenosphere)

Convective motions in the mantle drive plate tectonics on the Earth.

Terrestrial planets vary in their interior structure .....

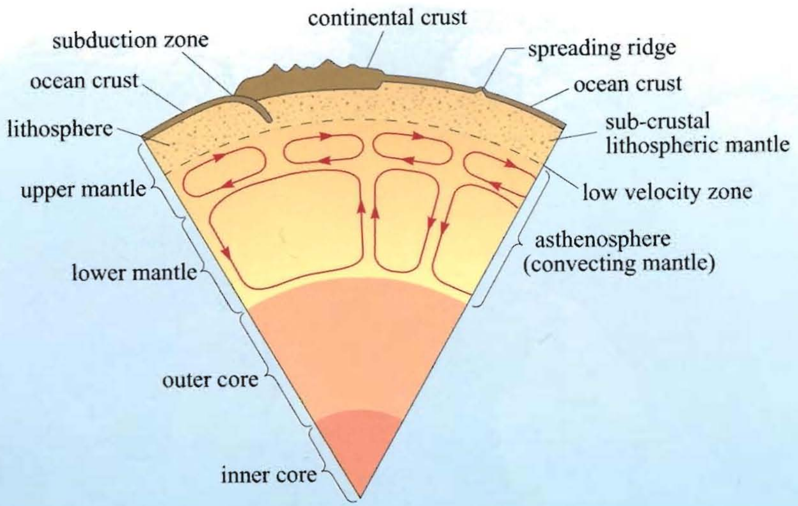


Figure 2.14 Section through the Earth showing the division of the mantle into the uppermost rigid lithosphere, and the mobile, convecting asthenosphere (not to scale).

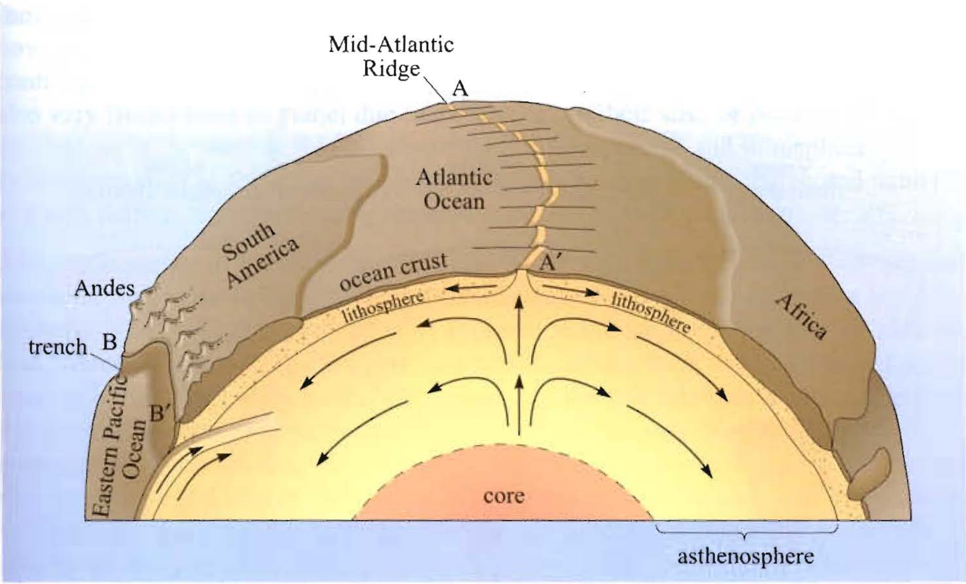


Figure 2.16 A vertically exaggerated model showing the main elements leading to plate tectonic movement on Earth, and showing the relationships between three plates: the African plate, the South American plate and the Pacific Ocean plate, called the Nazcan plate (beneath the eastern Pacific Ocean). Since the lithosphere is rigid and comprises the crust and uppermost mantle, heat transfer is primarily by conduction, with a component of volcanically driven advection. The asthenosphere is weak and comprises the underlying convecting mantle. Lithospheric plates move apart at divergent plate boundaries (mid-ocean ridge systems), where material is continually added incrementally by volcanism (A–A′), and is destroyed at convergent plate boundaries where one plate is forced below another and reabsorbed into the asthenospheric mantle at depth (B–B′).

Figure 2.17 compares the relative thicknesses of the lithosphere, asthenosphere and core for each of the terrestrial planets, and the Moon.

These diagrams are mainly based on model calculations. We only have well-constrained interior data (based on seismic studies) for the Earth and Moon.

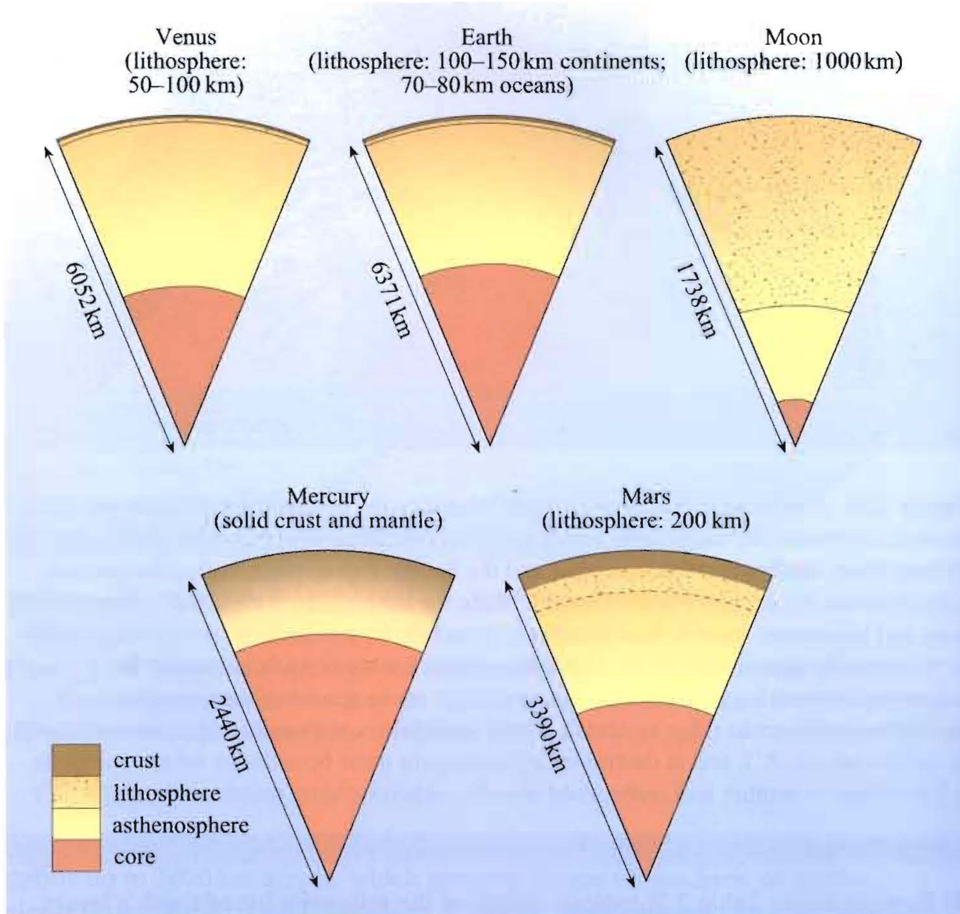


Figure 2.17 A comparison of lithospheric, and/or asthenospheric thicknesses, and core in the terrestrial planets and the Moon.

2.5 Dead or alive? Plate tectonics and resurfacing

Volcanism

All of terrestrial planets are losing more heat from interior than can be replenished (Io is different : ongoing tidal heating)

Depending on their size, and so the ratio of surface area to mass, they can cool faster (Moon, Mercury) or more slowly (Earth, Venus)

Heat loss processes are the main drivers of volcanic and tectonic activity.

Compare Earth and Moon : Earth has a relatively young surface, ongoing tectonics & volcanism, Moon had early volcanism only.

Earth and Venus have similar sizes, but while the Earth is still tectonically active, Venus does not show the signature of plate tectonics :

Tectonic plates on Earth can either be all ocean .... higher density, on average 4-5 km below sea level .... or continental + oceanic, often lying just ~~$~~ above sea level.

So global topography v. bimodal.

Venus has a much more uniform distribution of topography.

It may undergo periodic, planet-wide, catastrophic resurfacing events.

dead' planets, provided the thickened lithosphere can be breached by the rising magma. Under these circumstances volcanic resurfacing, such as blanketing of earlier topography by lava flows or ash deposits, could continue even after surface tectonic processes have apparently ceased altogether (e.g. on Mars). The terrestrial-like bodies within the Solar System display a wide variety of surface features. From studying such features it is possible to determine which of these bodies are tectonically and volcanically dead, and which examples display surface features which are indicative of geological activity.

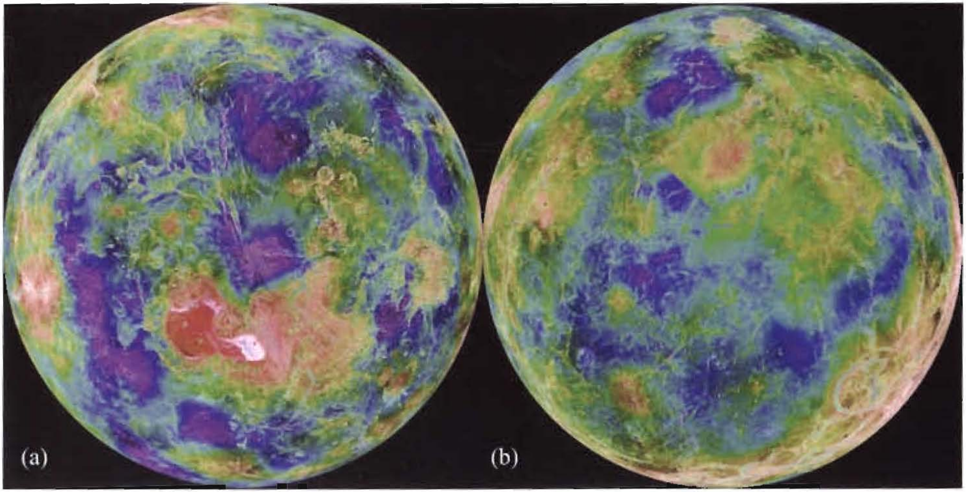
2.5.1 Earth

Mantle convection, together with lithospheric conduction, are the processes that enable the generation of internal heat (i.e. by radiogenic and tidal processes) to be balanced efficiently over the short term by heat loss at the Earth's surface. Above the convecting part of the mantle, Earth's lithosphere is broken into a number of tectonic plates. Some are surfaced only by an oceanic crust, whilst others carry both oceanic and continental material (Table 2.8). The higher density oceanic crust lies on average 4–5 km below sea-level, whilst many of the continental plains lie just above sea-level. This confers a very distinct bimodal height distribution to the global topography (Figure 2.18).

Figure 2.18 View of the east Pacific Ocean, the Americas and, in the Gulf of Mexico, Hurricane Andrew (25 August 1992). (NASA)

Figure 2.24 Two hemispheric views of Venus (a) from the north pole and (b) from the south pole as revealed by radar investigations by the Magellan space probe. These composite images have been colour-coded to provide elevational information across Venus's 15 km topographic range (blue is lowest elevation, and green, brown and white progressively higher elevations). (NASA)

and so it is believed that Venus's interior is gradual
becoming trapped in the upper mantle, below this s
'lid'. Continuation of this process over the long ter
increased partial melting of the sub-lithospheric ma
volcanism on Earth, and associated reduction of ma
process continues, this hot mantle material may eve
the overlying rigid lithosphere. This is an unstable s
catastrophic 'overturn', causing sinking of large are
surfaceward escape of immense volumes of trappe
would produce a massive resurfacing of the planet.
geologically short-lived, episode and associated rele
would once again cool, thicken and become rigid, a
i
b
p
e
a
a
a
lo



MARS:

<u>Large</u> volcanoes

Olympus Mons – shield volcano,

3 times as high as Mt Everest

(almost 27 km high)

500 km across

Valles marineris – the size of the

US

Q

Mars has volcanoes, ⇒ but we can tell from the number of craters that it does not have plate tectonics.

How might the lack of plate tectonics contribute to its oversize volcanos?

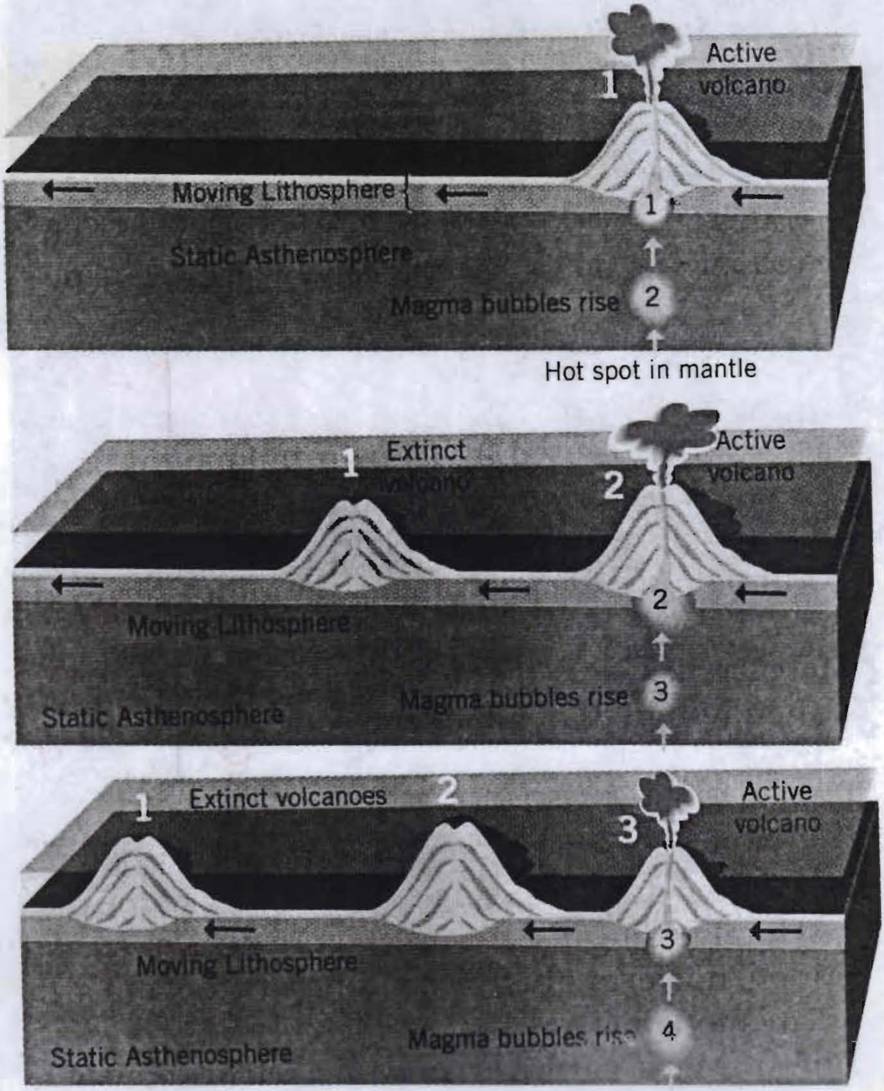


FIGURE 9–22. Why volcanoes on Mars are larger than those on Earth. Formation on a moving lithosphere limits volcanic sizes on Earth, while the lack of motion on Mars allows them to grow.