5 Planetary cooling: The surface area to volume ratio

The total heat contained in a planet depends upon its volume. However, as the planet cools, this heat escapes through the planet's surface.

The rate at which a planet cools will in part be determined by the ratio of its surface area to its volume. For a spherical planet of radius r, the volume is $\frac{4}{3}\pi r^3$ and the surface area is $4\pi r^2$. The ratio of these two quantities may be written as

$$\text{SAV} = \frac{4\pi r^2}{4/3\pi r^3} = \frac{3}{r}.$$

So the SAV ratio is smaller for larger planets. Therefore, all else being equal, a larger planet will cool more slowly than a smaller planet.

Let's compare the SAV ratios for the Moon, Earth and Mars.

$$r_{Moon} = 1,738 \text{ km}, \quad r_{Earth} = 6,378 \text{ km}, \quad r_{Mars} = 3,397 \text{ km}$$

$$\begin{aligned}
\frac{\text{SAV}_{\text{Moon}}}{\text{SAV}_{\text{Earth}}} &= \frac{3}{r_{Moon}} \times \frac{r_{Earth}}{3} = \frac{6378 \text{ km}}{1738 \text{ km}} = 3.7 \\
\frac{\text{SAV}_{\text{Mars}}}{\text{SAV}_{\text{Earth}}} &= \frac{3}{r_{Mars}} \times \frac{r_{Earth}}{3} = \frac{6378 \text{ km}}{3397 \text{ km}} = 1.9
\end{aligned}$$

Therefore, ignoring effects such as internal heat from radioactive decay, the Moon cools twice as fast as Mars, which cools twice as fast as the Earth.