WATER IN TERRESTRIAL PLANETS

F. Albarede. Ecole Normale Supérieure, 69007 Lyon, France, albarede@ens-lyon.fr.

Mars and the Moon are dry and inactive deserts. Their interiors came to rest within one billion years of accretion. Venus, although internally very active, has a dry inferno for a surface. In contrast, the Earth is tectonically active and largely covered by a deep ocean. The strong gravity field of large planets allows for an enormous amount of gravitational energy to be released, causing the outer part of the planetary body to melt (magma ocean), thus helping retain water on the planet. The analysis of K/U and $^{87}Sr/^{86}Sr$ ratios in planetary objects further demonstrates that the Inner Solar System lost up to 95% of its K and Rb. Planets in such an environment cannot contain much water (~20 ppm).

The relationship between terrestrial element abundances and condensation temperatures shows that the Earth and the other terrestrial planets accreted dry. I here assume that the nebular gas is an ideal gas and use Raoult's law and the Sackur-Tetrode equation to build a simple Rayleigh distillation model accounting for nebular condensation. Using proper simplifications, the 50-percent condensation temperature of each element (T_{50}) can be shown to be roughly proportional to its vaporization enthalpy with a proportionality constant mildly dependent on the molar mass. This model suggests that most of the Earth's material formed at temperature in excess of 1200 K and that the terrestrial water content greatly exceeds the concentration expected in a solid phase condensing at such a high temperature. Dry planetary interiors are most easily reconciled with 3D N-body simulations. I here investigate the consequences of a scenario in which terrestrial planets accreted bone-dry and water rained down into the mantle over the planets history.

On Earth, buoyant serpentines produced by reactions between the dry terrestrial magma ocean and icy impactors received from the outer Solar System isolated the magma and kept it molten for ~30 million years. Subsequent foundering of this wet surface material gradually softened the terrestrial mantle, transporting water to depth, increased the Rayleigh number, and set the scene for the onset of plate tectonics which currently lets the ocean rain into the mantle. The very same processes may have acted to remove all the water from the surface of Venus 500 My ago and added enough water to its mantle to make its internal dynamics active and keep the surface young. In contrast, because of the smaller radius of Mars compared to that of the Earth, not enough water could be drawn into the Martian mantle before it was lost to space and Martian plate tectonics never began.