Geology:

Extraterrestrial soils

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Extraterrestrial soils may be defined as any of the solid granular crustal features of planets and moon other than those soils on planet Earth. Despite four decades of space exploration, which greatly expanded our understanding of the Solar System, there is considerable debate as to the loose covers of rocky planets and moons are soils in a pedological sense [1][1,2]. On Earth, soil form thanks to the combined action of at least five factors: parent rock, climate, topography, living organisms and time.

A few other factors can concur to drive pedogenesis[3]. However, the necessity of biota as unavoidable soil forming factor is debated. In fact, important parts of Earth, such as the hyperarid Atacama Desert of Chile and the Dry Valleys of Antarctica, host virtually life-free soils with advanced horizonation. Actually, although most people invokes the ability to support plant growth in its natural environment as condicio sine qua non for soil, a scientific definition considers soil to be any in situ weathered veneer of a planetary surface that retains information on its climatic and geochemical history. A current or past mineral weathering is hence the pivotal requisite for soil.

Table of Contents

Weathering processes

On Earth, weathering is promoted by liquid water, which is the solvent where most of reactions happen and a carrier of matter and energy. Oxygen or, in anaerobic environments, weaker electron acceptor such as nitrates, sulphates and ferric iron allow the altering action of proton donors. Several sources of energy are finally the motor of pedogenesis. Outside Earth most water probably occurs as ice, but weathering might be caused by thin layers of liquid water at the rock-ice interface, as documented to happen in frozen soils on Earth[4]. Furthermore, there are several polar solvents able to replace liquid water, such as sulphuric, hydrofluoric and hydrocyanic acids, ammonia, methanol and hydrazine[5]. Finally, a variety of energy sources can drive chemical reactions in space: thermal, osmotic and ionic gradients, solar wind, magnetosphere energy and radioactivity are the most important among those detected. What soil genesis cannot prescind from is a rocky parent material, which in the Solar System occurs just on the other three inner planets – Mercury, Venus and Mars –, a few planets’ moons, and the largest asteroids. Any consideration on the occurrence of soils on exoplanets – those orbiting other stars – some of which are expected to be solid, is nonsense given their remoteness that do not allow direct observation.

Within the Earth's solar system

Mercury, which is devoid of any atmosphere, is greatly affected by meteorite and solar bombardment and shows evidences of maturation[6]. Venus, on the contrary, has a dense atmosphere, mainly composed of carbon dioxide and sulphuric acid droplets, which protects the surface from erosion by cosmic particles but is effective at degrading rocks into secondary weathering products[7]. The recent direct investigations of three rovers on Mars, one of which in 2008 even opened the first soil profile outside Earth (Fig. 1), clearly demonstrated that chemical weathering combined with leaching occur in many geological settings of this planet[8]. The Earth's moon is the only celestial body samples of which were returned and studied on Earth. Lunar surface shows a thin rim of weathering on grains and even horizonation induced by meteorite impacts, chemical interactions of impact-generated and sputtered ions, and irradiation by solar wind, which darkens and reddens powders in proportion to their Fe content[9]. Additionally, opposite to what believed until a little time ago, a minor hydrated phase occurs in the upper millimetres of lunar surface[10]. The largely prevailing icy nature – as in the cases of Phobos and Deimos, the two small moons of Mars, or Titan, the largest moon of Saturn – or volcanism that continuously reworks the crust, thus reducing the time available for any pedogenic processes – as in the case of Io, the only telluric moon of Jupiter – make the presence of soils on moons improbable, although not yet impossible. Asteroids are rocky bodies that mainly lie in a belt between Mars and Jupiter and that are believed to be left over from the beginning of the Solar System. They have round or irregular shapes up to several 100 km across, but often are much smaller. Such a small size deprives them of any internal heat and, as a consequence, volcanism and tectonics that could rejuvenate their surface. However, too little is known of the Asteroids' nature to make deductions about the occurrence of soils on them. After capturing samples from the asteroid 25143 Itokawa, the Japanese spacecraft Hayabusa is returning to the Earth and will soon provide the first direct information on an asteroid's skin and its stage of alteration.

Summary

To summarise, our nearest planetary neighbours, Venus, Mars and our moon, possess weathered mantles that should be considered to be soils in a pedological sense, while Mercury and some large asteroids have loose portions of surface that only a future better knowledge may eventually grant of the rank of soils.

See also

- Extremophile
- Moon shrinkage

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External links

- www.nasa.gov/mission_pages/exploration/news/presskits/living_on_the_moon.html

Fig. 1. Centimetric soil profiles at 68°N in the Martian arctic plain URL www.nasa.gov/mission_pages/phoenix/images/phx-17062.html [Courtesy of NASA/JPL-Caltech/University of Arizona/Texas A&M University/Max Planck Institute]

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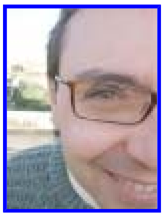
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