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Main Forms of Energy Driving Soil Formation

Abstract
Four different forms of energy are involved in soil formation: gravity, orogenic energy, solar energy and anthropogenic energy. The specific influence of these forces is important for understanding soil development under different physio-geographic conditions and for soil classification.

Key words: soil formation, gravity, orogenic energy, solar energy, anthropogenic energy, soil classification.

Introduction

Soils are providing goods and services of paramount importance for sustaining human societies and the environment (Blum 2005; Frossard et al., 2006; Costanza et al., 1997).

In view of the world wide losses of soil, e.g. through sealing, erosion and further impacts, information about the time scale of soil formation becomes increasingly important (European Commission, 2006). Until today, we have measurements and assessments regarding soil losses, e.g. through erosion, but no solid data about the pace of soil formation. Therefore, the question arises: How much soil is formed with time, under different climatic, geological, topographical, hydrological and biotic conditions, under the influence of human activities, including different forms of land use and climate change and how to classify these soils. – At the moment, national and international research groups on critical zone processes are targeting this issue (Chorover et al., 2007).

Material and Methods

For answering this question, a first approach could be to identify the basic forms of energy involved in soil forming processes. With such an approach, it would also be possible to develop a comprehensive concept, which would allow to describe processes of soil formation as well as methods to measure them, e.g. weathering of rock parent material and the development of the regolith zone, as well as the further development from regolith to soil. This concept could also allow to define measurable indicators for the different characteristics of rock, regolith and soil and to improve soil classification.

Results and Discussion

Soil formation is driven by four main forms of energy: gravity, orogenic energy, solar energy and anthropogenic energy.

Gravity influences all movements of solid, liquid and gaseous materials. It is an inherent form of energy and influences the vector and the velocity of fluxes within soils (e.g. movement of solutes) as well as at their surface (e.g. soil erosion by water). – Therefore, gravity is one of the main factors of morphogenesis.

Orogenic energy is the second form of energy and is herited from the rock parent material, which was formed through orogenesis, an endogenic process which created very diverse types of rocks and minerals under high temperature and pressure. This endogenic energy, which can also be called orogenic energy, is still contained in rocks and in the rock forming minerals. This energy is normally not renewed for a long time, except in cases such as volcanic activities and others. – Through exogenic forces, derived from

solar energy, e.g. through processes of weathering and transport (e.g. erosion), this orogenic energy pool is constantly lowered. Primary minerals, such as micas and feldspars contain more energy, derived from orogenesis as their weathering products, e.g. clay minerals and oxides. Moreover, the resistance of different minerals against weathering or the buffer capacity of soils against acidification can also be explained by orogenic energy. Orogenic energy is manifest in the texture and structure of rocks and the crystallography of minerals and their resistance to exogenic forces, which is mainly explained by the form and density of the mineral package in the rocks or the element package in the crystal structure of minerals. Orogenic energy is also manifest in the chemical composition of minerals, which plays an important role, e.g. through the content of alkaline and earth alkaline cations in relation to silica, aluminium and metals such as iron, manganese, copper, zinc and others. In detail, this becomes evident in the thermodynamics and kinetics of weathering processes:

Thermodynamically, 4 characteristics of minerals are important for weathering processes:

- the type of mineral structure, e.g. phyllosilicates, chain silicates etc.;
- substitution of Si by Al in the mineral lattice (Al-ion is about 50% larger than Si);
- type of metal cations connecting the Si-tetraeder in the silicate structure, e.g. Ca, Mg, Fe^{2+} in biotite or Al in muscovite;
- amount of oxidizable Fe^{2+} and Mn^{2+} in the crystal structure.

Kinetically, 3 main factors are important for the weathering of minerals:

- the surface of minerals in the rock texture: fine-grained, e.g. basalt or coarse-grained, e.g. granite;
- the amount of protons in the soil solution, e.g. expressed by the pH or other specific indicators;
- the velocity of percolation (leaching) creating disequilibria in the weathering environment.

Solar energy is the third form of energy, deriving directly from solar radiation or from diffuse radiation through reflection. Solar radiation is the basis of photosynthesis producing biomass, which again is the basis of physical, chemical and biological weathering, producing protons in the form of H_2CO_3 and organic acids through the biological decomposition of litter at the soil surface and of roots within the soil or the delivering of photosynthates to root-mycorrhiza, which acts at the weathering front by exsudates and other organics delivering protons. Therefore it can be concluded that the intensity of photosynthesis is directly correlated with the intensity of weathering processes. This means that clear differences exist between the influence of forests, grass covers and land surfaces without vegetation, on weathering processes.

In the past, soils developed under different climatic conditions (paleoclimates) and types of vegetation, especially in the tropics and sub-tropics, which makes it difficult to use current climatic data, such as temperature and/or precipitation to classify soils witch have developed over a long period of time.

Anthropogenic energy is the fourth form of energy, deriving from anthropogenic activities. It is a mixture of different energy forms, including human labour, and is mainly based on fossil energy and non-renewable resources, such as oil, coal, rocks and minerals. - Since the end of the 18th century, anthropogenic influences on terrestrial and aquatic ecosystems have been exceeding natural impacts (Crutzen, 2002; Blum and Eswaran, 2004) and are therefore important for understanding soil formation and for classifying soils in general.

Conclusions

For making soil formation understandable and for classifying soils, the energy concept is a useful tool. This is also the aim of the critical zone approach.

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