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MAIN FORMS OF ENERGY GOVERNING SOIL FORMATION

Abstract: Soil formation is governed by four different forms of energy: gravity, orogenic energy, solar energy and anthropogenic energy. The specific influence of these four different energy forms is explained, thus making soil development under different physiogeographic and environmental conditions more understandable. In this context, it is also shown that human impact plays an increasingly important role on soil formation and functioning.

Keywords: soil formation, gravity, orogenic energy, solar energy, anthropogenic energy

INTRODUCTION

Soils provide goods and services of paramount importance for sustaining human societies and the environment [Costanza et al. 1997; Blum 2005; Frossard et al. 2006].

In view of the worldwide losses of soil, e.g. through sealing, erosion and further impacts, information about soil formation processes and their time scale becomes increasingly important [European Commission 2006]. To date, we have measurements and assessments regarding soil losses, e.g. through erosion, but there is no solid data about the rate of soil formation. Therefore, the question arises: how and 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. For many years, national and international research groups on the critical zone processes have been targeting this issue [Chorover et al. 2007].

MATERIALS AND METHODS

To answer this question, the first approach should be identifying key soil characteristics and their development, e.g. soil structure, and distinguishing basic forms of energy involved in soil structure formation. With such an approach, it might also be possible to develop a comprehensive concept, which would allow a describtion of the processes of soil formation as well as methods to measure them, e.g. weathering of the parent rock material and development of the regolith zone, as well as further development from regolith to soil, based on soil structure. This concept should also allow defining measurable indicators for the different characteristics of rock, regolith and soil and 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 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 inherited from the parent rock material that 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 present in rocks and 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. 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, compared to 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 manifested in the texture and structure of rocks and the crystallo-

graphy 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 manifested in the chemical composition of minerals, which plays an important role, e.g. through the content of alkaline and alkaline earth 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 the weathering processes. Thermodynamically, four characteristics of minerals are important for weathering processes:
– type of mineral structure, e.g. phyllosilicates, chain silicates etc.;
– substitution of Si by Al in the mineral lattice (the Al-ion is about 50% larger than the Si-ion);
– type of metal cations connecting the Si-tetrahedron 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, three main factors are important for the weathering of minerals:
– surface of minerals in the rock texture: fine-grained, e.g. basalt or coarse-grained, e.g. granite,
– amount of protons in the soil solution, e.g. expressed by the pH or other specific indicators,
– velocity of percolation (leaching) and ion uptake, e.g. by plant roots, creating disequilibria in the weathering environment.

Solar energy is the third form of energy, deriving directly from solar radiation, or 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 mycorrhizas, which acts at the weathering front by exponentially increasing of the rooting surface, delivering exudates and other organic forms of protons. Therefore, it can be concluded that the intensity of weathering processes is directly correlated with the intensity of photosynthesis. This means that different forms of vegetation, e.g. forests, grass covers and land surfaces without vegetation, have very diverse impacts on weathering and soil forming processes.

In the past, soils developed under different climatic conditions (palaeoclimates) 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 which 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 the understanding of current soil formation as well as identifying new soils, derived from human activities.

CONCLUSIONS

The energy concept is a useful tool for a better understanding of the formation of soils, and their importance for humans and the environment. This is also the aim of the critical zone approach.

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