Soil Forming Processes

Introduction

Soil forming processes are determined by climate and organisms (both plants and animals) acting on the local geological surface materials over time under the influence of the slope of the land and human activities. The interaction between these factors initiates a variety of processes including biologically driven accumulation and destruction of organic matter, transformation of substances, the migration and translocation of the products of soil formation which all together gradually change geological materials into a soil with distinct and well-defined horizons.

Some soil types are deep or have thick organic layers that allow roots to penetrate easily, others have strongly cemented horizons or acid subsoil that inhibit rooting. These differences arise from the interaction of local environmental processes acting upon the soil fabric.

Time is an important consideration since the soil forming factors must act for a considerable period to develop a mature soil profile with well expressed horizons. Some soil forming processes, such as gleying (water-logging) might occur within a few years while podzolization (the downward migration of aluminium and iron and subsequent immobilisation at depth) might take centuries.

Finally, humans play an important role in soil formation by manipulating, irrigating, draining, liming and ploughing the land. More details can be found in any standard soil science textbook.[18]

The dominating soil processes in northern latitudes can be grouped into:

- cryogenic process, where the role of ice and cold temperature are important;
- the accumulation of organic matter, including peat formation;
- weathering;
- brunification;
- leaching, clay movement and destruction;
- podzolization;
- gleying (waterlogging);
- salinisation (high salt levels).

Cryogenic processes

As a consequence of the cold, dry climates of the northern circumpolar region, cryogenic processes, which lead to the formation of permafrost-affected soils, dominate soil genesis.

The presence and mobility of unfrozen soil water drives this process as it migrates along the thermal gradient towards the freezing front in the soil.

The specific cryogenic processes that affect the genesis of circumpolar soils are frost heave, cryoturbation (frost churning), thermal cracking, and ice build-up. All these processes also contribute to the development of patterned grounds.

Other soil-forming processes, as mentioned above and described later, can leave an imprint on these soils.

Frost heave

When the ground freezes, soil material can be displaced as a result of a process known as ‘frost heave’. One of the most common mechanisms that drives frost heave is the migration of water from warm to cold areas because ice molecules have a lower energy state than liquid water. Since the system tends towards a lower energy level, the free water flows towards the developing segregated ice forms (ice lenses, ice crystals and vein ice). Because these ice forms develop parallel to the freezing front and continuously increase in size, the result is an upward movement of the ground (frost heave). This process depends on temperature, the availability of water, and the texture of the soil.

If the soil is underlain by a layer of permafrost (or by some other impermeable barrier such as hard massive rock) and at the same time, bounded by a lateral obstruction such as ice wedges, tremendous cryostatic pressure can build up when the soil freezes. This pressure leads to dramatic structural changes in the soil and may result in the upward or downward movement of rock fragments within the profile. This movement may cause a bulging (differential heave) of the surface or even the expulsion of material from the soil (e.g. the frost heaved boulder in the above photograph).

Frost-heave causes fine particles to be separated from coarse fragments and stone (Frost sorting). In addition, stones in the soil become orientated in a uniform direction (oriented stones).

Cryoturbation

An important consequence of frost-heave processes are cryoturbated soils that includes the displacement and mixing of soil materials; frost sorting (which separates fine materials from coarse materials) and oriented stones (see above). On the soil surface cryoturbation results in patterned ground, frost-heaved stones and boulders.

Cryoturbation occurs to varying degrees in most permafrost-affected soils and is characterised by deformed soil horizons and the mixing of materials within the soil. Cryoturbation is often unaffected by ‘conventional’ soil forming processes. Therefore, the features of cryoturbation are often preserved in soil which allows past climatic features to be recognized.

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