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FORMATION OF THE PARENT MATERIALS IN SOILS OVER LIMESTONE TERRAINS

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Abstract: Derivation of the parent material in soils over limestone terrains is a complex process. It is because limestone usually gives a small amount of insoluble residue, and the insoluble residue is usually eroded away along with dissolved material. Therefore, on limestone terrains drift material plays an important role on the formation of soils. This drift material can be originated from the weathering of limestone directly or/and can be an airborne material, such as dust, loess and volcanic ash originating from different sources.

Kireçtaşları üzerindeki toprakların ana materyallerinin oluşumu

Özet: Kireçtaşları üzerinde oluşmuş olan toprakların ana materyallerinin oluşumu karmaşık bir durum arzeder. Bunun sebebi, kireçtaşlarının tecezziye uğradıkları zaman çok az miktarda erimeyen bir artık bırakmaları ve bu artığın genellikle suda eriyen kısımla beraber ortamdan uzaklaştırılmalarıdır. Bu nedenle, kireçtaşları üzerindeki toprakların oluşumunda, taşınmış ve birikmiş materyallerin önemli bir rolü vardır. Bu materyaller direk olarak kireç taşlarının tecezzisinden oluşabileceği gibi ince toz, lös ve volkanik materyaller gibi rüzgarlarla taşınmış da olabilir.

Introduction

Soils of limestone terrains, particularly in the Mediterranean type of climate, have had much dispute concerning the parent material on which they developed. It is because hard massive limestone usually gives only about 0.01 % insoluble residue. Moreover, the insoluble residue is generally carried away along with dissolved material. Hence it is necessary to dissolve a substantial amount of limestone to get a few centimeters of insoluble residue soil. As a result, on limestone terrains the formation of deep soils from the insoluble residue is difficult and soils are dependent very much on the existence of drift rather than on the solution of limestone alone. If the drift is originated from limestone a carbonate rich soil will develop, such as a rendzinas, but if the drift is derived from other sources rather than limestone, such as aeolian deposits, the soil development may show no relationship to the limestone below the drift.

Hence it is possible to suggest that the derivation of soil material of the limestone terrains are two fold as follows: (1) Weathering of the limestone and deposition of insoluble residue in the depressions, poljes and on lower slopes; (2) Airborne material, such as fine dust, loess and volcanic ash originating from the different sources.

All three materials contribute the soil material in two ways; a) they directly mix with soil material and b) first they were trapped in the limestone complex and then after freed by dissolution. At the present time it is very difficult to suggest precisely what proportion of soil material is originated from the weathering of the limestone below and what proportion has been introduced as aeolian dust.

1. Sedentary Formation

Limestone and chalk

Although there are great variations between different limestones in appearance and properties, the minerals constituting the calcareous rocks are few in number essentially calcite and aragonite.

These variations result principally from the almost endless variety of organic and other structures into which crystals of these minerals may be aggregated. Calcite can be regarded as the principal mineral of limestone, which is the stable form of calcium carbonate at ordinary temperature.

When a limestone surface exposed and in contact with rain water, which is slightly acidic, it can be easily dissolved and washed away leaving a small amount of insoluble residue. The insoluble residue of carbonate rocks contains SiO_2, Al_2O_3 and FeO_3. The silica may be in the form of chert, silicified fossil fragments, detrital or authigenic sand grains, or as a number of other silica minerals. Aluminium and iron may be present within the clay structure or as a hydrated oxide. The insoluble residue may contain phosphates, sulfides, feldspar and some amount of organic matter as minor non-carbonate minerals. Silica and clay minerals, which are mainly illite and kaolinite constitute the bulk of the insoluble fraction of most carbonate rocks. Crystalline quartz or chalcedony represent free silica, which make up the sand and silt size particles. However, silica in the insoluble residue is fairly soluble, particularly if it is an amorphous form. Hence, it easily gets into solution as silicic acid complexes. In the tropics, the leaching of silica may be almost completed, even quartz and chalcedony are removed, the clay minerals are broken down and iron exist in the form of dispersed hematite. But the immobile character of aluminum keeps it in the soils in the form of gibbsite, boehmite and diaspore.

A work (1) on limestone terrains of Epirus, Greece, showed that limestone weathering had not made a significant contribution to soil parent material. Hence an extraneous material must have been deposited at the limestone surface on which soil have developed. However, where weathering is prolonged there is no doubt limestone underlying a soil has the same composition as the strata from which the soil has developed. He proposed an aeolian origin for the parent material which is brought into the Epirus by the Sirocco wind from the north Africa.

The new formation of soil from limestone is estimated as 1 to 2 cm 1000 year-1 in Israel (2) and 1 μm $year^{-1}$ in the central Algarve, Portugal (3). The total erosion loss in places was 54 and 32 mm year-1, in 1984/85, and concluded that the formation of soils on the limestone terrains entirely from the limestone residue, even in the places with no erosion effect, is unlikely.

The amount of mineral material released by dissolution of chalk is usually very low, due to the its purity, and depth of soil which can form simply from chalk residue is very shallow. In many situations losses from the surface by erosion are likely to be at least as rapid as gain in depth by soil formation, and in the complementary situations of accumulation the depth is achieved by derivation from a wide area. However, the chalk of the temperate regions occurs in areas of deposition of till, outwash material or loess during glacial period, and few chalk soils could have been derived completely from chalk alone.

Chalk is a soft limestone and weathers by solution in the same way as the hard limestone and as a soil parent material chalk has two important features: (1) the structure, card-house-like, of chalk allows water to percolate and then drain away through the small fissures in the rock; (2) soils derived exclusively from insoluble residue of chalk are initially extremely calcareous. In humid climates, such as in Britain, carbonates are leached out, leaving a non-carbonate clayey residue (4).

2. Extraneous Origins

a) Loess

Loess is defined simply as a terrestrial windblown silt deposit consisting chiefly quartz, feldspar, mica, clay minerals and carbonate grains in varying proportions. Heavy minerals, phytoliths, and volcanic ash shards are also sometimes important constituents. Fresh, unweathered loess is typically homogeneous, non-or weakly stratified and highly porous. most commonly it is buff in colour but may be gray, red, yellow or brown. When dry, loess has the ability to stand in vertical sections and sometimes show a tendency to fracture along systems of vertical joints, but when saturated with water the shear strength is greatly reduced and the material is subject to subsidence, flowage and sliding. The grain size distribution of typical loess shows a pronounced mode in the range 20-40 µm and is positively skewed, toward the finer sizes (5).

The size of the average grains of a loess deposit can vary considerably and contain different proportions of fine sand, silt and clay, depending upon the distance from the source, the type of source material and how it is deposited out of atmosphere. Loess deposits display good sorting and are generally massive, with no traces of bedding. Silt size grains of quartz, in particular, are usually angular and subangular, whereas sand-size particles are more or less rounded. Mineral composition of loess show variation due to the differences in source material and the age of the deposit.

When loess is weathered, its sedimentary characteristics are markedly modified by weathering, soil formation and diagenesis. Weathered loess is usually decalcified and contains more clay (15-35 %, and most usually 20-30 % Burnham, per com) than unweathered loess.

Due to the its high porosity and permeability, infiltration rates in loess are relatively high, although on bare surfaces infiltration may be reduced by crusts formed during rainstorms. In humid areas, redistribution of carbonate in loess after deposition usually involves leaching of the A horizon and carbonate redeposition, partly as nodules, in the B horizon. The depth of leaching increases with time, although relict carbonate concretions may remain in the A horizon as leaching progresses downward. Commonly loess has been reworked by fluvial activity and has been largely eroded from the upper slopes to the lower slopes where it often forms weakly stratified accumulation.

Loess typically forms a blanket of varying thickness, covering a variety of relief features including steep valley slopes, plateau, terraces, alluvial fans and pediments. The surface morphology of loess sheets is strongly controlled by the underlying topography. Loess is found over a very wide latitudinal range, occurring near sea level in northwest Europe to more than 2000 m in part of Central Asia and China (5).

b) Aerosol dust (non-volcanic)

More recently, an appreciation of the continuous deposition of dust, assuming global significance, has emerged from measurement of atmospheric dust transported at various location. Dust can be defined as a suspension of solid particles in a gas or a deposit of such particles. Particles of dust transported in suspension in the Earth's atmosphere are smaller than 100 µm. Grains larger than 20 µm settle back to the surface quite quickly when the turbulence associated with strong wind decreases, but smaller particles can remain in suspension for days or even weeks unless washed out by rain. Continental loess is composed mainly of particles in the 10-50 µm. size range which have not been transported great distances, while aeolian deposits in the oceans are composed mostly of far traveled material finer than 10 µm.

Deposition of dust has been and is an active factor of soil formation, which has affected the properties of many soils during the Quaternary. The particle size of the dust transported a long distance is 1 to 20 µm and usually is washed out of atmosphere by rainfall. It is stated that material of larger grain size than 20 µm falls on the Mediterranean Sea and over the entire southern Europe after a wind storm in the Sahara Desert, whereas finer material floated several times around the Earth (6).

Particle size distribution of dust changes in the range of silt size, 2-50 µm, being dependent on the source material, distance and power of transport agent. For instance, six dust samples have been collected in south of Turkey during 1987 and 1992 and found that the dominant particle size in all samples was between 10-50 µm with decreasing around to 300-500 µm with a few 500-1000 µm particles (7). Dust, even after very long transport, frequently contains substantial numbers of fresh water diatoms, phytoliths, fungal spores and opaque organic spherules (8,9).

The precise composition of a given dust is dependent on the nature of the source material. However, coarse grained dust is usually rich in quartz, feldspar and carbonate minerals, while far traveled dust is typically enriched in fine-grained mica and clays (5). The North African dust transported over the Mediterranean have collected and found that their clay minerals composition as 50 % kaolinite, 40 % illite, < 8 % chlorite and < 5 % montmorillonite (10).

Aeolian dust transported and deposition over Crete and adjacent parts of the Mediterranean Sea showed that mineral composition of samples were quartz, calcite, clay minerals including illite, smectite and chlorite, with a small amount of dolomite, K-feldspar, gypsum, halite, simectite and palygorscite. However, the mineral composition varied significantly between different sampling periods, particularly with regard to calcite and dolomite content. Grain size analysis of selected samples indicated that most of the deposited dust is of fine silt and clay size, with a median size ranging from approximately 4 µm to 16 µm. The proportion of clay varies from 15 to 45 %. The dust contains very little sand and most of the larger grains present are composite of low density material, such as organic matter, porous aggregates of fine particles or anthropogenic pollutants(9).

Airborne accession of dust has a variety of effects in soil development and soils after they have been formed. Dust dominates processes of genesis in a few soils, affects horizon differentiation appreciably in many more, is a primary source of constituents essential to some horizons and layers in a number of soils, provides the bulk of the material for silty surface horizons in many soils.

The influence of aeolian material on soils is described (11) as follows;

1) Soil in which atmospheric dust has acted as modifying agent,
2) Soils in which atmospheric dust has significant effect on the nature of soils,
3) Soils on which there is a thin surface aeolian layer which is thinner than the depth of the solum,
4) Soils which formed entirely in the aeolian sediment

The dust reaching the Mediterranean basin is considerable compared with the other regions and affects the properties of soils of the areas. It is estimated that 20-30 million tons of dust are brought into the eastern Mediterranean Basin each year, by far the largest part of which is deposited in the Mediterranean sea (12). Between one-third and two-fifths of the soil material in the uplands of the limestone associated soils in Israel, where fluvial contamination can be excluded, is of aeolian origin and mostly originated from the Libyan, Egyptian, Sinai and Negev deserts (11).

Several investigators have been suggested that the terra rossa soils of southern Europe and the Levant have formed largely as a result of accumulation and weathering of airborne dust transported from north Africa (11, 1, 12). But some suggest that dust addition to the soils is of secondary importance and the most of the soil material is derived from limestone impurities and of other local rock types (13). The A horizon of the terra rossa soils with a high silt content has been usually attributed to an aeolian origin, as in Greece (1), in Israel (12) and in Turkey (7).

c) Volcanic ash

There are three basic mechanism of volcanic ash formation as : (a) the release of gases from solution because of decompression within the magma as it reaches the surface of the planet, magmatic eruption, (b) chilling and explosive fragmentation of magma during contact with ground and surface water or ice and snow, phreatic to magmatic eruption, and (c) the comminution and ejection of particles from vent walls or crater debris during eruptions of steam and hot water, phreatic eruptions (15).

Volcanic ash deposits are found throughout the entire geological record. Volcanic areas and rooks, which belong to the Tertiary and the Quaternary occupy a large place in Turkey, especially in Central Anatolia. Generally a calm period is observed in the middle Pliocene. Volcanic activities are dated during the Upper Pliocene and the Quaternary and a large part of the Central Anatolia is composed of young volcanic features. In the Anatolia two large eruption periods occurred. The first eruption period took place during the Miocene-Lower Pliocene, and the second during the Upper Pliocene and the Quaternary which was central activity. As a result, volcanoes were formed by severe eruption , ash and pyroclastic cones by feeble eruption. The first eruption period brought out andesite and dacite lavas but the second basaltic material (16).

Volcanic ash parent materials are composed of non-crystalline, tiny, glass fragments, bits of the easily weatherable feldspars and ferromagnesian minerals, and varying amount of quartz. Most of the volcanic ash deposits are andesitic but also there is iron and magnesium rich, basic volcanic debris usually as granular basaltic sand. Volcanic ash gives rather distinctive properties to soils over a wide range of climatic conditions. One of the main features of soils inherited from volcanic ash parent material is allophone, an amorphous hydrated aluminum silicate with which abundant organic matter and gives an isotropic character to soil material is complexed in the upper solum.

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