Ak. Ü. Zir. Fak. Derg., 8, 197-205, 1995.

PROPERTIES OF TRANSPORTED SOIL MATERIAL

Zeki ALAGÖZ

Akdeniz Üniversitesi, Ziraat Fakültesi, Toprak Bölümü, Antalya

Abstract: Three alternating types of periods may be recognized in the development of landscape; 1) period of landscape stability; 2) period of landscape instability in which transported deposits are formed; and 3) period in which both case can be seen. Therefore transported material can provide valuable information on the conditions and developments of the unstable periods. It is possible to get valuable information not only on the origin but also on the mode of formation of the transported material by field (macromorphology) and laboratory (analytical and micromorphological) investigations.

Taşınmış Toprak Materyallerinin Özellikleri

Özet: Yeryüzündeki topoğrafyanın gelişmesinde birbirini takip eden üç ayrı periyod gözlemlenebilir; 1) durağan period; 2) taşınmış materyalin ouştuğu durağan olmayan period; ve 3) her iki periyodun görüldüğü durum. Bu nedenle taşınmış materyaller oluşmuş oldukları periyod hakkında değerli bilgiler sağlarlar. Arazi (makromorfolojik) ve laboratuvar (analitik ve mikromorfolojik) çalışmaları ile yalnızca taşınan materyallerin kaynağı hakkında değil, aynı zamanda onların nasıl oluştuklarını da içeren bilgiler elde etmek mümkündür.

Introduction

Three alternating types of periods may be recognized in the development of a landscape: 1)periods of landscape stability during which the process of soil formation takes place; 2) and periods of landscape instability when slope deposits and sediments are formed; and 3) periods in which both soil formation and the deposition of slope deposits and sediments occur (1).

Transported materials are principally formed during the periods of landscape instability. Hence they can provide valuable information about the unstable periods of landscape development in which they are formed and further, by means of soil relicts that they contain, indicate the conditions prevailing during the proceeding stable phase of landscape development (2).

The nature of the sediment is influenced by the same main factors as control erosion. First the nature of the source material, from which the colluvium was derived, the processes by which the material have been transported and deposited from upper slopes to lower. Then the climate, and topography which governs movement of water in the catchment and finally the vegetation and especially human activities on the land are highly important other factors.

Processes responsible for detachment, transportation and deposition have selectivity for particle sizes, and this selectivity takes place either on the interrill areas or during deposition on the landscape (3). Detached primary clay particles can be easily transported by interrill flow, and as a result sediment transported by interrill flow (erosion) have higher clay content than original soils (4). The clay enrichment of eroded aggregates have been usually attributed to an increase in the selectivity of the erosion process for the finer fractions of the soil.

Aggregates and cohesiveness of the soil matrix influences the types of eroded particles. Meyer *et al.*, (5) noted that much of the sediment from cohesive soils was in the form of aggregates, and some of them were much larger than the primary particles of which soils were composed. Finer soils usually produced coarser sediment due to the greater aggregation. The size distribution of the primary particles that made up partially aggregated sediment were similar to the size distribution of the primary particles of the surface soil from which sediment eroded.

In general, soil with high sand-size particles content are not well aggregated, thus these kinds of soils tend to erode as mostly primary particles, with sediment particle size distribution similar to the matrix soil, whereas clay soils originally well aggregated are eroded primarily as sand-size aggregates, or aggregates larger than 50 μm in diameter.

Determinative Properties

1. Macromorphological properties (in the field)

Transported materials are mainly unstratified, unsorted or poorly sorted, depending upon the type of transportation. On the valley slopes it shows no stratification at all, while in the valley bottoms it sometimes appears to be weakly laminated under the microscope. However, the strong suspicion is that the non-sorted character of colluvium is usually a result of cultivation and mixing of original sorted sediment (6). In contrast alluvial deposits, except the B horizon, are characterized by a clear stratification, various hydromorphic properties, a specific porosity pattern and clay coatings which are closely related to the sedimentary laminae and fine stratification in some part.

In the field, transported material can be identified by its position, by a sharp boundary with the underlying truncated soil profile and by its more or less homogeneous appearance, which can be different from the structure of the undisturbed profiles of flat land. Soils developed on the recent colluvium may show absence of soil profile creation or weakly differentiated horizons; if present, a Bw horizon is differentiated primarily by structure, shows little or no evidence of weathering *in situ* and normally fails to qualify as cambic (7).

Transported material normally thickens downslope and rests unconformably on an older deposit which commonly has pre-existing soil horizons, lag gravel or a stone line. When debris left behind a coarse-textured material that has experienced selective removal of fine constituents through the action of water and/or wind, aided by small scale mass wasting phenomena or selective dissolution, as in cherty limestone terrains, the results are stonelines. Thus, stonelines may reflect wind or water erosion.

Sedimentary structures within flood-plain deposits are characterized by thinly bedded units, which, depending upon the magnitude and duration of a flooding event, vary in thickness from millimeters to a few centimeters. Ripple marks are quite common, as are deformational structures, the latter being related to the soft , water saturated nature of sediment. This saturation is also responsible for the occurrence of mottling and iron staining, commonly observed in flood-plain sediments.

2. Analytical properties

Organic-carbon content of colluvium and alluvium decreases gradually or irregularly with increasing depth. $CaCO_3$ content of a calcareous deposit, originated on limestones, decreases or remains nearly constant with increasing depth, and at the base of the deposit may be seen to change to non calcareous soil (7).

The abundance of coarse mica flakes and their angular orientation in parent material indicates alluvial sedimentation. The presence of both very fine sand and coarse mica flakes suggest transport in suspension in non-turbulent waters. The abundance of weakly altered minerals such as biotite and feldspar indicates that sediment originated in the region (8).

Particle size distribution, and mineralogy can provide important evidence for the provenance and mode of deposition. Sediment eroded from soil surface is composed of both primary and aggregated particles. The size distribution will vary depending on soil texture and the degree of soil aggregation.

Valentine and Dalrymple (9) used particle size distribution and the heavy minerals of the sand fraction to differentiate sedimentary strata from soil.

3. Micromorphological properties

Sometimes displacement is not observed in the field, in fact frequently micromorphological investigations show movement to have taken place. With the exception of macrostructure, many of the phenomena characteristic of soil development, the reorientation of material as a result of transport, and sedimentary structure, can only be observed under the microscope. When used conjunction with other pedological, sedimentological, and geomorphological data, micromorphological analysis can be a particularly effective tool for distinguishing and separating soil horizons and sedimentary layers.

In the absence of features in the field, micromorphological features, such as microstructure and voids, micro lamination, skeleton grains, lithorelict or rock fragments, aggregates, pedotubules, nodules, papules mud crusts, biorelicts, fecal pellets and presence of charcoal and anthropogenic debris can be used to detect transported material. However, it is necessary to notice that some disturbance of the profile is caused by biological activity and that it is not the solitary occurrence of one of the phenomena listed above that point to the transportation of soil material, but rather the combination of these phenomena in the soil profile.

Depth functions of particular microfeatures may supply valuable informations as to weather a unit is an *in situ* soil, providing similar depth functions have been established for soil forming at the present landsurface (9). Micromorphological evidence can be used not simply to establish whether or not displacement has taken place, but also to provide information on the nature of the geomorphic process involved.

a) Micro laminations

While transported material shows no stratification in the field it can show lamination under the microscope. However, laminae can be destroyed by biological activity (even at microscopic level) and by the effect of tillage (most probably at macroscopic levels). In transported deposits, faunal excrements and a new random distribution pattern can be observed when the lamination is destroyed by biological activity.

In colluvium derived from loess, Mücher and De Ploey (11) showed that the deposits produced from flow without rainsplash exhibit good layering and very good sorting while the effect of washing by rain resulted in poorly layered deposits and poor sorting within individual laminae. Therefore lamination not only shows transportation but also it can indicate the type of transportation.

In younger alluvial soils, a succession of flood deposits may remain visible even when soil forming processes have been active for some time. Also older soils can retain evidence of the deposition environment of a sedimentary parent material even when no visible trace of lamination remains (12).

b) Microstructure and voids

These are entities, which are interconnected with each other either through voids of dissimilar size and shape, through narrow necks, or through intersection with voids of similar size and shape (13). The pattern of voids forming pore structures and the arrangement of mineral particles and voids, which determines the soil fabric, are important features distinguishing soils from sediments.

The conducting pores are often preserved by formation of (neo) cutans of sesquioxide and carbonates. The original horizontal planar voids between platy peds are sometimes preserved by pedogenic clay illuviation. Specific porosity pattern such as vesicular microstructure is clearly linked to the heterogeneity of the original sediment. The specific vesicular microstructure is linked to the sedimentary environment and its associated moisture regime.

Colluvium may have been emplaced by rainwash and subsequently modified by structure form agencies, or by soil creep in which the original structure was to some extent preserved. Brewer (14) stated that some plasmic fabric of transported material may be inherited from original soil.

c) Skeleton grains

Skeleton grains of a soil material are individual grains which are relatively stable and not readily transported, concentrated or reorganized by soil-forming processes. They include mineral grains and resistant siliceous and organic bodies larger than colloidal size (15). The size distribution and shape of skeleton grains have often been used to determine condition of sedimentation.

Goudie and Bull (16) carried out research on colluvium with the scanning electron microscope, and showed that the quartz grains exhibit marked edge abrasion, which can be effected in a distance of only a few hundred meters, in the uppermost beds of exposures whereas this is lacking in the lower beds, these results indicate that slope processes may change during colluvium deposition. Also edge abrasion was most evident at the top of each section and absent at the bottom of the profile.

Green (12) suggests that the size-shape relationship both of transported and non transported parent materials can survive pedogenesis sufficiently well to enable them to be distinguished (though there may be some limitation) by size-shape analysis.

Valentine and Dalrymple (17) used the measurement of the long axis (preferred) orientation of sand grains in thin section as a quantitative expression of the presence of sedimentary structure in buried soil.

d) Lithorelicts or rock fragments

These are features derived from the parent rock, usually recognizable by their rock structure and fabric (13). Lithorelicts can provide information about the original rock from which the sediment has been derived. The presence of lithorelicts, for instance chert fragments, in loess deposits, suggests that the loess was reworked after aeolian deposition. In a deposit the presence of rock fragments not naturally occurring in the area may be evidence of anthropogenic origin. Pedo- and lithorelicts also can provide information about the origin of the slope deposit.

e) Aggregates

These are discrete groupings of particles formed naturally or artificially and includes such units as crumbs, granules, clods, faecal pellets and their fragments, and concretions (18). Aggregates are rounded during transport and consist of material which also partly reflect past soil formation apart from the transport process. Laboratory experiments by Mucher and de Ploey (11) and Mücher and Vreeken, W. J. (19) showed that water-stable loess aggregates smaller than 0.5 mm formed during flow without splash and larger ones during rainwash.

Aggregates which are rounded and show a different fabric from the soil matrix reflect the transport process and apart from this also partly reflect past soil formation. Bullock and Murphy (20) used rounded fossil aggregates in Plateau Drift as evidence of some degree of transportation.

Soil creep has a partially remolding influence on the sediment. If the distance of transport is not very long some pre-existing aggregates may remain intact, but most of them are destroyed although not completely dispersed. Mudflow is a type of mass movement that is relatively fast and the result of rapid saturation of fine grained material. This kind of material, in the field and under the microscope, is massive, non-bedded, poorly sorted and composed of stony material in a fine grained matrix.

f) Pedotubules

These are pedological features consisting of soil material, skeleton grains or skeleton grains plus plasma, as distinct from concentration of fractions of the plasma, and having a tubular internal form, either single tubes or branching systems of tubes, its external boundaries are relatively sharp (13). An abrupt change in the frequency of pedotubules with depth can be attributed to a discontinuity in the profile. Paraisotubules may contain unaggregated soil originating from another horizon, not existing in the studied profile. In this case the pedotubules are evidence of on erosional break in the profile.

g) Nodules

These are glaebules with an undifferentiated internal fabric. A glaebule is a three dimensional unit within the s-matrix of the soil material, and usually approximately prolate to elongate in shape. Its morphology is incompatible within its present occurrence being within a single void in the present soil material. It is recognized as a unit either because of a greater concentration of some constituent and/or difference in fabric compared with the enclosing soil material, or because it has a distinct boundary with the enclosing soil material (13).

Ferric and manganiferous nodules formed in situ, have diffuse boundaries. If they are transported or disturbed by mechanical forces they are sharply bounded. The occurrence of sharply bounded nodules in layers, and with inclusion of grains or features that differ from the surrounding s-matrix (groundmass), indicates that they have a sedimentary origin. Nodules often contain impregnated clay coatings show identical internal fabric which is similar to fabric in the B horizon of soil upslope.

h) Papules and mud crusts

Papules are glaebules composed dominantly of clay minerals without skeleton grains. They have characteristic extinction patterns, with crossed nicols under the petrological microscope, and sharp external boundaries (13). These are mostly associated with remnants of older soil formation.

Although papules are mostly remnants of older soils they may be derived from these in various ways;
(a) Disruption through mixing by the roots and fauna (21).

(b) Disruption by solifluction and cryoturbation of a former argillic horizon during periglacial climatic phases (19).
(c) Cutan destruction by shrink and swell movements as a result of wetting and drying stresses (21).
(d) By mass-wasting processes (22).
(e) Papules can also be inherited rock fragments, and formed during sedimentation(23).
(f) Also they can be formed as clay flakes during deposition of a sediment (14).

It is apparent that any pedological feature that is sufficiently resistant to survive the process of erosion and sedimentation can be inherited in younger soil profiles from their parent material. This applies not only to relatively hard discrete features such as sesquioxide nodules, but also to fragments of other features that may be fractured during the process of erosion and sedimentation, for example, void argillans in older soils may be the source of inherited papules in a younger soil.

Absence of cutans in the sediment while soils with argillic horizons are present in the area shows both transport and destruction of argillic horizon. Fragments of previously developed mud crusts or clay curls that have been incorporated in to the groundmass shows the occurrence of transport. Mud crust may represent old soil surfaces and reflect a period of stability when slope deposits were not being formed.

i)Lithorelicts

These are inherited biological features, such as diatoms, charcoal, molluscs, phytoliths, sponge specules and pollen etc., in the mineral soil which are stable under the present soil conditions.

All these biological features can be found mixed within deposits, such as phytoliths in subsurface horizons. This can indicate transportation process and also provide evidence for the conditions under which the deposit was formed. Presence of plant and root fragments parallel to the soil surface may show transport and redeposition process.

j) Faecal Pellets

These are rounded and subrounded aggregates of faecal material produced by the soil fauna (18). Their occurrence results from biological activity mainly in the original surface horizons. The repeated occurrence of excrements from the same species in successive layers indicates a stable accumulation site in the past landscape. If the original distribution pattern of the pellets has disappeared and the pellets occur in laminae, this indicates that they have been transported after formation. Sometimes matrix faecal pellets are difficult to distinguish from transported and rounded soil aggregates. The latter can often be recognized by their larger variations in size and roundness than the faecal pellets.

k) Presence of anthropogenic debris

Presence of debris, such as coal, pottery fragments, slags and plasters indicate the occurrence of transport and human endeavours that may have played a role in the accumulation of such deposits, including burning, deforestation or other clearing activities.

Literature

1. Butler, B. E. Periodic phenomena in landscapes as a basis for soil studies. Soil Publication No: 14. Commonwealth Scientific and Industrial Research Organisation, Australia Melbourne. 1959.

2. Mucher, H. J. Micromorphology of slope deposits: the necessity of classification, 553-566. In: Rutherford, G. K. (Eds.) *Soil Microscopy*. Proceedings of the 4th International Working-Meeting on Soil Micromorphology. Department of Geography, Quens University. Kingston, Ontario, Canada. 1974.

3. Foster, G. R. and Mayer, L. D. Mathematical simulation of upland erosion by fundamental erosion mechanics, 190-207. In: Present and perspective technology of predicting sediment yield and sources, ARS-40, USDA, Washington. 1975.

4. Monke, E. J., Marelli, H. J., Meyer, L. D. and De Jong, J. F. Runoff, Erosion, and Nutrient movement from interrill areas. Trans. ASAE. 58-61. 1977.

5. Meyer, L. D., Harmon, W. C. and McDowell, L. L. Sediment sizes eroded from crop row sideslopes. Transection of the ASAE, 23(4): 891-898. 1980.

6. Bolt, A. J., Mucher, H. J., Sevink, J. and Verstraten, J. M. A study on loess-derived colluvia in southern Limburg (The Netherlands). Net. J. Agric. Sci. 28: 110-126. 1980.

7. Avery, B. W. Soils of the British Isles. CAB International. 1990.

8. Courty, M. A. and Fedoroff, N. Micromorphology of a Holocene dwelling. PACT, 7: 257-277. 1985.

9. Valentine, K. W. G. and Dalrymple, J. B. The identification, lateral variation, and chronology of two buried palaecatenas at Woodhall Spa and West Runton, England. Quat. Res. 5: 551-590. 1975.

10. Kemp, R. A. Soil micromorphology and the Quaternary: Q.R.A. Tecnical guide No 2. Cambridge. 1985.

11. Mucher, H. J. and De Ploey J. Experimental and micromorphologycal investigation of erosion and redeposition of loess by water. Earth Surface Processes, 2,117-124. 1977.

12. Green, P. Recognition of sedimentary characteristics in soils by size-

shape analysis. Geoderma, 11: 181-193. 1974.

13. Brewer, R. Fabrics and Mineral Analysis of Soils. John Wiley and Sons. Inc. 1964.

14. Brewer, R. Use of macro and micromorphological data in soil stratigraphy to elucidate surficial geology and soil genesis. J. Geo. Soc. Australia, 19: (3) 331-344. 1972.

15. Brewer, R. and Sleeman, J. R. Soil structure and fabric, their definition and description. J. Soil Sci. 11 (1): 173-185. 1960.

16. Goudie, A. and Bull, P. A. Slope process change and colluvium deposition in Swaziland: SEM analysis. Earth Surface Process and Landforms, 9: 289-299. 1984.

18. FitzPatrick, E. A. Micromorphology of soils. Chapman and Hall, London. 1984.

19. Mucher, H. J. and Vreeken, W. J. (Re)deposition of loess in Southern Limbourg, the Netherlands, 2. Micromorphology of the lower silt loam complex and comparison with deposits produced under laboratory conditions. Earth Surface Processes and Landforms, 6: 355-363. 1981.

20. Bullock, P. and Murphy, C. P. Evolution of a Paleo-Argillic Brown Earth (Paleudalf) from Oxfordshire, England. Geoderma, 22: 225-252. 1979.

21. Birkeland, P. W. Soils and geomorphology. Oxford University Press. 1984.

22. Mucher, H. J., Carballas, T., Guitian Ojea, F., Jungerius, P. D., Kroonenberg, S. B. and Villar, M. C. Micromorphological analysis of effects of alternating phases of landscape stability and instability on two soil profiles in Galicia, N. W. Spain. Geoderma, 8: 241-266. 1972.

23. Mucher, H. J. and Morozova, T. D. The application of soil micromorphology in Quaternary geology and geomorphology, (1): 151-194. In: Bullock, P. and Murphy, C. P. (Ed) *Soil Micromorphology*. Proceeding 6th International Working Meeting on Soil Micromorpholgy, 1981, London. A.B. Academic Publishers, Berkhamsted England. 1983.