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Stratified Slope-Waste Deposits in the Esino River Basin, Umbria-Marche Apennines, Central Italy

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Summary: More than one hundred occurrences of stratified slope-waste deposits have been studied in an area of the Umbria-Marche Apennines (Central Italy). The area is characterized by mountains rising up to 1,700 m a. s. l. and underlain by mainly calcareous bedrock. The investigation took the structural and textural aspects of the deposits into account with the intent of understanding the genesis. In the deposits open-work beds can be recognised, probably emplaced by gravity and slopewash on vegetation-free slopes, together with beds rich in matrix emplaced by solifluction. The alternation of different bed types can be related to climatic variations over relatively long periods in conditions substantially colder than the present.

Zusammenfassung: Untersucht wurden mehr als hundert Vorkommen von geschichteten Hangsedimenten in den Appeninen von Umbrien und Marken (Mittelitalien), die Höhen von 1700 m erreichen und überwiegend aus Kalkgestein aufgebaut werden. Der Schwerpunkt lag auf der Untersuchung der Struktur und Textur der Ablagerungen, um deren Genese zu klären. In den Ablagerungen kann man „open work" (matrixfreie Schuttlagerung) beobachten, die wahrscheinlich gravitativ oder durch Abspülung entstand, darüber hinaus matrixführende Solifluktionsdecken. Das Alternieren der unterschiedlichen Ablagerungstypen wird durch Schwankungen innerhalb eines kälteren Vorzeitklimas erklärt, das über einen längeren Zeitraum anhielt.

INTRODUCTION

During the Pleistocene, following the establishment of cold climate conditions, there was the development of a periglacial environment in Italy (TRICART & CAILLEUX, 1953; NANGERONI, 1962; DEMANGEOT, 1965; DRAMIS et al., 1980; COLTORTI et al., 1980). After the degradation and/or complete elimination of vegetation, slopes were subject to intense erosional processes connected with the action of frost and snow. These processes resulted in the accumulation of important waste deposits, of which stratified slope-waste deposits, "grèzes litées" (GUILLIEN, 1951) or "éboulis ordonnés" (TRICART & CAILLEUX, 1967) assume particular interest for their widespread distribution and morphogenetic significance.

In the Umbria-Marche Apennines, these deposits are particularly widespread and connected with outcrops of limestone and marly limestone bedrock (CASTIGLIONI et al., 1979; COLTORTI et al., 1979). In this area, several generations of waste deposits have been recognised, separated by paleosols. Their chronology is based on stratigraphic relations with alluvial terraced deposits for which an age has been proposed based on radiometric, paleoethnologic and pedologic data (ALESSIO et al., 1979).

The deposits appear truncated and altered by forest soils, at the top of which ceramics and neo-eneolithical artifacts are present. They are also deeply dissected by linear erosion.

The deposits can be found on all exposures and at all altitudes ranging between 200 m and 2,000 m. They are often located at the base of escarpments which sometimes can be completely masked by the deposit itself, at the foot of rectified slopes or down-slope of ancient nivation hollows.

As regard the genesis of these deposits there is a agreement that frost shattering played a major role in the production of waste elements. However, various opinions have been expressed on the genetic factors and on the environmental significance of the deposits but no agreement has yet been reached (WASHBURN, 1979).

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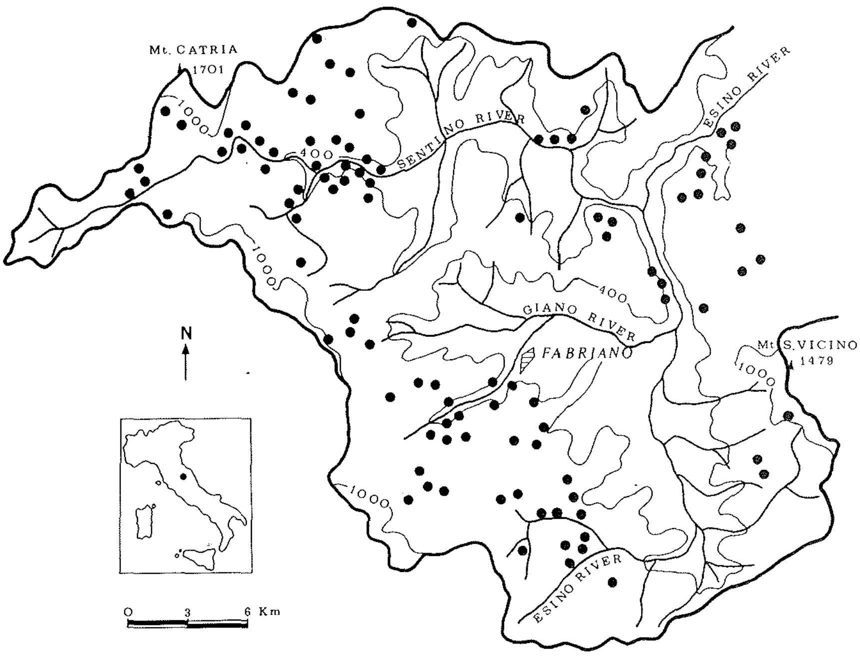

Fig. 1: Map of the area examined with location of stratified slope-waste deposits.

Abb. 1: Übersichtskarte des Arbeitsgebietes mit Lage der geschichteten Hangsedimente.

Within the framework of an investigation on the geomorphological evolution of Central Italy, a systematic study of stratified slope-waste deposits in the Umbria-Marche Apennine was conducted. More than a hundred localities were examined in an area (Esino River Basin, Fig. 1) characterised by relief rising to 1,700 m and by mainly calcareous bedrock. The overall tectonic setting is that of anticlines and synclines striking approximately NNW-SSE and cut by fault systems. The area was subjected to important uplift which produced strong dissection in the valley systems. The Quaternary tectonic activity is of the extentional type and some faults are probably active at present (CENTAMORE et al., 1980) as is suggested by the frequent occurrence of earthquakes in the area.

In order to identify the genetic mechanisms and environmental conditions which controlled the origin of the deposits data relating to the bedrock geology and the geomorphological, topographical and morphometrical setting were observed. In addition, samples were taken from each deposit in order to determine the main sedimentological characteristics by laboratory methods.

This paper aims to illustrate the preliminary results and to discuss the hypotheses suggested by the data.

THE STRATIFIED SLOPE-WASTE DEPOSITS IN THE ESINO RIVER BASIN

The deposits examined are situated on all exposures although they are found more frequently on slopes of southeastern orientation. They are located at altitudes from 200 m to 1,000 m (Fig. 2). The thickness of the deposits varies from a few metres to more than 20 m with maximum values on southeastern exposures. The beds dip between 10° and 38° but are most frequent between 20° and 30°. The parent rocks are mainly marly limestone (''Scaglia Rosata and Bianca'' of the Middle Eocene-Cenomanian) and micritic limestone (''Maiolica'' of the Titonian P. P.-Barremian).

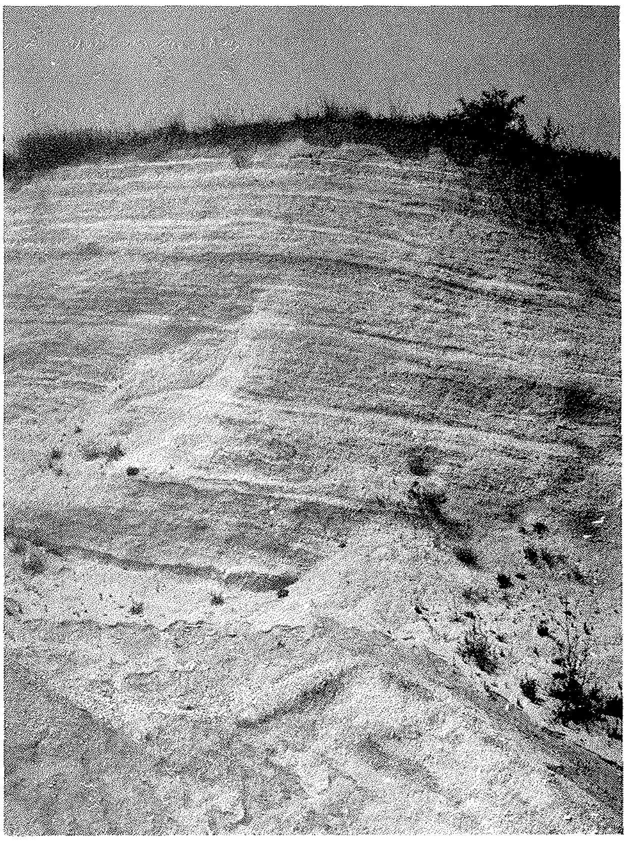

Fig. 2: Stratified slope-waste deposit at Castelletta in the eastern part of the basin.

Abb. 2: Geschichtete Hangsedimente bei Castelletta im Ostteil des Beckens.

Characteristics of the four types of sedimentary beds described by WASSON (1979) were recognised: type 1 (open-work) when the clasts are in contact with each other without or almost without matrix; type 2 (partially open-work), when some of the voids are filled by finer sediments; type 3 (clast supported), when all the voids are filled by finer sediments; type 4 (matrix supported), when the clasts are not in contact with each other and float within a finer matrix.

The thickness of the individual beds varies from a few centimetres to a few metres but more frequently is around 10 to 20 cm.

These different beds alternate with each other (Fig. 3). It was observed that alternations of type 1/2 and type 1/4 were more frequent although succession of type 1/2/3 or 1/2/4 were also noted. The sequence of type 1/2/3/4 is rare. In some cases the deposits consist only of type 2. Beds of type 3 are extremely rare.

The vertical transition from one level to another is often abrupt, corresponding in many cases to erosional surfaces. Sometimes, however, gradual transitions from type 1 to type 2 or from type 2 to type 4, passing through a thin type 3 bed, have been recorded. In some cases slopeward progressive transitions from open-work to partially open-work materials and vice-versa, or from partially open-work to matrix supported materials have been observed in a single bed.

Some deposits show a marked disorderly arrangement of the beds which are related to large scale mass

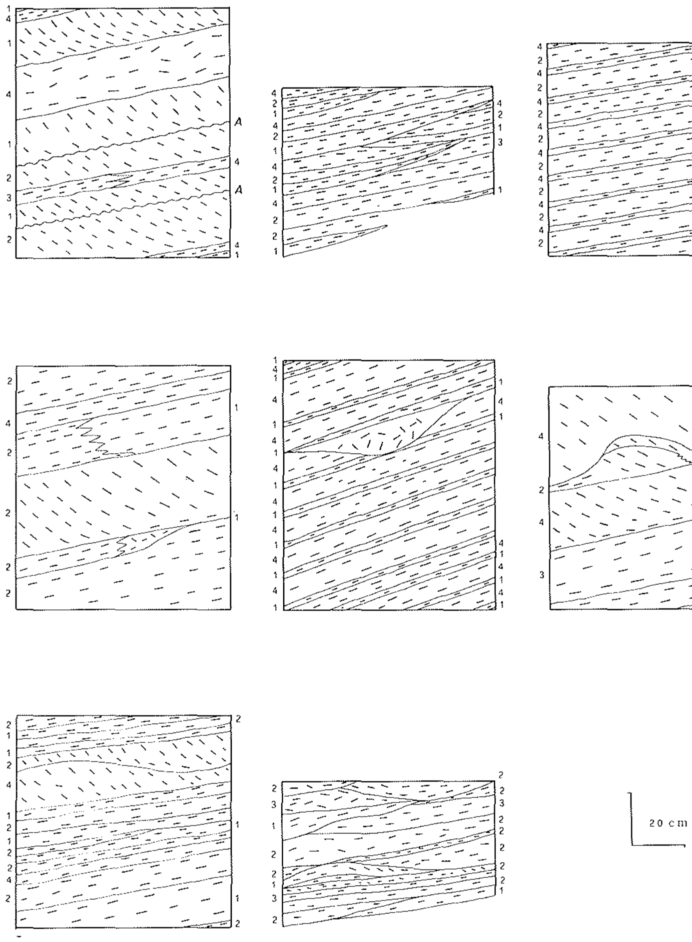

Fig. 3: Some representative sections of stratified slope-waste deposits in the Esino River Basin.

Abb. 3: Typische Aufschlüsse geschichteter Hangsedimente im Esino-Flußgebiet.

movements following the emplacement of the waste body. Sometimes these movements were contemporaneous to the deposition of the stratified materials which levelled out the irregularities of the slope. Possibly, these large scale mass movements are connected with earthquakes.

Generally, the lower borders of the open-work levels are regular and often correspond to erosional flat surfaces. In many cases, however, small depressions filled with open-work materials exist at the base which are interpreted as gullies. Laterally the type 1 beds are discontinuous and often pinch out. The top of these beds is either flat or weakly irregular. In some cases convexities have been observed.

The clasts in the open-work levels often show an isotropic arrangement. Frequently, however, beds have been observed with the particles crudely oriented downslope. The orientation of the clasts may vary within a single bed. Moreover, beds can be found where most of the waste has its long axis counterslope or showing imbrications.

The partially open-work beds are more continuous laterally. They contain alternating beds of various size. Analogous characteristics show clast supported beds.

The lower borders of the matrix supported beds are less regular. The particles are generally clearly arranged with the long axis parallel to the slope. In many cases, however, the particles turn gradually to the counterslope or show an ondulating trend, while the top of the beds outlines irregularities sometimes truncated by erosion or infilled by open-work or partially open-work materials.

The relative frequency of the different beds appears to be conditioned by the lithology of the clasts; open-work or partially open-work levels are more frequent in the deposits composed of micritic limestone and matrix supported beds are more frequent in the deposits composed of marly limestone (Tab. 1a).

From an analysis of the relationship between exposure and stratification characteristics one can observe that on northerly and easterly exposures (2), stratification appears sharper and more continuous, with thickness of individual beds greater than those observed on the southern and western slopes (3). A similar trend exists from less to more elevated deposits.

As regards the distribution of the four types of sedimentary beds it was noted that open-work and partially open-work beds are more frequent on slopes with a northern and eastern aspect and that matrix supported levels are less frequent (Tab. 1b). This distributional pattern has been found valid also for lithologically homogeneous deposits. A similar trend exists from lower to higher elevations.

A relationship also exists between the gradient of the layers and the distribution of the various bed types: matrix supported beds increase in frequency at higher slope angles; open-work beds seem to be more numerous both on lower (less than 20°) and higher (more than 30°) slope angles (Tab. 1d). The thickness of the stratified beds tends to increase as slope angle increases.

As regards the granulometric characteristics of the clasts, grain size analysis shows a clear prevalence in the 32 to 16 or 16 to 8 mm range for the open-work beds. In a few cases, clasts of dimension over 32 mm are encountered. The partially open-work and clast supported beds show maxima in the 16 to 8 mm range, and less frequency in the 8 to 4 mm range. The matrix supported beds show various grain size compositions, at times clearly bimodal and with abundant coarse elements. The average median values of the four beds are shown in Tab. 1c for any type of parent rocks. In Fig. 4 the histograms of the more characteristic size distributions for each bed are represented.

The dimensions of the particles do not appear clearly conditioned by lithology, even if, owing to the greater frequency of open-work beds, the deposits made of micritic limestone show a coarser texture. Usual-

	1	2	3	4
(A) Marly limestone	34%	39%	4%	23%
Micritic limestone	38%	44%	1%	17%
(B) SE to NW clockwise	33%	31%	2%	33%
NW to SE clockwise	34%	46%	5%	15%
(C) <20°	43%	35%	5%	17%
20°—30°	33%	34%	7%	26%
>30°	38%	30%	2%	30%
(D) Marly limestone	11.5 mm	6.3 mm	4.8 mm	4.5 mm
Micritic limestone	11.3 mm	6.8 mm	5.2 mm	5.2 mm

Tab. 1: Per cent distribution of the four types of beds: (A) inside the deposits made of marly and micritic limestone, (B) in relation to slope aspect, (C) in relation to gradient, and (D) average values of the particle median size inside the deposits made of marly and micritic limestone.

Tab. 1: Prozentualer Anteil der vier verschiedenen Ablagerungstypen: (A) in mergeligen und mikritischen Kalken, (B) in Abhängigkeit von der Exposition, (C) in Abhängigkeit vom Gefälle und (D) Mittelwerte für den Korngrößenmedian in mergeligen und kalkigen Ablagerungen.

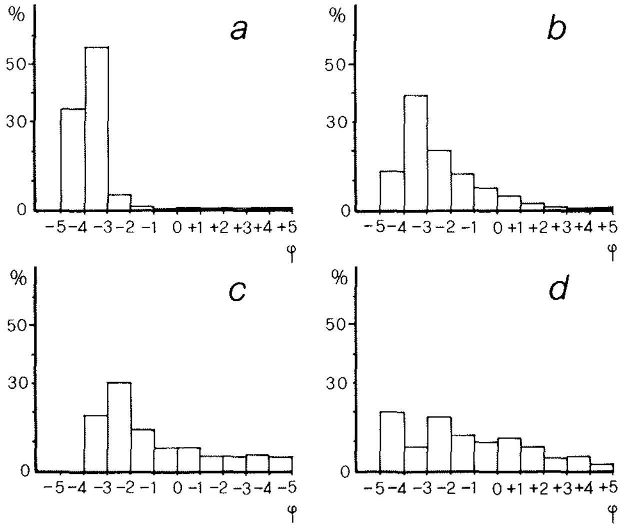

Fig. 4: Standard histograms of grain size for the various beds: a) open-work, b) partially open-work, c) clast-supported, d) matrix-supported.

Abb. 4: Standard-Korngrößen Histogramme verschiedener Ablagerungen: a) matrixfrei, b) teilweise matrixfrei, (c) überwiegend klastisch, d) überwiegend Matrix.

ly, the dimensions of the clasts are relatively constant within the various beds, even if a gradual reduction in mean size is sometimes noted downslope.

Invariably the clasts have sharp edges with obvious frostshattering cupules on their surface; only in the most distal part of the deposits are slightly rounded elements noted. A relationship between the median values of the particle size and the aspect and altitude of the deposits is evident. Considering beds of the same lithology and type, values are higher on the northern and eastern exposures and at lower elevations, due possibly to a greater importance of frost-shattering connected with more frequent freeze-thaw cycles.

No clear relationship between slope angle and average clast size exists. This implies the importance of genetic agents different from gravity.

The median values of the Cailleux flatness index appear to be strongly conditioned by the lithological nature of the clasts. Values are lower for elements made of micritic limestone (marly limestone: 3,31; micritic limestone: 2,80). Significant differences between the flatness index values of clasts in the various types of beds are not evident. A clear relationship also exists between flatness index and aspect of the deposits: considering elements with the same lithological characteristics, the flatness values correspond highly with the southern and western expositions (marly limestone: 3,51, southern and western exposures; 3,19, northern and eastern exposures). This could be related, as for particle size, to more frequent frost-shattering. However, it is probable that other factors are important as is demonstrated by the decrease of flatness as altitude increases (marly limestone, above 700 m: 3,31; below 700 m: 3,27).

DISCUSSION

The structural and textural characteristics of the stratified deposits and their relationship with the different topographic situations allow expression of an hypothesis regarding the depositional mechanisms of the layers and their environmental significance.

The absence of matrix and the sharp surfaces of unconformity, sometimes clear, which generally marks the base of open-work beds, sometimes with traces of canalization, and the disposition of the clasts seem to indicate the action of slopewash on bare slopes. The frequent orientation of the particles with their long axis parallel to the slope may derive from the action of running water (RAYNAL, 1970) and also produce the local imbrication observed in some cases.

The downward disposition of the clasts suggests frostcreep action (ALBJÄR et al., 1979).

When single beds of isoriented debris tilt progressively counter to the slope it may be due to slide movements involving the whole stratified beds. In such cases the slide surfaces may be situated at the base of the bed or in the underlying layer which is of the matrix-supported type. The more abundant open-work materials, often with isotropic fabric, which are present in the beds dipping more than 30° might be ascribed mostly to gravity processes such as single particle fall or debris flow (WASSON, 1979). The importance of gravity processes can be demonstrated by the greater thicknesses of beds of steeper angle.

The inferred importance of slopewash action on bare slopes may be connected with the melting of long-lasting snowbanks. The greater frequency of open-work levels on the northern and eastern expositions and at higher elevations, where probably snowbanks were more widespread and persistent, supports this hypothesis. On the other hand, there is a frequent association between stratified deposits and nivation hollows.

The fabric of matrix supported beds, with clasts immersed in a mass of finer materials and arranged in most cases with their long axes parallel to the slope, suggests a mechanism of laminar solifluction (WASSON, 1979; HARRIS, 1981). The fluidal structures identified from preliminary micromorphological observations confirm the action of plastic movements.

The origin of the matrix is problematic even though some authors have recorded weathered materials inherited from the erosion of soils in the finer components of stratified slope-waste deposits (VAN BREDERODE et al., 1980; KARTE, 1982). Thin layers of poorly developed soils, parallel to the stratified beds, are often present. This sustains the above-mentioned origin of the matrix materials. Moreover, preliminary X-ray analysis indicates a discrete amount of smectites in the finer components which testify to their pedogenetic origin.

The environment which led to the formation of these beds is substantially different from the one which conditioned the formation of open-work beds. The probable origin of the finer material and the presence of soils suggest milder conditions and the presence of a vegetational cover. The greater frequency of these beds on southern and eastern expositions and at lower elevations supports this hypothesis.

Partially open-work levels have been referred either to the washing away of matrix materials (GUILLIEN, 1951; RAYNAL, 1970) or to the infilling of pre-existing open-work levels by finer materials brought from upslope by running water (WASSON, 1979). The progressive vertical transition observed in some cases from open-work to partially open-work beds and from partially open-work to matrix supported beds with the intercalation of thin clast supported beds might support the latter hypothesis. The alternation of different types of beds inside the deposits may be connected with climatic variations over relatively long periods, as suggested by GUILLIEN (1964).

CONCLUSIONS

The occurrence of stratified slopewaste deposits is a very complex phenomenon. In many cases, it is wrong to refer to a simple genetic agent. It is evident that, within the deposits, vertical and lateral variations in structure and texture exist, testifying how the genetic conditions varied both in space and time.

The alternation of open-work beds, that may have originated in periods of cold climate on bare slopes with long-lasting snow cover, and matrix supported beds, that may have originated during periods of milder climate, lead one to recognize cyclic sequences in these deposits. These sequences are linked to climatic variations over relatively long periods in an environment substantially colder than the present.

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