

ARID PROCESSES IN THE SE-BRAZILIAN RELIEF EVOLUTION DURING THE LAST GLACIAL

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ABSTRACT

The general index-plain "Sulamericana" can be found in vast areas of SE-Brazil. It is mainly conserved with the help of a duricrust and covered by laterite. The next younger element of relief-evolution, a level 40 to 60 m below the Sulamericana, is completely different: the weathered rock is covered by a stoneline and a fine-textured sediment.

This structure was examined with the help of granulometry, analyses of heavy minerals, thermoluminescence datings, pollen analyses and ^{14}C -datings.

Different conditions for the development of stonelines may occur according to the climatic conditions at the time of their origin; in this case it must be assumed that the stonelines were formed by slope-wash due to episodic precipitation under the condition of nearly complete absence of vegetation (geologic or climatic reasons). They are a clear post-Sulamericana development.

A fine-textured sediment was deposited on top of the stonelines. The material of the fine-textured sediment was, according to the then prevailing conditions, transported by as well slope-wash as eolian processes; especially for the "demi-oranges" we must assume eolian transport. The material was probably derived partly from the local material which covers the remnants of the Sulamericana, but may be seen as an eolian sediment transported for long distances as well.

The time of the deposition of the fine-textured sediment on the stonelines coincides with the climax of the last Glacial; the ^{14}C -dating indicates 19,700 years B.P., the thermoluminescence-dating about 20,000 years B.P.. The climatic conditions were probably semi-arid.

These results are supported by the findings of other researches of the Southamerican

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climate during the last Glacial.

STRUCTURE OF THE AREA OF WORK

The area of work is situated east of Belo Horizonte (on the eastern margin of the Quadrilátero Ferrífero), Minas Gerais, Brazil. It presents a typical structure which can be found all over SE-Brazil.

The dominating element are remnants of the great index-plain "Sulamericana", partly conserved in larger patches with the help of Canga (massive Fe-crust). Some remnants of the Sulamericana canga in the area of work cover fluvial and lacustrine sediments of Pliocene age (DOLIANITI, quoted in MAXWELL, 1972). Other remnants of the Sulamericana form crystalline watersheds covered by a duricrust.

The generally acknowledged characteristic of the Sulamericana is a duricrust (concentration of Fe and Al), which is found either as a primary (couraça) or a secondary (carapaça) formation.

Usually the duricrusts of the Sulamericana are overlain by a laterite-cover. The duricrusts were formed at the ground-water level (cf. KLAMMER, 1963). As the duricrusts in some places are very massive we must assume an originally very massive laterite-cover.

The next younger element of the modern relief is a level 40-60 m below the Sulamericana, which is completely different.

Partly it is connected with the remnants of the Sulamericana with a steep slope, partly it consists of isolated hills, the so-called "demi-oranges" (meia laranjas). This level, including the demi-oranges, has got no duricrust, but is covered by a stoneline which finishes slightly above the modern river level. The stoneline in turn is covered by a fine-textured material.

The modern river level lies about 40-80 m below the level in question.

This general situation can be seen on Figure 1, a typical cross - section on Figure 2. Figures 3 and 4 sum up the important details.

In the headwater areas of the whole region at the foot of the hills we find buried layers of a sort of peat whose composition of pollen was examined.

The river terraces in the mountain areas can be correlated to this set of relief-levels.

The climatic implications of this situation are the topic of this paper.

METHODS OF WORK

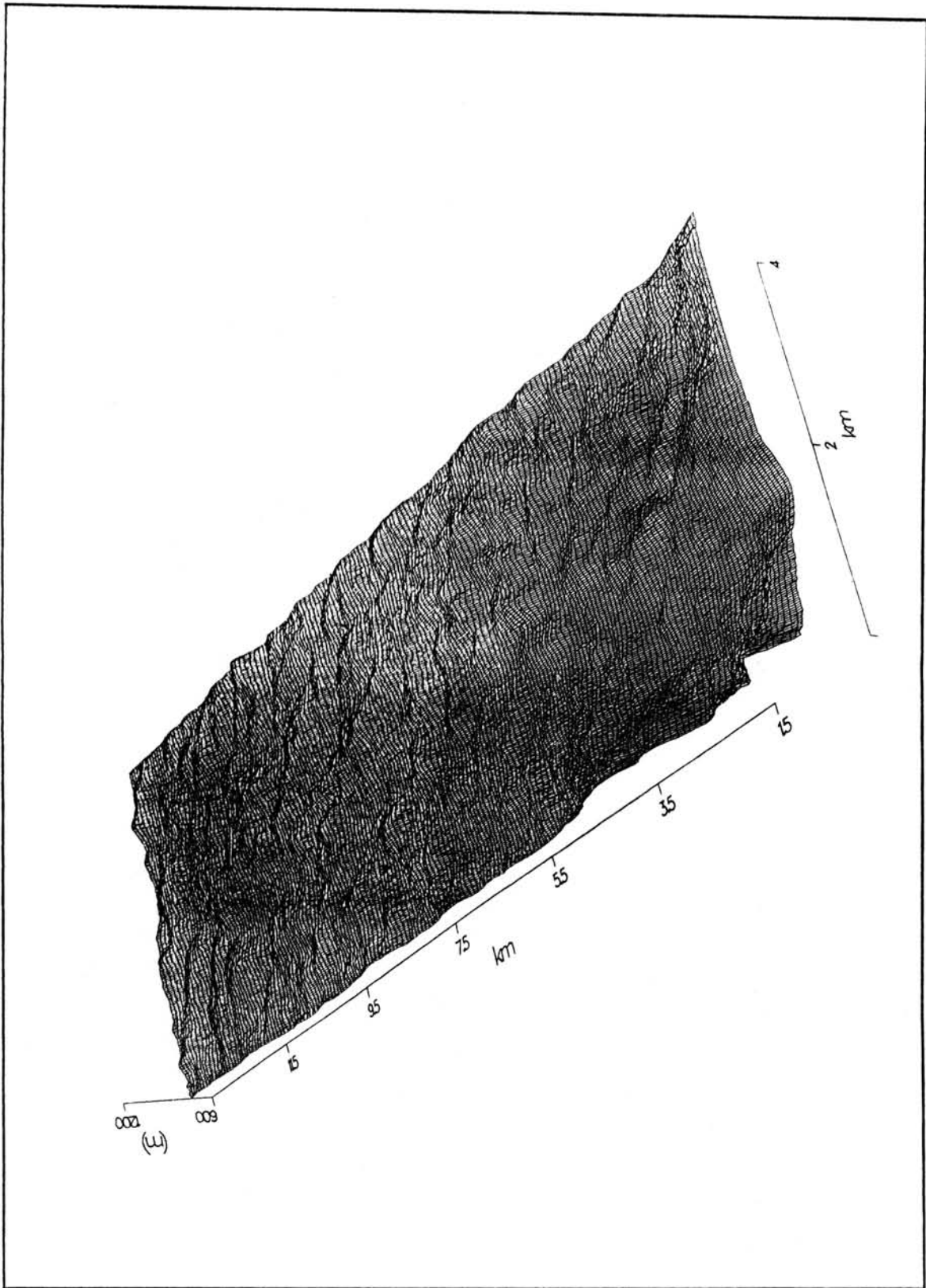


Figure 1 - Computer graphic showing the general situation of a demi-orange landscape: this example is from the area East of the Serra do Caraça. On the southern margin a part of a larger patch of the Sulamericana can be seen.

Typified cross-section of the Post-Sulamericana - landscape

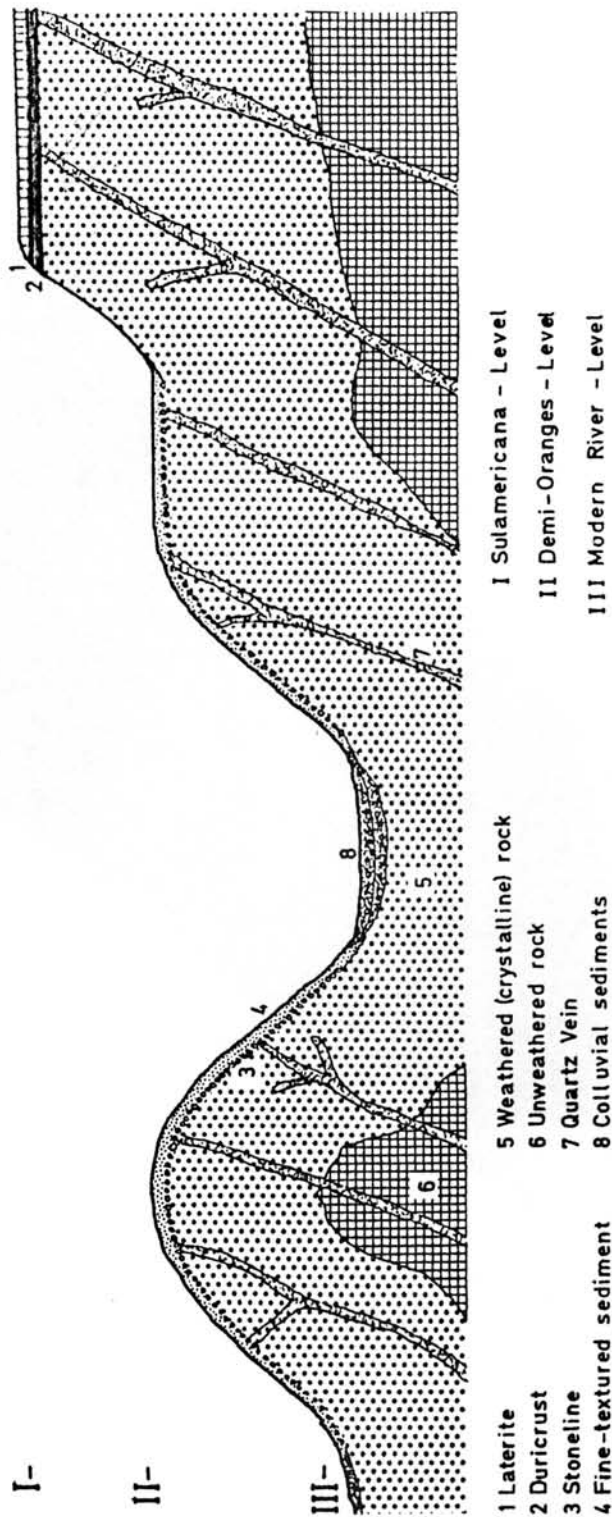


Figure 2 - Typified cross-section of the sequence of Sulamericana - Demi-Orange-Level - Modern River-Level.

name	characteristic
1. Sulamericana-level 40 - 60 a below	- duricrust, canga - laterite-cover
2. Demi-orange - level 40 - 80 a below	- stoneline - fine-textured material
3. Modern river-level	- peats in headwater-areas

Figure 3 - Different Levels of Landscape-evolution

form	age	climate	process
1. stoneline (only on demi-orange - level)	older than 20,000 yrs B.P.	arid	distribution by slope-wash
2. fine-textured sediment (on top of stoneline)	20,000 yrs B.P.	semiarid	sedimentation (eolian/slope wash)
3. peat in modern river-level (headwater area)	19,700 yrs B.P. (and younger)	semiarid	deposition of pollen and fine-grained sediments

Notes:

- a) The river terraces in the mountain areas can be correlated to this set of relief-levels.
- b) The climatic implications of this situation are the topic of this paper.

Figure 4 - Details of the "demi-orange" (meia laranja) level.

Two slope sequences from the Sulamericana top to the modern river level bottom were examined. Moreover, samples from the Sulamericana level, from the "demi-oranges" level and from the modern river level were collected and, according to the requirements of each, examined with the help of granulometry, the analyses of heavy minerals, thermoluminescence, pollen, and ^{14}C -datings.

RESULTS

The composition of pollen of the peats in the headwater areas (the main part of the pollen consists of graminea and the peat contains obviously wind-transported material) points to a rather semi-arid climate with periodic precipitation at the time of the peat-formation, which supported just a thin grass vegetation and probably a higher gallery-vegetation along the course of the river. These peats occur only along a stretch of up to 150 m in the headwater areas, in which the environment for the conservation of pollen was facilitated. They show the old river level which nowadays lies 1-2 m below the peat.

The peats in the headwater areas were found on a large scale, and they also occur in other regions of SE-Brazil.

The ^{14}C -dating of the peat in the area of work gives an age $19,700 \pm 185$ years B.P., which points to the climax of the last Glacial.

Thermoluminescence measures the time which has passed since a sediment was exposed to daylight for the last time. As the best conditions for this exposure of material to daylight are found during eolian transport, the existence of reactions to the process of thermoluminescence datings in sediments is a strong indicator for eolian transport and deposition.

The thermoluminescence dating of fine-textured material from the top of a "demi-orange" (just above the stoneline) gives an age of $20,000 \pm 2,400$ years B.P..

The composition of the heavy minerals was analysed as well. The results show in general an image of crystalline minerals in various degrees of alteration. Near the borderlines to different geologic formations whose positions are above this relief level these geologic formations sometimes influence the composition of heavy minerals. This fact rather indicates slope-wash.

CONCLUSIONS

The origin of stonelines in soil profiles is a lovely topic for an extremely controversial discussion.

Two main lines of interpretation are discussed:

1. The interpretation of a depositional origin of the stonelines and the subsequent sedimentation of the material above them is generally connected with the assumption of semi-arid climatic conditions (cf. BIGARELLA & BECKER, 1975; BIBUS, 1983, 1984; STOCKING, 1978, and others). Especially BIBUS (1984, p.1433) points out the similarity of escarpment slopes with the stoneline-structure to those found in modern semi-arid and arid zones. I myself have observed the formation of modern depositional stonelines in mountainous areas on the surface under the conditions of the present climate of a clear rainy season and a drier season decomposed quartzite sands. In those areas of modern stoneline-formation we find a nearly complete lack of vegetation due to geologic reasons.

2. The autochthonist "in situ" concentration of the stonelines explained quite clearly by LECOMTE (1988) as the result of a downward migration of coarse fragments in a water impregnated layer, thus representing an impregnation front. He stresses the fact that this kind of stoneline is formed under wet tropical conditions.

I think that STOCKING (1978) arrives at a very true viewpoint to objectify the discussion when he says (p. 121), "A retort to these many hypotheses is that perhaps stonelines suffer from "geomorphological equifinality", that is, no single hypothesis will provide an universal explanation and apparently similar stonelines may be formed as a result of different combinations of environmental circumstance".

Perhaps it is really not possible to find one general solution for the origin of all the stoneline-profiles. We may have different processes which in the end lead to results of similar appearance.

Keeping in mind the different climatic conditions in the background of these hypotheses we should try to define the paleoclimatic conditions during the time of the formation of the stoneline-profiles.

So let's have a look at the paleoclimatic evidence of the area of work. Especially the pollen-composition of the peats in the headwater-areas indicates a rather semi-arid climate during the maximum of the last glacial. In addition to this the existence of reactions to the process of thermoluminescence forms yet another proof for a drier climate at that time.

The results confirm the generally accepted concept that the last phases of relief development are due to climatic changes (cf. BIGARELLA & BECKER, 1975; BIBUS, 1983; OCHSENIUS, 1983, etc.).

BIBUS (1984) identifies several recent climatic changes and their respective effects on the formation of the modern relief in SE and Central Brazil. Especially relating to an arid climate he points out that "based on the morphological findings one can assume that during the Late Pleistocene a drier activity phase affected extensively vast areas of Brazil" (p. 1437). According to his results the megafauna points to an arid climate during the Late Pleistocene from about 10,000 to 18,000 years B.C. (12,000 to 20,000 years B.P.).

OCHSENIUS (1983) points out that the Northernmost South America experienced

predominantly arid climates during and after the last Glacial (along the whole Holocene); in addition to this we should keep in mind that the sea level at the time of the last maximum Glacial is supposed to have rested some 60 to 130 m below the present sea level, which also reduces the general supply of water for the whole continent of South America at that period.

The thermoluminescence datings as well as the ^{14}C -datings fit well into this picture.

These facts indicate that in the area of work the depositional form of stonelines occurs. We can assume that the development of the stoneline in this area of work is the result of a distribution of pebbles by slope-wash under the condition of nearly complete absence of vegetation; the pebbles are provided by quartz veins which are contained in the crystalline rocks, in other cases they may consist of remnants of other alteration-resistant rocks. The absence of vegetation may be due to climatic or geologic factors (cf. BIGARELLA & BECKER, 1975 and LICHTER, 1980). In the area of work whose main part is formed by now thoroughly weathered crystalline rocks the impression arises that the pebbles were distributed on the at that time still unweathered rock of kind of Bornhardt-landscape. It must be kept in mind that stonelines do not exist on remnants of the Sulamericana, they are a distinct characteristic of a post-Sulamericana development.

The stoneline is covered by a fine-textured material.

Now arises the next difficulty: how can we explain the origin of this material above the stoneline?

Again we come across a highly controversial point of discussion.

In those parts of the relief which are connected with remnants of the Sulamericana the process of sedimentation can be explained quite easily: parts of the lateritic cover were transported and sedimented by slope-wash.

The difficulty lies in the explanation of the sediment cover of the isolated hills, the "demi-orange" (cf. Fig. 2).

In my opinion there can't be a monocausal explanation of the origin of the sedimentary cover. We must assume that several processes, the slope-wash in the case of periodic precipitation as well as the eolian transport in the more arid phases, took part in the construction of the fine-textured sediment on top of the stonelines.

The mineralogical composition shows that this material contains local elements as well as elements which can't have originated from this area (cf. LICHTER, 1980).

As such a lot of material was transported, both means of transport require the condition of scarce and scattered vegetation; reason for this can only be semi-arid climatic conditions, as unweathered rock, which usually bars vegetation as well, can't provide those masses of material.

One possible area of origin of the transported material may have been the lateritic cover on top of the Sulamericana. In this case parts of it were eroded, transported and sedimented by slope-wash

and eolian processes on the next younger level of relief; on top of the "demi-oranges", however, eolian transport and accumulation seems to be only logical explanation.

The conditions also allow the interpretation of the material as an eolian sediment transported for long distances, such as we know it from the Chinese loess-areas.

It is also well known that e.g. dust and even fine sand from the African Sahara are blown well into Europe; in the Alps you tend to find these deposits nowadays fairly often, and they even arrive occasionally in Scandinavia, which means a transport for more than 3,000 km.

These transport don't run in the surface-winds of the planetary circulation, but in the elevated wind-zones in the atmosphere; thus long distances can be covered contrasting the wind-directions influencing the surface of the Earth.

Wind-transported sediments of this kind are deposited on areas with at least scarce grass-vegetation which is able retain the sediments, while they are blown away from fresh rock or other areas free of vegetation which have no means of keeping them.

The relief above the Sulamericana in the area of work was not affected by this phase of sedimentation, though it may have provided additional material for sedimentation in the lower parts of the area.

MÖRNER (1989, and discussion in São Paulo, 1989) suggest that loess-like sediments of this kind may well be a result of the Andean Glaciations, which were described e.g. by CLAPPERTON (1989). Mörner found old loess-like sediments in Patagonia and stresses the possibility of a similar development in the area of work subsequent tropical alteration.

We have got a comparatively high portion of clay (28 - 40%) in these sediments which seems to contradict the idea of eolian transport: the European loess contains in general 15 - 20% clay, and its maximum grain-size consists of silt. This is, as DUCKER (1937) showed, a result of periglacial climatic conditions, as mechanical weathering by frost doesn't provide particle-sizes below 0.020 mm (silt).

The transported material in the area of work, however, originates from an area which was not subjected to mechanical weathering by frost. We must assume therefore an originally much smaller grain-size.

As can be seen by the Sahara-dusts distributed all over Europe wind-transported material is not necessarily silt-sized but may consist of smaller grain-sizes as well.

Therefore I don't really like the term "loess-like" sediments which is connected too strongly with the concept of European loess-development, but prefer the "eolian sediments".

The subsequent change towards a more humid climate led to a fast alteration of the crystalline rocks as well as the sediments on top of the stoneline, and local elements have entered into soils that developed.

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