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SOME REFLECTIONS ON THE ORIGIN AND LAND USE OF PEDIMENTS ON ETHIOPIAN HIGHLANDS

Abstract: BERAKHI O. & BRANCACCIO L., *Some reflections on the origin and land use of pediments on Ethiopians Highlands.* (IT ISSN 0391-9838, 1993).

Pediments seem to be widespread on the Ethiopian highlands. They form smooth transition between the steeper mountain or hill front and the flat surfaces downslope. The piedmont angle, characteristic of pediments elsewhere (arid and semi arid zones) is, here, absent. This form is not due to the original structural surface formed by the aggradation of the pyroclastic materials at the foot of the volcanic hills or mountains, since pediments also occur at the base of horizontally bedded remnant hills of Trap series lavas and sedimentary rocks. Where they are formed at the foot of volcanic hills, they do not correspond to the much steeper original bedding of the pyroclastic deposits. They are cut in rock (lava, pyroclastic, sedimentary) and are covered by a thin veneer of soil and colluvium.

The relative absence of linear erosion and the smooth, grading of the slope (both upward and down to the present day valley bottoms or flat plains) suggest that the modelling of many of these pediments is either very recent or belongs to the present-day processes (mainly sheet flow). These surfaces mainly act as transport slope for the finer particles (soil and pyroclastics) brought from upslope.

The sheet flow along the pediments is frequently changed into channelled flow because of the presence of roads collecting water of the slope. Gullies are forming in the basal part of pediments, whose maximum depth is close to the base of the bridge, where discharge is concentrated. Downslope, the depth decreases, until finally the gullies disappear.

KEY WORDS: Pediments, Ethiopia.

Riassunto: BERAKHI O. & BRANCACCIO L., *Alcune riflessioni sull'origine e l'uso del suolo dei pediments dell'Altopiano Etiopico.* (IT ISSN 0391-9838, 1993).

I pediments sono largamente diffusi sull'altopiano etiopico dove costituiscono forme di transizione tra i rilievi isolati di diversa natura geologica e la piatta superficie dell'altopiano spesso occupata da paludi effimere. Laddove i rilievi sono costituiti da vulcani queste forme possono essere confuse con piedimonti vulcanici di tipo aggradazionale; tuttavia, in alcune sezioni naturali appare chiaro che i pediments tagliano nettamente le successioni laviche o vulcanoclastiche.

I pediments si caratterizzano per l'assenza di incisioni lineari. Tuttavia quando essi sono attraversati da strade, si rileva frequentemente a valle della strada la formazione di alcune vallecole la cui profondità diminuisce verso la piana. Queste incisioni sono legate alla variazione del regime di deflusso dell'acqua superficiale, da *sheet* a concentrato determinato dalla presenza delle strade. Non tutte le incisioni che solcano i pediments sono di questo tipo, in quanto l'erosione da parte delle acque correnti può essere innescata da altre cause (variazione del livello di base, deforestazione, ecc.).

TERMINI CHIAVE: Pediments, Etiopia.

1. INTRODUCTION

One of the main physiographic characteristics of the Ethiopian highlands is the presence of hills and mountains rising from the flat-topped plateau, which is generally at about 2 000 m a.s.l. These features are mainly of volcanic origin (central volcanoes made up of trachytes and rhyolites of Mio-Pliocene age). Most of the highland plane surface, on the other hand, corresponds either to the top of the original horizontal Trap series (basalts of Tertiary age) or to the erosional surface parallel to this. The Addis Ababa region, in particular, lies on the edge of the plateau, where the western escarpment, here, is «physiographically less defined» (MOHR, 1961). Close to the edge of the Rift valley a number of younger and relatively better preserved hills made up of Quaternary pyroclastics successions dot the sorrounding, where as the flat surfaces are associated with the Quaternary lacustrine deposits (TAIEB, 1974).

The contact between the two morphological units (hills or mountains and highland planes) is generally not marked by a sharp break of slope, but by an inclined surface (mostly 1-3 degrees). These basal slopes are similar to pediments, because of their geometry and their position with respect to other elements of relief. They have a planar inclined surface and are located between the steeper slopes of the mountain front and the flat surface of the highland. A brief description of the possible origin, recent evolution and land use of these gentle surface is the objective of these paper.

2. THE ORIGIN OF PEDIMENTS

The classical works on the origin of pediments (TWIDALE, 1968) ascribe their sculpture to arid and especially semi-arid climates with infrequent but strong rainy events, even though some autors (especially, L. KING) considered

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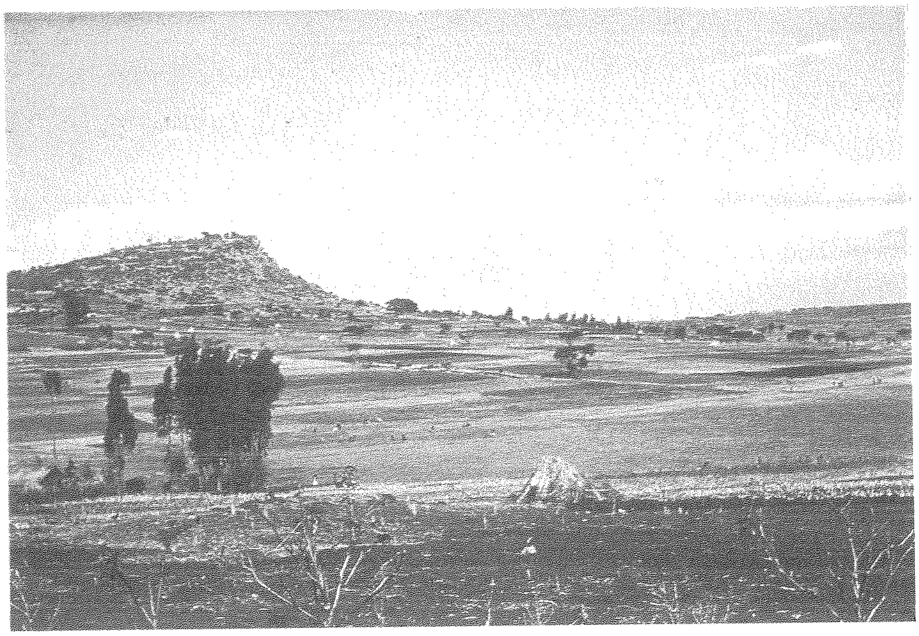

FIG. 1 - A pediment near the town of Lange (Hararghe).

that all plains moulded by running water are of this type. There is no doubt, however, that these forms, very diffused within semi-arid and arid regions, are more or less absent in middle-latitude temperate regions.

This is not the place for a complete review of the very aboundant literature on pediments. Here, only a brief recall of some of the ideas on their genesis will be made.

The most important process moulding the pediment slope seem to be sheet flood. This process was in detail observed and descriped by McGEE (1897). More recently, TWIDALE (1968) noted that many workers now consider that complex of processes-weathering, rills wash, sheet wash and sheet flow responsible for the moulding of pediments. However it is clear that the running water has an essential role. Just like the longitudinal profiles of streams, the pediments have concave upward profiles (EARNER, 1974), strongly indicating that running water is the dominant agent responsible for fashioning them (KING, 1968).

Because of its position, being in between an erosional mountainous area and a depositional basin, the pediment assumes the function of a transport slope. Here, the running water has just enough energy, free, to transport the debris but not to incise. It is obvious that, on such gentle slope (not more than 7 degrees) and with this type of flow (mainly sheet) the grain size of the particles transported has to be low.

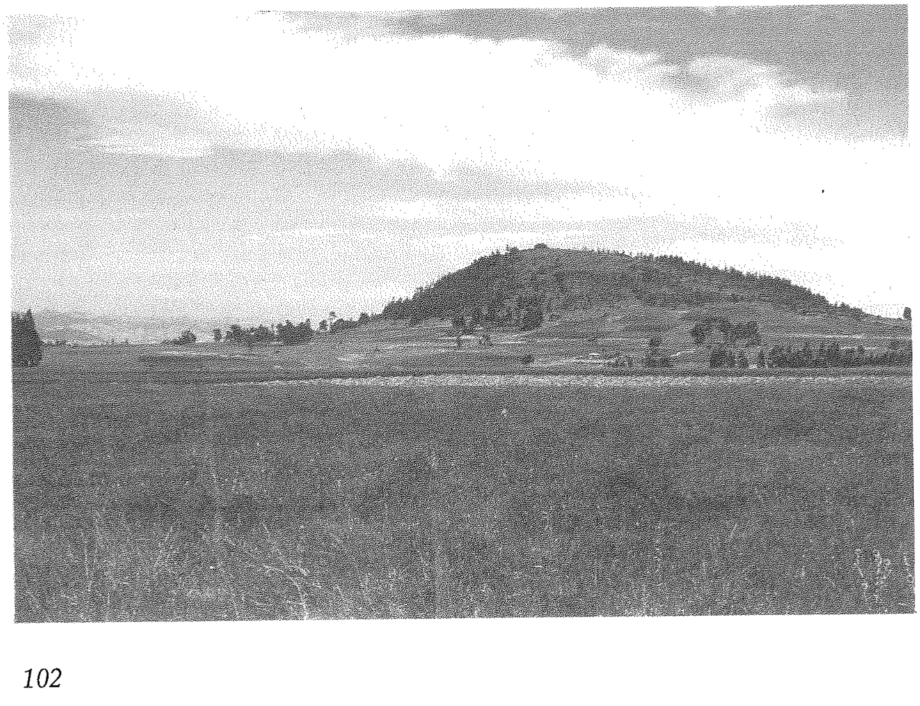

FIG. 2 - This pediment has been formed at the base of horizontally bedded remnant hill (near Ambo). Note the basal concavity and the absence of a piedmont angle.

Pediments are commonly veneered with rocks waste in transit and deposited during the waning stage of floods. Beneath the waste mantle, the bedrock is often smoothly carved, showing that they are truly cutrock land features.

3. THE PEDIMENTS OF THE ETHIOPIAN HIGHLANDS

Two question can be raised on the origin of pediments on Ethiopian highlands: 1) do these surfaces correspond to the primary pyroclastic aggradational slope at the foot of volcanic hills and mountains? 2) are these pediments in equilibrium with present geomorphic system or are they relict forms of paste climates? These are briefly discussed below.

3.1. *Pediments or volcanic Piedmonts?*

One of the characteristics of pediments in Ethiopian highlands is the absence of the so called piedmont angle. They are usually graded down slope to the seasonally marshy aggradational area, while upward, their angle of inclination gradually increases and merges to the hillslope, giving a concave upward profile, without a break in slope. This form makes these basal slopes to be very similar to the original (aggradational or constructional) volcanic piedmont. The doubt is further reinforced because of the existence of volcanic hills and mountains (shield volcanoes or other minor volcanic cones) rising from the highland plains. However, it has been observed in many cases, that this morphological convergence is either absent or not evident.

Besides, we have seen many pediments bordering hills of different geological origin. In many places, on the Harerge Highlands such basal slopes are found at the base of residual hills made by mesozoic sedimentary cover (fig. 1). Similar features were also observed in Bale Highlands, along the Robe-Sofomar-Gasera road and near the town of Ambo, about 120 Kms West of Addis Ababa (fig. 2), where the pediments occurr at the foot of remnant hills of horizontally bedded Trap series lava. In all of these cases, the topographic surfaces do not correspond to the structure (hence no structural control).

On the other hand, many recent volcanic hills, in the sorroundings of Addis Ababa show their pyroclastic beds cut by the pediment surface. Such is the case of a small hill, close to Akaki town along the Addis Ababa-Debrezeit road (fig. 3), where deep quarries have exposed the bedrock face. Here, the surface of the pediment is cut in red coloured pyroclastic beds dipping down slope (fig. 4) 18-20 degrees steeper than the topographic surface.

Similar relationship, between pediments and the geological setting, is also observed in a nearby quarry, where the loose product of a scoriaceous cone are actively (but often not correctly) exploited. On the vertical cliffs of the quarry, the bedding is clearly exposed revealing the primary pyroclastic aggradational slope much more inclined than the pediment surface.

Near Alem Gena, about 20 Kms South West of Addis Ababa, on the Butajira road, a pediment is formed on hard rock. Here, at the foot of Mount Furi, a volcanic mountain, the pediment is cut in a solid lava of tertiary age.

To sum up, there are quite some evidences that suggest for the widespread existence of pediments on Ethiopian highlands. They are cut either in soft or hard rocks. Obviously, the presence of gentle slopes of volcanic aggradational surfaces (volcanic piedmonts), resembling erosional pediments cannot be excluded. They do occur at the base of the very recent volcanic cones.

FIG. 3 - Basal slope of a volcanic hill, gradually grading into the plain in the foreground, near the town of Akaki.

FIG. 4 - Part of pediment surfaces cut in much steeper pyroclastic beds. Quarry near Akaki.

3.2. *Present form or relics?*

The other problem is the age of the pediments. Are these pediments in equilibrium with the present geomorphic system or are they morphoclimatic relics?

The pediments, generally, seem to be part of the most recent elements in the landscape of the highlands. They are not dissected very much; they are graded to present valley bottoms or the flat plains, without any break of slope (either in the lower or upper part). All these morphological events suggest that the modelling of the pediments is either very recent or belong to the present day processes.

In few other places, as in western base of Mount Wachacha, a Lower Pliocene volcanic mountain, close to Addis Ababa, some terraced pediments have been observed, suggesting that these are relics of past geological time. A detailed survey will, however, have to be made in the future to help us reconstruct the morphoevolutional sequences in which the repeated phases of pediment formation can be framed.

At the present we can say that, on some of the pediments of the Ethiopian highlands, the same processes that moulded them (i.e. sheet wash) are still working, as testified by the absence of linear dissection. In general, these forms (cut in lava, pyroclastic or sedimentary rocks), are covered by a thin veneer of soil or colluvial materials. In our opinion, the materials moving along them are mostly represented by fine-grained ones coming from the weathering products of the retreating slope.

In some cases, it can also be the fine pyroclastic grains mechanically derived (eroded) from the steeper upper slopes. The present forms of these pediments and the processes (mainly sheet wash, as indicated by the absence of linear dissection) may probably suggest a catchment area devoid of vegetation cover due to climatic changes and more recently to human interference which favours debris production. This in turn leaves the running water with energy, just enaugh to transport debris (by sheet wash) on the surface and not to do vertical incision. Such surficial processes (sheet flow) could also be favoured by the rainy clima (an annual total of more than 1200 mm, around Addis Ababa), most of which is concentrated in a short rainy season (June, July and August).

4. PEDIMENTS AND LAND USE

The pediments are largely used for different human activities. Because of the suitable topography, excellent drainage (they are always out of reach of marsh), and thick soil and colluvial cover, they have been used for agriculture and settlement. To avoid the marshy areas downslope and the steep mountains front, roads are often built across the pediments. All these human practices seem to have an effect on the geomorphic dynamics acting on the slopes.

The foot paths and animal tracks that criss-cross the pediments, the drainage furrows, cut by farmers and absenced widespred conservation measures have facilitated the development of linear erosion. The most spectacular of these are the gullies, whose growth seem to be strongly associated with the construction of roads accross the pediments (following the contour). Some of these are described below.

Few kilometers from Addis Ababa, along the Jimma road (just before Alem Gena), one sees a dissected pediment. The gullies cutting it present some particularities, they are deeper and more widespread on the lower side of the road and are either absent or not much developed on the upper side (fig. 5).

Similar conditions are evident accross many roads that pass trough pediments. The road linking Nazareth and

FIG. 5 - Gully being formed just below the road. On the background (i.e. upperside of the road) the pediment is little or not affected by such erosional features.

Wolenchiti can be taken as another example. Here, 5 Km out of Nazareth, the gullies below the road (bridge) are 6 to 8 meters deep, while on the upper side, they are very shallow.

A detailed survey of the gullies shows that their depth decrease from the base of the road or the bridge downward towards the aggradational basin. The maximum depth is, therefore, close to the bridge (or outlet); and as shown from the sills recently constructed to protect the road or bridge, the ephemeral streams are actively eroding at their base. Down slope close to the flat plain, the gullies normally disappear (fig. 6). This proves that the downcutting by the ephemeral stream is not due to a base-level lowering. This has to be in connection with an increase in discharge, that evidently occurs at the point of maximum incision just below the bridge, and with the relative decrease of debris load.

As a matter of fact the amount of sheet flow coming from the upper part of the pediment is barred and collected by the road, flows, along the upper side of it and is conveyed «downstream» below the bridge or trough drainage cement pipes. Two things are happening as a result. Maximum discharge is suddenly channelled through these outlets into the lower side. Having lost much of the load, when the debris settle on the upperside of the road, the running water is relatively free of load now and uses this extra energy to erode (fig. 7).

Sometimes, the gully deepening (and undercutting) is so strong that the gully-side slopes become highly unstable. A wawe of parallel retreat begins, resulting in rapid gully widening.

As it could be oserved in the other places, linear erosion on such footslopes due to deforestation, base level lowering and maybe due to climatic changes, could not be excluded.

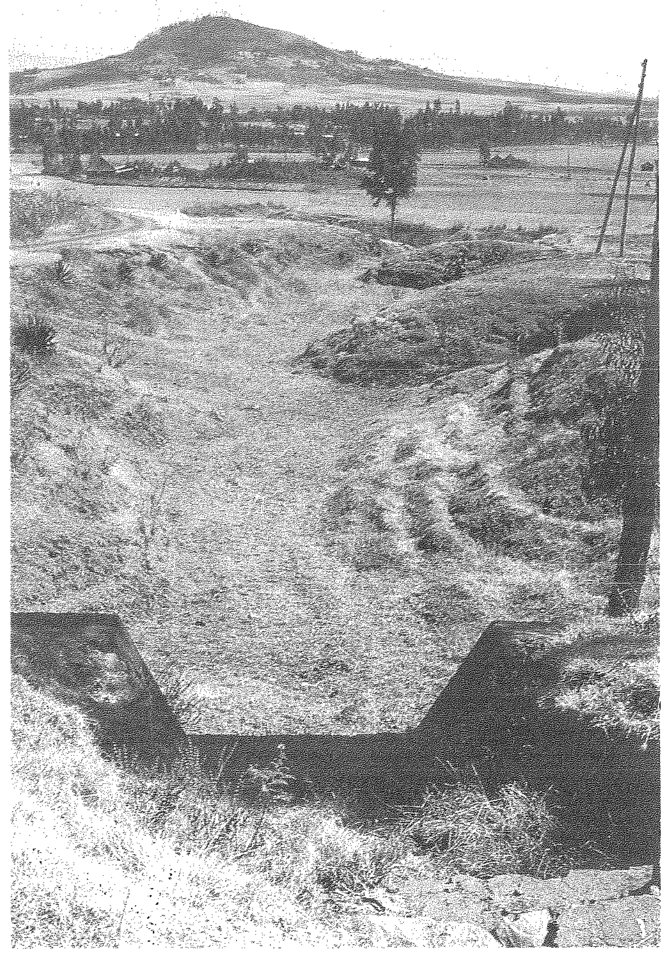

FIG. 6 - To minimize the undercutting, sills are constructed. Gullies are here deep and gradually become shallower and disappear downslope.

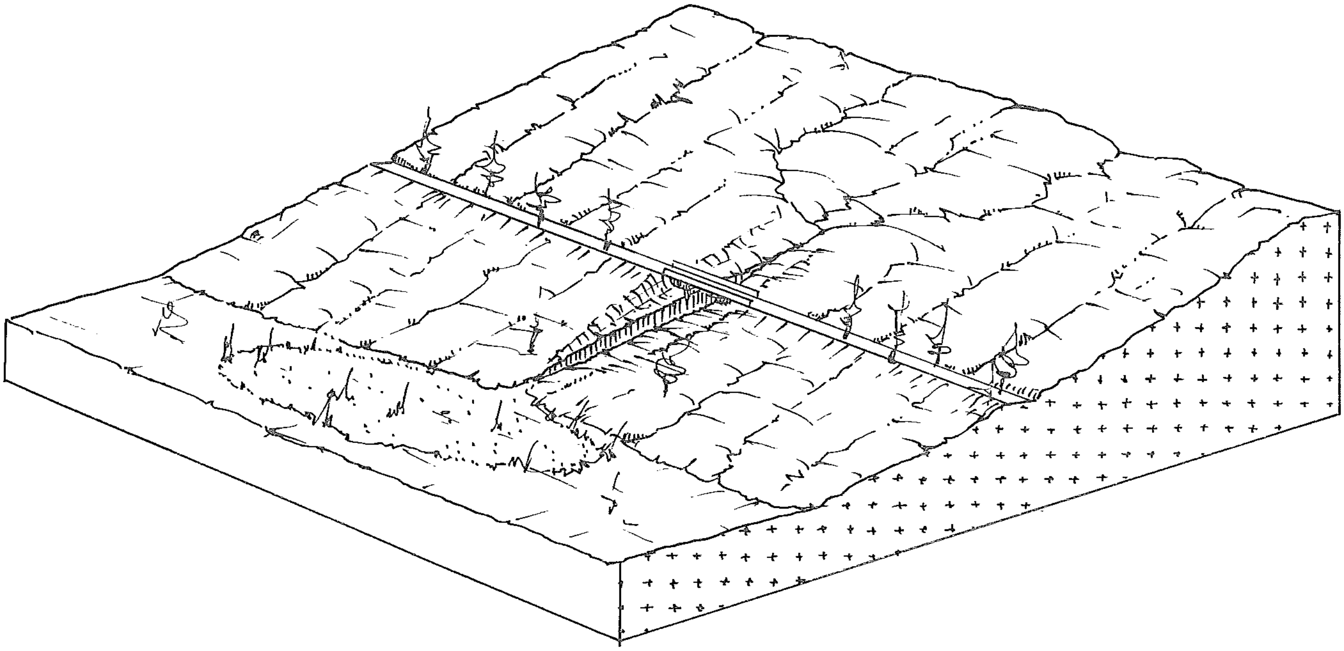

FIG. 7 - A scheme showing the change of sheet into channelled flow along a pediment because of the presence of a road.

These and similar erosional features are fast encroaching on the farmlands, grazing area, settlements and are actually damaging roads and bridges. Needless to say, this calls for an immediate and appropriate land use and conservation measures, before the situation further aggravates.

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