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REPORT ON "GLACIAL" FORMS OBSERVED ON AMBA ARADAM MOUNTAIN (NORTHERN ETHIOPIA)

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ABSTRACT
Some geomorphologic characteristics observed on Amba Aradam Mountain (Tigray region, northern Ethiopia) at altitudes of about 2500 to 2780 m a.s.l. and latitude of about 13°30' N, are described. These features might be ascribed to glacial modeling: cirques, roches moutonnées, glacial shoulders, moraine deposits and moraine arc and palustrine deposit due to moraine barrage. This framework is strongly in contrast with the fact that in Ethiopia the presence of glacial cirques and moraines was reported only in mountain areas at altitudes exceeding 4000 m a.s.l. An alternative assumption is that all these features might constitute a very singular case of "geomorphologic convergence", that is, landforms that have the same shape and appearance but different genesis.

RIASSUNTO
Relazione su forme "glaciali" osservate sul Monte Amba Aradam (Etiopia settentrionale). *Vengono segnalate alcune caratteristiche geomorfologiche sul Monte Amba Aradam (regione del Tigrai, nord Ethiopia) a quote fra circa 2500 e 2780 m .s.l.m. ed a una latitudine di circa 30°30' N, che potrebbero far pensare a un modellamento glaciale: circhi, rocce montonate, spalle glaciali, depositi e arco morenici, deposito palustre di sbarramento morenico. Questo quadro risulta in contrasto col fatto che in Ethiopia la presenza di circhi e morene glaciali sono state segnalati soltanto a quote superiori ai 4000 m s.l.m. Un'ipotesi alternativa è che ci si trovi di fronte a un caso molto singolare di "convergenza geomorfologica", cioè di forme del rilievo che hanno la stessa forma, ma che sono il risultato di processi morfogenetici differenti.*

Keywords: Quaternary glaciation, Ethiopia, glacial morphology, geomorphological convergence

Parole chiave: Glaciazione quaternaria, Etiopia, morfologia glaciale, convergenza geomorfologica.

During the IAG International Symposium on "Climate Changes, Active Tectonics and Related Geomorphic Effects in High Mountain Belts and Plateaux", held in Ethiopia in December 2002, and, in particular, during an excursion to Amba Aradam Mountain, I had the opportunity to observe some very interesting geomorphologic features which are here described.

The area surveyed is located SW of Makalè, in the Tigray region, in northern Ethiopia (fig. 1), at an altitude of 2500 to 2780 m a.s.l. and an latitude of about 13°30' N. It corresponds to an E-W stretching valley, whose head is formed by two small tributary valleys with a NE to SW arrangement. From the geologic standpoint, it is made up of a silicoclastic sandstone sequence of continental facies with quartz conglomerate, shaly and laterite levels, known as "Amba Aradam Formation" (Shumburo, 1968; Beyth, 1972; Dramis, Coltorti and Pieruccini, 2002), also known as "Upper Sandstone" (Merla and Minucci, 1938; Mohr, 1962). The age of this formation is ascribable to the Cretaceous (see: Dramis, Coltorti and Pieruccini, 2002; Nyssen et al., 2002). From the structural viewpoint, the valley's lower portion seems to be affected by an E-W oriented tectonic line which might have conditioned the original modelling. This tectonic feature does not seem to be linked to the main fault systems described by Arkyn et al. (1971) and by Beyth, (1972), which are NNW-SSE and NNE-SSW oriented (Dramis, Coltorti and Pieruccini, 2002).

Starting from the double head of the valley, the geomorphologic features are as follows (fig. 1).

- The head of the little northern valley (1a in the geomorphologic sketch of fig. 1) is modeled within a semi-circular cavity with high and steep flanks, partially affected by rock falls which form debris accumulation at the foot of the rocky slopes. Also the head of the little NE valley (1b in the geomorphological sketch of fig. 1) has a similar form, although it is not as clearly defined and looks more degraded by erosion and accumulation processes.

- Immediately downstream of the confluence of the two small valleys, a debris deposit is found (fig. 2 and point 2 in the geomorphological sketch of fig. 1), made up of lithologically homogeneous elements (from the Amba Aradam Formation), though with quite a varied grain-size distribution (from blocks to sand and silt). These elements are mixed, non stratified or smoothed, with no apparent signs of friction.

- On the flanks of the main valley some sandstone outcrops appear to have been modeled in the form of convex and smoothed surfaces, with traces of sub-horizontal grooves which subsequently were partially sectioned by rock shattering processes (fig. 3 and points 3 in the geomorphological sketch of fig. 1).

- On the floor of the main valley a palustrine deposit is found (fig. 4A and point 4 in the geomorphological sketch of fig. 1); its origin is evidently due to the damming of the valley by debris accumulation.

- Two detrital bodies developed on the two sides of the valley (fig. 4), one facing south (B) and the other north (C), appear to be responsible for the valley damming and the afore mentioned palustrine deposit. On the whole these two deposits make up an arc-shaped form of varying clarity; the right-hand side deposit (B in fig. 4 and point 5a in the geomorphological sketch of fig. 1) has been partially terraced by anthropogenetic processes. From the grain-size viewpoint, they are both made up of very heterogeneous materials – up to boulders of about ten cubic meters in volume – resulting from the Amba Aradam Formation.

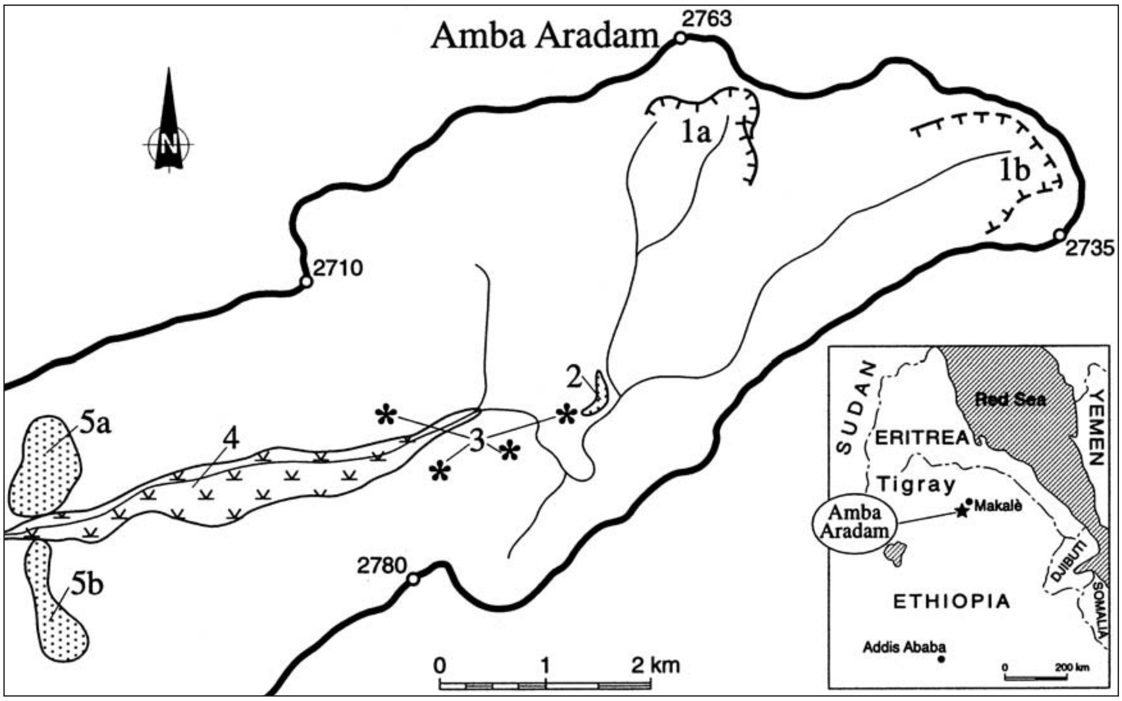

Fig 1 - Geomorphologic sketch of the Amba Aradam south-western slope and location of area surveyed. Legend: 1 - head of small valleys; 2 –debris deposit; 3 – rocks modeled in form of convex, worn smooth surfaces; 4 – palustrine deposits; 5 – debris deposits (5b: diamicton).

Schizzo geomorfologico del versante a sud-ovest dell'Amba Aradam e ubicazione dell'area studiata. Legenda: 1 – testata di vallecole; 2 – deposito detritico; 3 – roccia modellata in superfici convesse e levigate, con tracce di scanellature; 4 – deposito palustre; 5 – depositi detritici (5b: diamicton).

Fig. 2 - Debris deposit at the confluence of the two small valleys.

Deposito detritico alla confluenza delle due vallecole

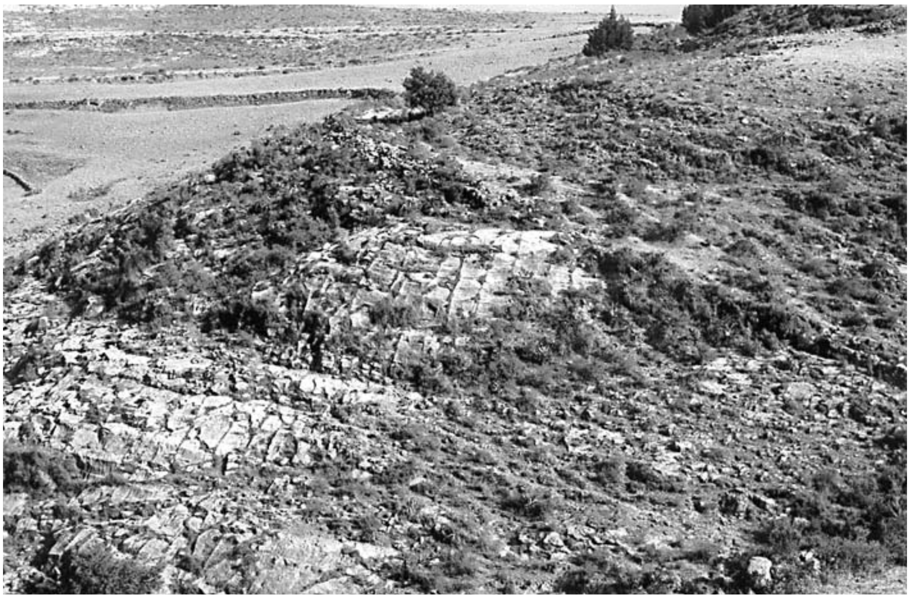

Fig. 3 - Arenaceous rocks modeled in the form of convex, worn smooth surfaces.

Rocce arenacee modellate in superfici convesse e levigate

Fig. 4 - Palustrine deposits (A) and debris accumulations (B and C); the former (B) have been partially modeled as terraces by anthropogenetic processes.

Deposito palustre (A) e accumuli detritici affacciantisi (B e C), dei quali il primo (B) parzialmente modellato a terrazzo da processi di antropizzione.

Fig. 5 - Diamicton from deposit 5b of the geomorphological sketch of fig. 1.

Diamicton del deposito 5b dello schizzo geomorfologico della fig. 1.

- Outcrop of the detrital body (fig. 5) (C in fig.4 and 5b in the geomorphological sketch of fig. 1): this is a diamicton-type deposit, that is unsorted with sand and coarse particles dispersed through a mud matrix. It is not stratified and some elements show a certain degree of smoothing.

The genetic picture of the area points to glacial modeling. There are very evident indications of this; in fact, from top to bottom, the six geomorphologic units previously described seem to be related respectively to: glacial cirques (points 1 in the geomorphological sketch of fig. 1), moraine deposit from glacial confluence (fig. 2 and point 2 in the geomorphological sketch of fig. 1), *roches moutonnées* (fig. 3 and points 3 in the geomorphological sketch of fig. 1), moraine barrage pond (fig. 4A and point 4 in the geomorphological sketch of fig. 1), small moraine arc (B and C in fig. 4 and points 5a and 5b in the geomorphological sketch of fig. 1) and lateral and frontal moraine deposits (B and C in fig. 4 and points 5a and 5b in the geomorphological sketch of fig. 1). This framework seems to be completed by the presence of less inclined portions of slope, similar to the so called "glacial shoulders".

This picture, though, is in contrast with the fact that in Ethiopia the presence of glacial cirques and moraines was reported only in mountain areas at much higher elevations (Mts. Simien, 4620 m a.s.l.; Arsi, 4180 m; Bale, 4357 m) (Nyssen et al., 2002). Some Authors, such as Nilsson (1940) and Hovermann (1954), described glacial traces found at lower altitudes, but subsequent researchers (Semmel, 1963; Potter, 1976; Hastenrath, 1977; Messerli and Rognon, 1980) refused this hypothesis with different arguments (Nyssen et al., 2002). Certainly the conformation of this E-W stretching narrow and deep valley, sheltered from the wind, could have favored the persistence of snow and ice during a cold Pleistocene period. This possibility, though, needs to be further investigated by means of particularly detailed geomorphologic surveys, correlations with other similar traces in other parts of Africa placed at the same latitude, and a precise reconstruction of the climatic conditions (temperature, precipitation and wind regimes etc.) existing in the Tigray during the Pleistocene.

As an alternative hypothesis, all these features might constitute a very singular case of "geomorphologic convergence", that is, landforms that have the same shape and appearance but different genesis. In this case, the area would be a very good educational example to alert the onlooker to simplistic deductions based mainly on exterior appearances, that is, on prevalently descriptive characteristics (Panizza, 1996).

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