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THE GEOMORPHOLOGY OF CALABRIA A SKETCH

Summary: SORRISO VALVO M., *The Geomorphology of Calabria. A sketch* (IT ISSN 0391-9838, 1993).

Calabria is a region of recent and active tectonic uplift. The difference in uplift rates results in the block-faulting of the crust and in the building of an irregular relief.

The paper presents a short description of the geology, climate and human presence and activity throughout the region. Then an attempt is made of describing main forms of the studied territory in terms of order of magnitude. Finally, it follows the description of the present morphodynamic processes which are characterized by high magnitude recurrent events. Mass-movement, stream and coastal erosion are the result of tectonic and climatic conditions of Calabria, as well as of non-regulated human activity.

KEY WORDS: Geomorphology, Calabria (Italy).

Riassunto: SORRISO VALVO M., *Schema geomorfologico della Calabria.* (IT ISSN 0391-9838, 1993).

La Calabria è una regione di recente sollevamento tettonico il cui rilievo di primo ordine (relativamente all'ambito del territorio studiato) è essenzialmente dovuto ai processi morfo-costruttori di natura tettonica. Nell'articolo si presenta un breve resoconto sulle condizioni geologiche e climatiche della regione, nonché sulla distribuzione e l'attività dell'Uomo che vi esercita da diversi millenni una notevole azione come modificatore ambientale.

Infine, si tenta la ricostruzione del quadro delle attività morfogenetiche attuali, sia naturali che dovute all'Uomo, da cui risulta evidente come la distribuzione e l'alta frequenza spazio-temporale dei fenomeni di movimento di massa e di erosione intensa, siano da collegare sia all'intensa attività tettonica dell'area, che alle particolari caratteristiche climatiche, che alla scarsa regolazione delle attività umane.

TERMINI CHIAVE: Geomorfologia, Calabria.

INTRODUCTION

The attempt of summarizing in few pages the geomorphology of Calabria would surely fail because this is a territory whose geomorphology is very complicated, with evidence of new forms due to active processes and old forms inherited from processes which have been active during pre-Holocene periods.

The knowledge on geomorphologic history and dynamics is scarse and incomplete because systematic studies, though producing quite a number of papers, have been initiated only recently by few researchers. Calabria, however, because little known in detail and mostly because really appealing on geomorphologist's point of view is a sort of «*Gymnasium*» for scholars, especially for applied geomorphologists.

The following description is not a state-of-the-art of Geomorphologic studies of Calabria. Indeed, only few studies have been made at the regional scale (GUEREMY, 1972) or at the sub-regional one (LEMBKE, 1931; VERSTAPPEN, 1977), and some of the concepts in these papers are incorporated in this short note which, however, is but only a synthesis of the literature on writer's knowledge.

ENVIRONMENT

Geology

The geology of Calabria is extremely complicated; however, the following synthesis and fig. 1 give the crude elements.

The most of Calabria is made of a sector of the Alpine chain made of nappes derived from oceanic and continental crust. These nappes were overthrust, in Middle Miocene, upon the carbonatic terranes of the Apennine range. During and after their piling-up, continental and marine sedimentary terranes have been deposited in the different basins that formed within and along the margins of the calabrian structure. The carbonatic units of the Apennine range make now the northern part of the region, i.e. the Mount Pollino Range, and constitute the autoctonous basement for the Alpine nappes on the northern half of the peninsula.

All the region is undergoing tectonic uplift that is accounted for the its topographic relief.

The geologic and tectonic history of the units is then more and more complex according to their age. Some units underwent at least two metamorphic events; all christalline units, and most of the Apennine units, are intensely jointed and/or folded; some display an extraordinary frequent partitioning in thrust units. In other words, most

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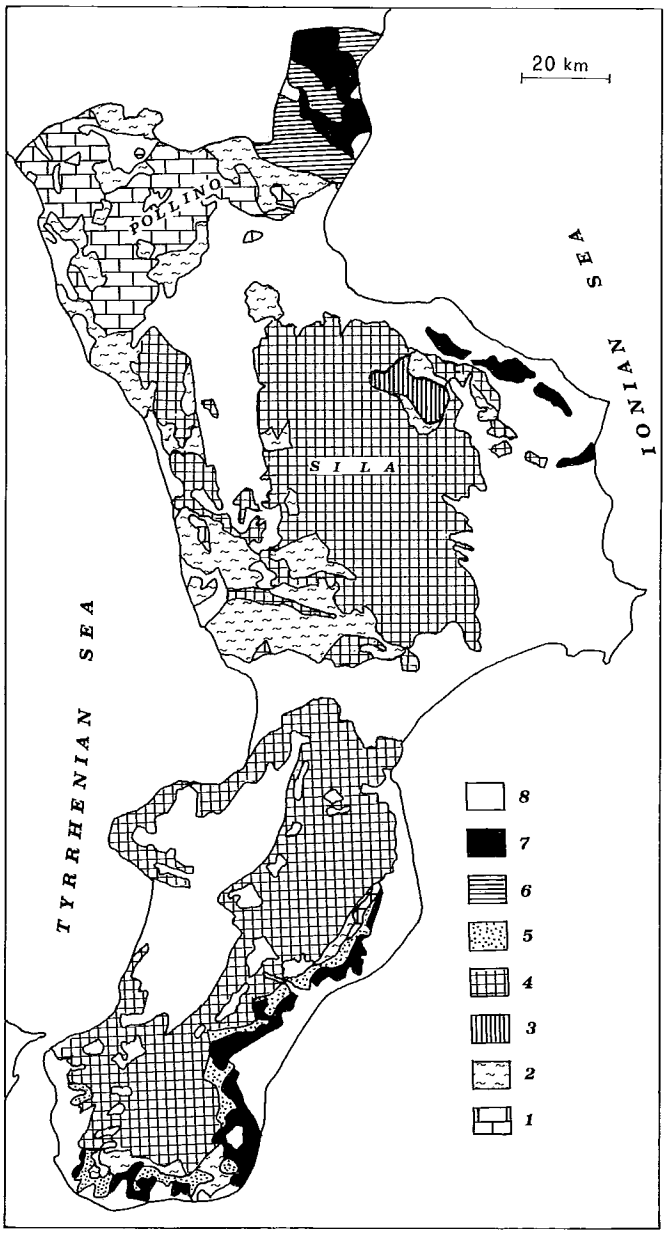

FIG. 1 - Principal rock complexes of Calabria. Units are grouped according to their principal lithologic components; thus, the tectonostratigraphic sequence may be not observed in the legend. Key to boxes: 1) mainly carbonatic units of the Appennine range and limestone cover of Alpine units (South Calabria); 2) very low to low-grade metamorphic units, at places with ophiolites. They principally belong to the nappes of the Alpine units derived by oceanic-crust, and, to a lesser extent, to the continental crust-derived Alpine units (4) and the Appennine units (1); 3) Sedimentary, flysh-type sequence of the the lowermost part of the continental crust-drived units; 4) intermediate to high grade metamorphic and intrusive rocks of the Alpine units derived from continental crust; 5) turbiditic, mainly coarse-grained deposits; 6) flysh-type nappes, mainly marly-clayey; 7) flysc-type nappes, with cahotic structure; 8) sedimentary autochtonous units from Miocene to Holocene age.

of tectonostratigraphic untis and some of the younger sedimentary units, have been intensely deformed.

Fig. 2 shows the uplift rate values throughout the region. Data come from different papers and refer to different time intervals (CAROBENE & FERRINI, 1992; DAMIANI, 1970; DUMAS & *alii*, 1978, 1992; GUEREMY, 1972; OGNIBEN, 1973; SORRISO-VALVO & SYLVESTER, 1992; VERSTAPPEN, 1977). There is a good correlation between site elevation and uplift rate. The negative value in the northern coast results from archeological evidence but it might be influenced by recent sediments consolidation.

Remnants of morphological surfaces (paleosurfaces) little affected by the acceleration of dismantling processes triggered by the increase of uplift rate in Quaternary age, are preserved in the inner parts of highlands; small remnants are to be found close to the coasts, where, as said before, uplifting is slower. The age of these paleosurfaces is referred

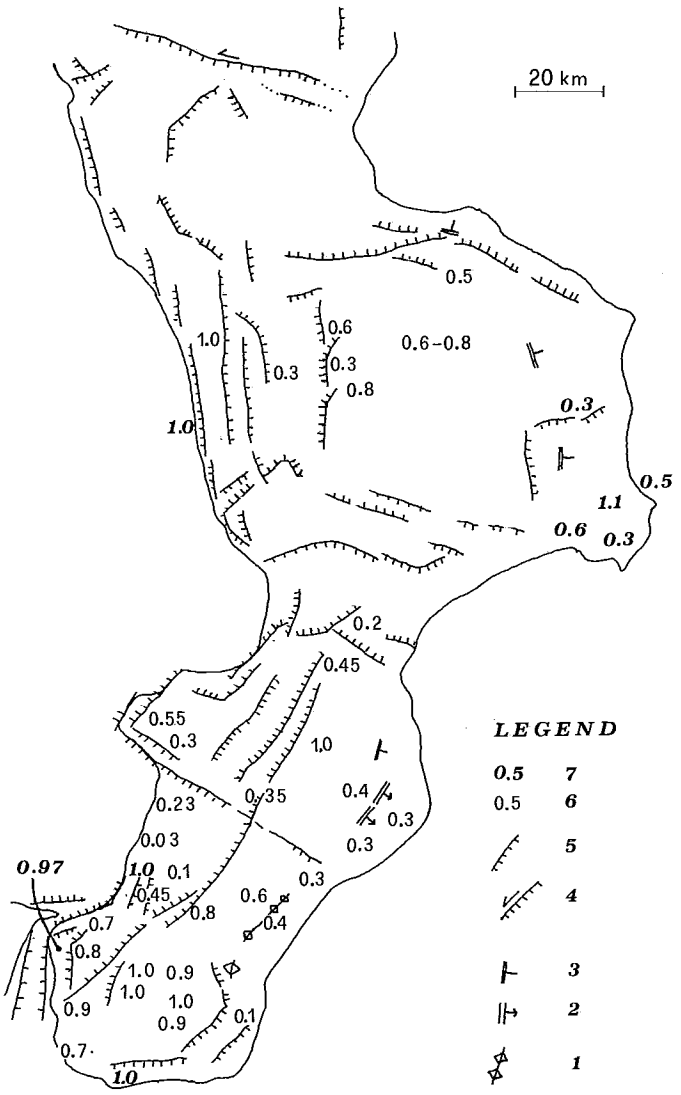

FIG. 2 - Main neotectonic morphostructures and Quaternary uplift rates in Calabria. Key to legend: 1) eroded anticlinal depression; 2) hogsback; 3) cuesta; 4) stike-slip fault scarp; 5) normal fault scarp; 6) and 7) average uplift rates over a period of 1 million and 40,000-125,000 years, respectively.

to the end of Lower Pleistocene (1 million year) but reliable dating is not available.

The paleogeography of that time was that of an arc-shaped archipelago with the Sila and Coastal Chain (North-West Calabria) constituting the major island.

The history of this paleosurface is more complicated than it might appear judging by its simple appearance. The surface is in fact truncated by several erosional episodes, including those due to small glaciers whose scarse and faint evidence has been found on highest tops of Sila and Mount Pollino range (BOENZI & PALMENTOLA, 1975).

The paleosurfaces can be traced out by the smoothed (though not flat) morphology, the soil development, the scattering of poaches of loess deposits. Available datings, however, indicate a much younger age for sediments of a small lake of Sila (about 31,000 years B.p., CALDERONI & *alii*, 1989), and of the major of the Sila lakes, the Cecita (about 40,000 years B.p., G. FERRINI, *pers. comm.*). This indicates that actually morphodynamics did not stop even in these areas that are referred to as paleosurfaces.

Quaternary normal faulting began first in the inner part of the region and then it shifted towards its external sides, thus defining several uplifting blocks. The shifting, then, continued towards the external sides of the blocks. We can observed this along the stepwise NW slope of the Aspromonte range (South-Calabria): all fault scarps involve rocks of comparable resistance to erosion; nevertheless, the external ones appear progressively less degraded than the inner ones that then should be older. A similar situation is detectable by means of geomorphological and seismological evidence along both sides of the Tyrrhenian Coastal Chain and the Ionian side of Sila.

Climate

The present Calabrian climate is Mediterranean (Cs), with warm summer (Csa) along the coastal zones, plains and hills up to the elevation of 400-600 m according to aspect. Modifications towards montane characteristics, with cool winters and relatively wet summers are to found at elevations above 1000 m. In fig. 3a it is shown the average year precipitation and temperature recorded at rain-gaging stations above and below 600 m a.s.l.

The temperature-precipitation plane is partitioned in fields where different types of extreme meteorological events are responsible for landscape evolution (STARKEL, 1976). It is apparent that most of Calabrian lowlands are characterized by intensive rains (points with higher mean temperature, sector A in fig. 3a), while as altitude increases rains tend to be continuous (sector A + B); few stations fall outside the delimited temperature-rain fields, this meaning that high precipitation and low temperature is a combination not involving extreme meteorological events, as apparently is the case, being disastrous storms generally confined to the low and mid-altitude zones.

In recent hydrological studies (VERSACE & *alii*, 1987), three main types of rain regimes could be statistically distinguished on the basis of daily rains (fig. 3b). Note how the extremely intense, clustered rains are dominant on the northern and southern parts of Ionian side.

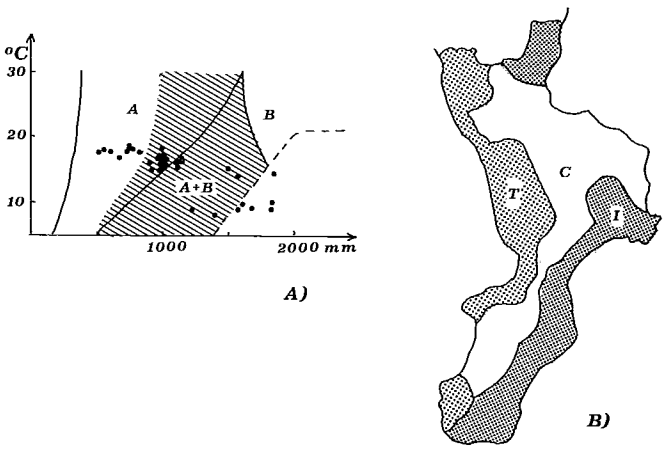

FIG. 3 - Climatic and physiographic character of Calabria. In A), dots represent the mean annual precipitation and temperature in meteorological stations sited below (lower cluster) and bove (upper cluster) 600 m a.s.l. According to the physiographic partitioning as in Starkel (1976), most of the dots fall in the field of very intense and short rains (downpours, field A) and in the field of transition between downpours and continuous rains (field A + B, being B the field of continuous rains only). The discontinuous line is the boundary of existing conditions in the study by Starkel (1976); dots outside this boundary can be included in A + B field. The hatched area represents the field of forest cover; indeed, Calabria has a forest coverage of more than 34%. In B), according to statistic elaboration of rain series (VERSACE *et al.*, 1987), Calabria is subdivided in areas characterized by very frequent rains (T), frequent, intense rains (C) and extremely intense, clustered rains (I).

Human pressure

Like all Mediterranean lands, Calabria is under the pressure of human activity since pre-Magna Graecia times. Clear cutting of forests is probably the most important single factor in landscape evolution of european countries (NIR, 1983), so it is worth while to briefly recall the deforestation history of Calabria.

Populations from Paleolithic to Bronze Age were settled along the coast and on the hills and terraces. Forest clear cutting was a common practice although it is impossible to state to which extent and incidence.

When Greek colonies as those of Sybaris, Locri, Crotone, Temesa, etc. began to be stablished (8th century B.C.) pushing inland the local pupulations, clear cutting increased considerably. This is assumed to have been one of the determinant causes of riverbed aggradation that progressively changed Calabrian rivers into «fiumare» (FAIRBRIDGE, 1968), i.e. ephemeral streams with braided and coarse-grained channel bed and steep longitudinal profiles. Indeed, still during Greek times, some of the Calabrian rivers had estuarine debouching so that small ports, like that discovered at Locri, could be built in safe position with respect to winter surf and enemy raids (NUCERA, 1974).

Clear cut and land reclamation to agriculture was still more intense and diffused during Roman age, when the «*Pax Romana*» (the Roman Peace) was ruling also the interior of Calabria, permitting the building of new and safe roads and the settling of farms and villages. This was continued until the 5th century A.D., even though since the 2nd century B.C. frequent droughts and the wars against Carthage had been causing recurrent strong decline of the agricultural population of Ionian Calabria (NUCERA, 1974).

With the decay and fall of the Roman Empire, in 6th century most of the population living on the coasts moved inland in safer places. Consequently, we have to assume that clear cutting and land reclamation, but also some mountain stream regulations, were spread on the highest slopes of the mountains. We do not have reliable informations about land use in the Middle Age. The few available normally come from request of tax relief after earthquakes, floods or wars. Coastal lands were left nearly abandoned because of piracy until a relative safety was assured by the Svevian dynasty in 13th century. In the meanwhile, because of the nearly total abandonment by farmers and citizens, as well as because of the increase in bedload transport from the upper reaches of the watersheds, the Calabrian coasts were turned in swampy areas and so they remained until the last century. This added malaria to problems of already troubled Calabria.

This region since ever has been, and still is, the wildest of the Italian regions. After the Roman age, road conditions became extremely bad and so they remained until few decades ago. In early 19th century (DE TAVEL, 1812) Calabria appeared to the few travellers as a contrasting country where gorgeous views were alternated with frightening forests and inhospitable swamps; no one road was paved, bridges were rare.

In Moder Age, clear cuttings appear to have been operated with high intensity in 17th and 18th centuries, and again in the first half to 20th century. This notwithstanding, and because of the absence of industrial settlements, Calabria is today the fourth Italian region with the highest percentage of forest-covered land (34%).

Human pressure in the last decades has been excerted towards semi-wild urbanization of the coastal environment, unplanned streams regulation, port design based on no-study of the coastal regimes, settlement of sewage cleaners and soccer fields on landslides, and endless such kind of cases of land mismanagement. As a consequence of these efforts, for geomorphologist's happiness, eccelerated erosion of rivers, on slopes and coasts has been successfully achieved throughout.

FIRST-ORDER, LOWER ORDERS LANDFORMS AND PROCESSES

A way to the systematic description of geomorphology of a region may be the ranking of morphological elements according to their magnitude of relief. The following classification do not conforms that of expanded theory (FAIRBRIDGE, 1968), since it is adapted to the size of the territory in question. However, the first order forms are those that account fot the total relief. Submarine features are not concerned.

First-order landforms

First-order landforms of Calabria are, at the scale of the peninsula, morphostructures generated by spatially and temporarily discontinuous, still active, uplift (fig. 2). We have then mountain ranges and highlands alternated with lowlands. The maximum elevation is about 2 200 m (Mount Pollino) while the local relief may reach 1 700 m (Sila). The maximum gradient of relief is at the boudaries of elevated blocks. These boundaries may take the shape of a single, very high fault scarp or that of a subparallel scarps arranged stepwise. In some places they appear as a degrading horst-and-graben sequence. In some cases a single scarp breacks in a stepwise sequence: for example, the 800 m high, NW slope of the Aspromonte range that dominates the Gioia Tauro Plain (South-Calabria) is a single fault scarp that continues soutwestward in a stepwise sequence of faults that account for the same relief over a tenfold distance.

There is scarce evidence of active tilting, while monoclinalic attitude of stratification, normally due to pre- or Lower Quaternary tectonics, is to be found only on the Ionian side of the region.

Tectonic depressions make valley or plain. Their uplift started later, as in the case of most of Tyrrhenian coastal zones and of the Gioia Tauro Plain, or it is going at lower average rate, as the river Crati and river Mesima valleys and the coastal area of Ionian side.

The Mount Pollino range is a huge pillar, wedging up along a strike-slip fault of regional extention, because of transpressive tectonic regime.

The first-order morphology, then, depends thoroughly on tectonic structures.

Lower orders landforms

Seond-order landforms are the largest component of first order landforms.

They include the high paleosurfaces of Pollino, Sila and Serre ranges, all river-eroded valleys and the coastal and intramontane plains. Second-order intramontane valleys and planes of tectonic origin include those depressions whose relief is much smaller than that of the first-order depressions.

Deep-seated rock creep is the dominant morphogenetic process on slopes carved out of either low-grade metamorphites or harder, intensely jointed rocks. High slope gradient and slope height over 106 m (SORRISO-VALVO, 1984), as well as a rapid dissection of the valley, are necessary conditions for the development of these phenomena. They have been discovered in early Seventies (GUERRICCHIO & MELIDORO, 1973) and their geomorphological importance has been acknowledged years later (SORRISO-VALVO, 1979; 1984; 1985).

Landscape elements of second order include the marine abrasion platforms and fan heads of Catena Costiera, Serre and Aspromonte, now appearing as large terrace flights elevated up to 1 400 m a.s.l., with slope-wash deposit covering thin and discontinuous layers of beach pebbles. They also include the marine terrace flights of the River Crati graben; the large-scale constructional forms, as the Crati delta and the several fan-deltas and bajadas that border the highlands; large karst forms (dolines, small tectonic depressions with or without lacustrine deposits).

Bajadas and the older fan-deltas which were deposited in the inner tectonic depressions, are presently non active. They were forming piedmont planes that at places have been multiplied by faulting. These planes are presently reduced to small remnants that often are difficult to correlate because of subsequent tectonic vertical displacements.

At this hierarchical level, the morphology is essentially controlled passively by geology and geological structure and actively by present tectonics and denudational agents as mass movement, erosion by running water and sea.

On slopes, mass-movement is widespread because of the high spatial frequency of landsliding-prone rocks (SORRISO-VALVO, 1985) and/or high relief energy. These conditions are widespread in Calabria (SORRISO-VALVO, 1985) so these processes may be of paramount importance for the understanding of landform evolution in most of the Calabrian zones. For instance, some of the above mentioned high aggradation phases in the fiumara riverbeds have been caused by temporaneous and spatially limited acceleration in mas-movement dynamics. So we can find now evidence of fill-and-cut cycles that involve only a portion of the drainage basins. It also appears that most of them have been formed in very short time intervals and that most of them are Holocenic or historical.

To each subsequent lower rank, we should ascribe the forms that compone those of immediately higher order, down to micro-forms and sand grains. It is not worth while to describe them in a so short scheme. It is important, instead, to stress that at lower-intermediate orders human activity exerts a determinant control on form development. Indeed, it is hard to find a landform that is not or has not been influenced by human activity.

PRESENT-DAY MORPHODYNAMICS

Mass-movement phenomena appears as the most effective present factor of slope and stream channel development. Indeed, in the last decades there has been a high incidence of landsliding (CARRARA & *alii*, 1982) and, as a consequence, a neat tendency to aggradation of stream channels, followed by the present degradation. This aggradation of streams, however, could have but little effect on the beach, because a relevant part of the sediment budget mobilized by the extreme floods in 1954 and 1973, has been stopped by the corrective measures undertaken in late Fifties and in Sixties.

Seismic, climatic, anthropic reasons may stand for these phases (ERGENZINGER & *alii*, 1978; SORRISO-VALVO, 1985; 1989).

Mass-movement incidence has been assessed in different study areas in Calabria, with different techniques, by several authors. Fig. 4 shows the synthetical results on landslide incidence obtained in several studies. Deep-seated gravitational slope deformations have been detected all over Calabria as part of a nation-wide co-ordinated project (SORRISO-VALVO, 1984).

The present dynamics of mass-movement phenomena is characterized by a tight dependence on climatic events. Such events, able to intensively reactivate mass-movement

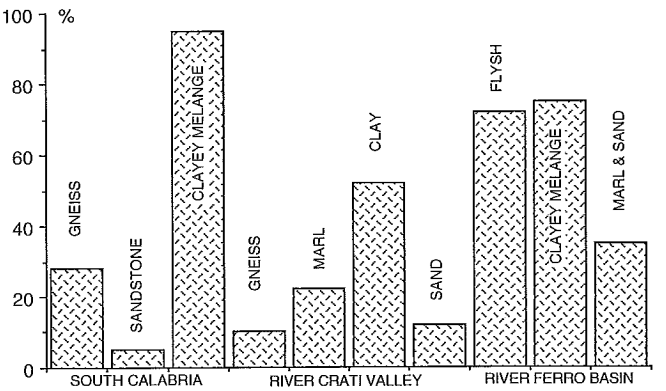

FIG. 4 - Landsliding incidence in percent of surface in three study zones of Calabria, according to different rock types. Clayey melange is equivalent to rock unit 7 in fig. 1.

and erosion over large portions of Calabria, occur with a period of roughly 20-year. The last two major storms occurred in 1951 and 1973, causing a large number of victims and enforcing the abandonment of several villages. Presently, mass-movement affects about 25% of the Calabrian territory; the areal incidence may locally be as high as 95% on slopes carved in clayey melange (fig. 4). As a general figure, the long-term average erosion rate due to mass-movement can be roughly assessed in the order of 0.2 mm/yr. A figure of cm/yr can be locally expected in occasion of extreme meteorological events. This means that a amount of about $3 \times 10^6 m^3$ debris is mobilized every year. This debris is in part washed to the sea and, in normal conditions, contributes to the budget of beaches balance. Thus, as a result of the widespread control works on streams, beach erosion is becoming a general problem along the Calabrian coasts. Further damages have been caused by badly planned shoreline corrective works. For example, groins built along the Tyrrhenian coast resulted in the accretion of the beach but they caused a contemporaneous erosion along the beach on the lee side with respect of the dominant coastal drift.

Some researchers have claimed for a present increase of mass-movement activity. Actually, there is no evidence for this increase, since observation time span is too short

yet. Moreover, there is evidence of downgrading of landsliding: all piedmont fans along the Tyrrenian mountain front have been built by debris flow, but these phenomena are unactive since 150 years b.P. (SORRISO-VALVO & SILVESTER, 1992).

Erosion processes display a fluctuating intensity. Recent studies (SORRISO-VALVO & *alii*, 1992) proved that the degree of erosion in badland areas has greatly decreased in the last decades, permitting the re-colonization of barren areas by vegetation. In general, the reduction of the degree of erosion has been the result of re-afforestation practices, but in some places there has been a spontaneous reduction.

On the contrary, beach erosion is dramatically progressing, also as a consequence of the decreasing of overland erosion intensity. The present rate of river erosion is not very well known. Recent studies on sediment budget in South Calabria assess an average erosion rate for different time intervals of the Quaternary and stress the pulsive character of coarse debris transport and its relationships with mass-movement (ERGENZINGER & *alii*, 1978). Similar studies are in course on a small catchment in Northern Calabria (TERRANOVA & *alii*, 1989), but available data are not enough yet for a reliable calculation of erosion rate.

Piping may occasionaly cause the cavern-size tunneling in gneisses in the Aspromonte. Sometimes, these forms are the result of the acceleration of underground erosion induced by human activity, as unmetalled road cuting, building of tunnels, brine techniques for exploitation of salt mines (SORRISO-VALVO, 1985).

Coast dynamics in Calabria is rather complicated. In the last decades, the general trend is towards erosion, after progradation had been active for several centuries: along the Tyrrhenian coast, the average retreat has been of about 50 m from 1954 to 1973 (D'ALESSANDRO & *alii*, 1983; 1987). The widespread use of check dams in watersheds and quarrying (often unauthorized) in riverbeds and beaches has played an important role in the present breach erosion.

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