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GEOMORPHOLOGICAL AND NEOTECTONIC EVOLUTION OF THE UMBRIA-MARCHE RIDGE, NORTHERN SECTOR(***)

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ABSTRACT

A morpho-evolutionary model of the northern sector of the Umbria-Marche Apennines, elaborated starting from systematical field observations, is presented.

The sequence of erosional surfaces and alluvial terraces there present points out the fountamental role played by regional uplift which starting from the Upper Pliocene, after the end of the main tectogenetic phase, involved the area.

The genesis of alluvial deposits is referred to Pleistocene when, as a consequence of cold climates, debris material coming for bare slopes overcharged rivers. They were subsequently incided by linear erosion, favored by climatic amelioration and vegetal covering of slopes which reduced debris production.

Both the erosions surfaces and the older alluviasl were variously displaced by recent tectonics which strongly affected also setting and evolution of drainage networks.

RIASSUNTO

Sulla base di osservazioni geomorfolofgiche sistematiche viene presentato un modello morfo-evolutivo dell'Appennino Umbro-Marchigiano settentrionale.

La sequenza di superfici di erosione e di terrazzi alluvionali mette in evidenza il ruolo fondamentale giocato nell'area dai sollevamenti a lungo raggio che l'hanno interessata a partire dal Pliocene superiore dopo l'esaurirsi della fase tettogenetica principale.

La genesi dei depositi alluvionali viene riferita alle condizioni climatiche fredde del Pleistocene in cui i versanti spogliati della copertura vegetale producevano detriti che andavano a sovraccaricare le acque fluviali, mentre la loro successiva erosione viene attribuita all'azione dell'erosione lineare resa di nuovo efficace dal miglioramento climatico e dal ripopolamento vegetale dei versanti che riducevano l'apporto detritico.

Sia le superfici che i terrazzi alluvionali piú antichi risultano poi deformati in diverso grado dalla tettonica recente che ha anche esercitato un'importante influenza sull'impostazione e sull'evoluzione dei sistemi idrografici.

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PAROLE CHIAVE: Geomorfologia, Neotettonica, Appennino, Marche.

INTRODUCTION

Only recently, geomorphological study of landscapes and of their connection to neotectonic activity were carried out by Italian researchers.

In order to prevent destructive effects of the catastrophic earthquakes recurrently affecting Italy, comprehension of their seismological characteristics and genesis is needed; this made it necessary to improve knowledges about the recent tectonic history and the evolutionary trends of the Italian territory.

To this end, in the framework of the CNR "Geodinamica" project, starting from the 70's, systematic neotectonic investigations were carried out all over the Italian territory. Some of these studies were concentrated on the relations existing between tectonics and geomorphological evolution.

The aim of these studies was the reconstruction of landform sequences, and thus of time references, in order to determine the periods of activity of the connected tectonic features (faults, fractures, folds and thrusts). However, in several cases, geomorphological motivations became dominant; consequently, systematic analyses of the factors of geomorphological evolution of relief, with special reference to vertical large-scale, tectonic movements, were carried out (AMBROSETTI *et al.*, 1982; CALAMITA *et al.*, 1982).

The crucial morphogenetic impact of these latter movements was well understood by old geographers (SAWICKI, 1909 a and b; CASTIGLIONI, 1934; SESTINI, 1939), but was subsequently overlooked by Italian researchers, who were mostly interested in tangential tectonics. Recently, however, various authors (BERNINI *et al.*, 1977; MARCHETTI *et al.*, 1979 BARTOLINI, 1980; NESCI *et al.*, 1983; BARTOLINI *et al.*, 1984) re-emphasized such impact on several parts of the Italian territory.

At the end of the above mentioned Project, researches about those topics continued mainly within the C.U.N. 40% Special Program "Morfoneotettonica", in whose framework the present study is set.

This latter is based on the analysis of landforms and associated deposits and of their time sequences and aims to develop an evolutionary model of the northern sector of the Umbria-Marche Apennines.

Starting from a long time ago, this part of the Apennines has been thoroughly investigated by stratigraphers, sedimentologists and structural geologists, which supplied a satisfactory sketch of its geological setting (CENTAMORE *et al.*, 1975; MICARELLI *et al.*, 1977; PREMOLI SILVA & PAGGI, 1977; SAVELLI & WEZEL, 1978; CALAMITA *et al.*, 1979 a and b; CENTAMORE *et al.*, 1979; BOCCALETTI *et al.*, 1983; LAVECCHIA, in press; MICARELLI & POTETTI, in press). Nevertheless, in spite of local and regional investigations (CATTUTO, 1976; CARRARO *et al.*, 1979; NESCI *et al.*, 1983; CICCACCI *et al.*, in press), geomorphological aspects are still to be studied in a unitary way, taking into account the latest data from literature.

From an orographic point of view, the area under examination includes two main mountain ridges, culminating the westernmost one in Mt. Catria (1,701 m) and the easternmost one in Mt. S. Vicino (1,479 m). Those ridges have a roughly NW-SE trend and are modeled on the mainly calcareous formations of the Umbria-Marche sequence, forming an anticline or anticlinorium. They are separated by a hilly belt modeled on Miocene terrigenous rocks, constituting a syncline or synclinorium, in which minor calcareous ridges emerge.

Predominantly clayey-marly-arenaceous hills, also enclosing minor calcareous reliefs, are located West and East of the above mentioned ridges and gently descend towards the Tiber river and the Adriatic sea, respectively.

TECTONIC-SEDIMENTARY EVOLUTION OF THE RIDGE

The tectogenesis of the mountain sector under review started in the Lower Miocene. During this period, the ridge-foredeep system which produced the Apennines continued its eastward migration, reaching the Umbria-Marche domain. Here, a prevalently calcareous pelagic sedimentation has operated starting from the Lias (CENTAMORE *et al.*, 1979).

As a consequence, the "Umbria basin", where thick turbidites belonging to the Marnoso-Arenacea formation were being deposited, was formed. Further East, in the Marche area, sedimentation of calcareous and pelitic hemipelagites of the Bisciaro (Burdigalian p.p. - Aquitanian) and of the Schlier formations (Lower Messinian - Burdigalian p.p.) continued. This sedimentation was separated from the previous one by a submarine ridge (the present westernmost ridge of the Umbria-Marche Apennines, northern sector) which was progressively developing. Subsequently, in the Tortonian, folding started in the "Umbria basin", while the easternmost Marche area, bounded eastwards by a new submarine ridge (the present easternmost ridge of the Umbria-Marche Apennines, nothern sector), was splitted into several "minor basins".

Beyond this ridge, the sedimentary basin had foreland features, even though more external "minor basins" were appearing. Here, West-originated arenaceous and marly turbiditic materials accumulated, crossing the ridge along tectonic depressions connected with the pre-Apennine faulting system (BOCCALETTI *et al.*, 1983).

Turbiditic sedimentation continued in both internal and external minor basins throughout the Lower Messinian; successively, in the Middle Messinian, it was followed by deposition of evaporitic materials (Gessoso-Solfifera formation) related to the salinity crisis of the Mediterranean.

During the Upper Messinian, a lagoonal or lacustrine-marine environment with prevalently pelitic sedimentation was settled in most of the minor basins.

The Lower Pliocene marked in the area the start of a new sedimentary cycle which was mostly characterized by bathyal pelites.

Towards the end of this period, the Apennines tectogenesis reached its climax, activating thrusts and backthrusts. These generated shortenings of the ridge (up to 10 km), giving it its current structure (DEIANA, 1979; LAVECCHIA & PIALLI, 1980; CALAMITA *et al.*, 1981; BOCCALETTI *et al.*, 1983; LAVECCHIA, in press).

In the northernmost portion of the ridge, a transversal tectonic depression received the Val Marecchia gravity flow. This latter consisted of Cretaceous Varicoloured clays with allochthonous inclusions of varying lithology and size.

These transversal features, which can be defined persistent regmatic structures according to CAIRE (1975), are typical of the Umbria-Marche Apennines. They were active at various times during the evolution of the Apennine ridge, both as normal and as dextral or sinistral transcurrent faults (transpressive or transtensional), depending on changes of geodynamic stress in the area (BOCCALETTI *et al.*, 1983).

The first evidence of activity of these tectonic lines leads back to the Tortonian. In this period, West-originated turbiditic materials fed the "minor basins", flowing along transversal depressions which followed the above mentioned tectonic lines.

During the Middle-Upper Pliocene, the continual compressional tectonics caused complete emersion of the area, while, further East, marine sedimentation continued transgressively over the folded substratum.

The second part of the Upper Pliocene identifies the progressive start of extensional tectonics, whose peak is in the Lower-Middle Pleistocene. This tectonics involved the entire Apennine area, as testified by geological and geomorphological records (CENTAMORE *et al.*, 1978 a; CENTAMORE *et al.*, 1980; AMBROSETTI *et al.*, 1981; AMBROSETTI *et al.*, 1982; CALAMITA *et al.*, 1982).

To extensional tectonics is combined a generalized uplift (likely isostatic) which mostly affected the most internal part of the ridge, giving a typical monoclinal structure to its easternmost post-transgressive deposits.

Starting from the late Lower Pleistocene, the above said process was associated with a more extensive one, more difficult to explain from a geodynamic point of view (AMBROSETTI *et al.*, 1982).

This latter process resulted in further uplift of the entire Umbria-Marche area up to several hundred meters; in particular, complete emergence of the Adriatic foredeep and displacement, up to more than 300 m a.s.l., of Sicilian marine sediments along the shoreline (CANTALAMESSA pers. com.) occurred.

Tensional tectonics gave rise to the depressions of Gubbio and of Gualdo Tadino, in Umbria, and to those of Colfiorito and of Montelago, on the westernmost Apennine ridge. These were subsequently raised by the more recent tectonic uplift and, in some cases, were affected by linear erosion, which made their filling materials to outcrop (CENTAMORE *et al.*, 1978 a and b; CENTAMORE *et al.*, 1979).

The above said geodynamic situation seems to have continued up to present times, as shown by hypocentral mechanisms of the most recent earthquakes (CAGNETTI *et al.*, 1978; RITSEMA, 1970; CENTAMORE *et al.*, 1980; GASPARINI *et al.*, 1980).

MAIN MORPHOLOGICAL FEATURES

a) **Summit surface of calcareous reliefs**

The summit surfaces of calcareous reliefs in the Marche Apennines (Fig. 1) are often planated or gently undulated, strikingly contrasting with the sorrounding valley slopes (DESPLANQUES, 1969; CARRARO *et al.* 1979; CALAMITA *et al.*, 1982).

Connection of these summit surfaces suggests an ancient low-energy landscape (summit surface), gently sloping towards the Adriatic sea.

This ancient landscape, besides being disarticulated by deeply cutting river erosion, was also displaced by extensional tectonics, which produced considerable differences in height, especially in correspondance of Apennine normal faults.

Geomorphological features, linked with this tectonic phase, are fault scarps (Figg. 2-3) - more or less remodeled by slope processes - and tectonic depressions (Colfiorito, Monte Lago). These latter housed lacustrine basins in the past whilst presently they drain surficial water in the underlying calcareous masses through sinkholes.

In correspondance of anti-Apennine fractures and faults, paleosurfaces show remains of wide transversal valleys, those latter being part of a drainage system prior to the upflift of the area (Fig. 4).

Most of the present streams, which transversally cross the Apennine ridges, flow along fractures and faults which controlled their direction also during the tectonic evolution of the area, (BOCCALETTI *et al.*, 1983).

b) **Summit surfaces of terrigenous reliefs**

On the Tyrrhenian side, West of the Umbria-Marche Apennine ridge, the summit of the reliefs, which were modelled on the Marnoso-Arenacea formation, also show relicts of an erosional surface. This latter is much more planated than the one present in the calcareous reliefs.

The above said surface gently slopes to the Tiber river, starting from approximately 700 m a.s.l. or, however, from elevations significantly lower than those of the calcareous summit surface.

A similar setting is observed in the terrigenous belt which extends between the two ridges, and especially on the Adriatic side, where hill tops show very evident relicts of a gently sea-dipping surface.

At elevations comparable with those of the Umbria hills, this surface truncates the folded Mio-Pliocene deposits and, further Est, the Upper Pliocene and Lower Pleistocene post-orogenic ones. Also this morphological feature was involved in the recent extensional tectonics, although to a lesser extent with respect to the summit surface modeled in limestones.

The same surface is also found further South, in the southern Marche and in the Abruzzi, where it was ascribed to the Lower Pleistocene (Villafranchian) by DEMANGEOT (1965). This time reference is validated by the Sicilian age of the sandy-clayey marine materials which are distributed along the Adriatic coast and which overlap the morphological feature in point. Both these sediments and the above said surface appear to

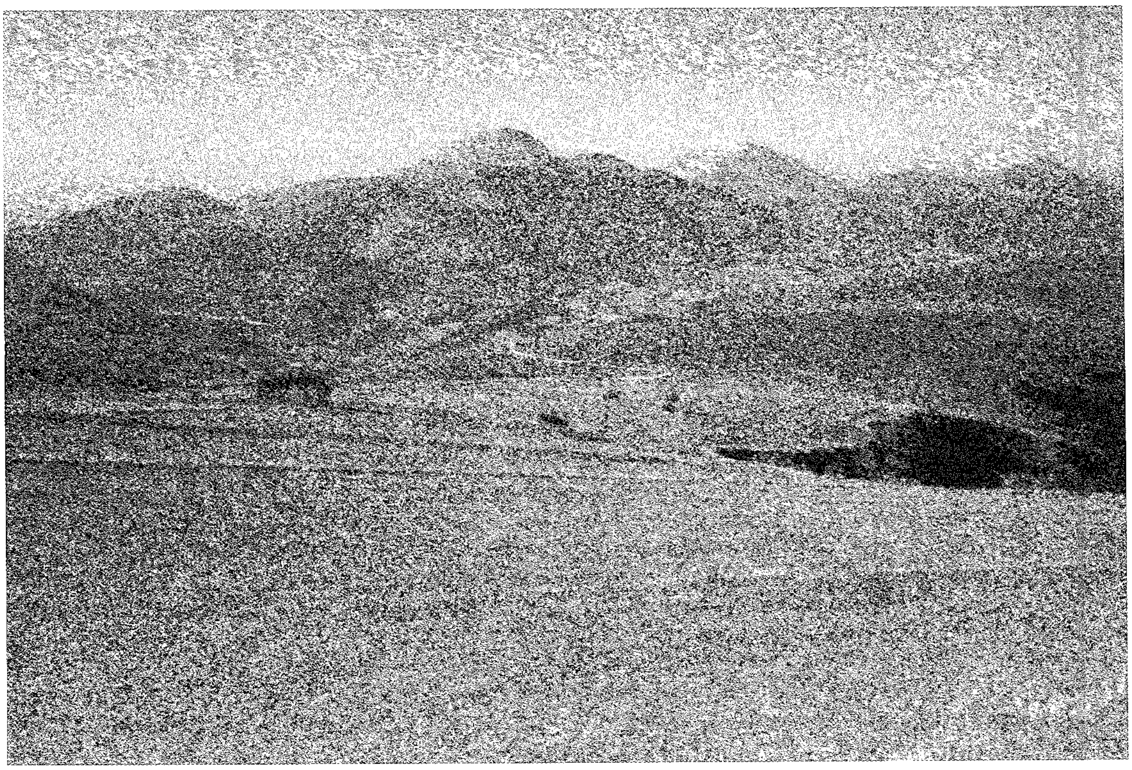

Fig. 1 - Mt. Rogedano summit palaeosurface.

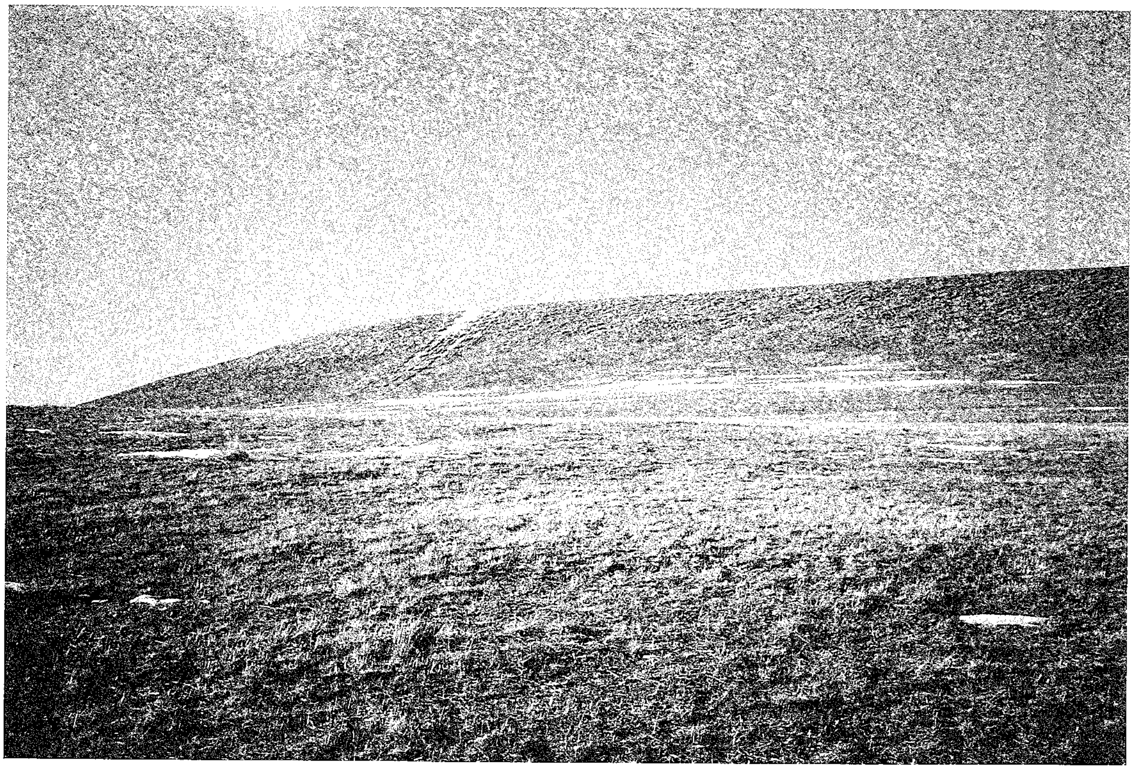

Fig. 2 - Fault scarp on the summit palaeosurface of Pian delle Vescole (West of Campodonico).

Fig. 3 - Fault scarp (the line indicates the border) on the summit paleosurface of Mt. Puro.

be uplifted along the coast up to some hundred metres above the present sea level.

c) **Valley slopes**

Valley slopes, which deeply furrow (with differences in height of up to 1,000 m) the summit part of calcareous reliefs, are generally rather steep. At times, transition to summit surface is abrupt whilst at other times it shows less inclined segments. These latter are remnants of wide valleys which, as previously observed, cutted the summit surfaces before the intensification of linear erosion. In the more elevated parts of valley slopes, less steep portions, which in several cases evolve in orographic terraces, are present.

Although they are isolated and were more or less dislocated by the recent tectonics, these morphological features can be divided in two groups (at elevations ranging around 650 and 800 m, respectively). These two groups can be referred to the shaping of two series of flat-floored wide valleys, cut into each other and corresponding to two important stages during which linear erosion was inibited and lateral erosion mainly operated (Fig. 5).

Externally, the more elevated valleys seem to correspond to the summit surfaces modeled in the terrigenous materials. The less elevated ones, instead, continue inside river valleys cut into these latter materials.

An outstanding geomorphological aspect of the long and steep valley slopes of the Apennine ridge is the recurrence of large deep-seated gravitational movements (sackungs and lateral spreads) and of ancient large-scale landslides (Fig. 6) favored by particular litho-structural conditions and, probably, by past seismic activity (Coppola *et al.* 1978; Carraro *et al.* 1979; Dramis 1984). Typical is also the occurrence of very extensive and thick (up to more than 20 m) stratified slope-waste deposits, which sometimes completely filled the valleys and flatted slope irregularities (Coltorti *et al.*, 1979).

Three main generations of these deposits were identified, located at different elevations on the slopes and occasionally separated by paleosoils. They are supposed to derive from gelifraction, widespread slope-wash and solifluction on bare slopes which occurred during the main cold stages of the Middle and Upper Pleistocene (Coltorti *et al.* 1983).

d) **Alluvial terraces**

Marche valleys accommodate four main orders of alluvial terraces, located at elevations ranging from a few meters (fourth order terrace) up to more than 100 m (first order terrace) above the present valley floor.

The first order terraces are observed in limited patches, always at minor elevations of both the lower flat-floored palaeovalleys and the Sicilian deposits.

They were strongly incided by areal erosion and, only in some cases, show the original depositional surface, which is deeply altered by fersiallitic soils.

Moreover, they are frequently dislocated by recent tectonics, like in the vicinity of Matelica (Fig. 7).

The second order terraces are more extensively found; they are up to 20-30 m thick and are located approximately 60 m above the present valley floor. These deposits, which are significantly less affected by tectonics, are often altered by a fersiallitic paleosol, which produced a typical cemented horizon at its base.

The third order terraces are much more widespread; urban settlements as well as main roads and railways are normally located over them.

These terraces, which hang more than 30-40 m above the present valley floor, are altered by a brown soil, which is much less evolved than the previous one (Alessio *et al.*, 1979).

Finally, the fourth order terraces, until a few decades ago, represented the flood plain of rivers; they were recently incided (up to 10 metres) by erosion due to anthropic activity (Biondi & Coltorti, 1982; Conti *et al.*, 1983).

EVOLUTIONARY MODEL OF THE AREA

On the basis of the above said morphological features, an evolutionary model for this sector of the Apennines can be proposed. It mainly refers to vertical tectonic movements, to their interaction with different climatic conditions and to structural characteristics of the bedrock.

The first stage in this evolution is represented by the emergence of the first reliefs which occurred in the Messinian. From this time on, denudational processes took place, giving rise to a gently undulated, East-dipping, landscape (summit paleosurface). On this landscape, wide valleys were present, following the tectonic lines which previously allowed West-originated turbiditic flows to reach the eastermost sedimentary basin (Fig. 8a).

The first river systems settled in these depressions during the early phases of emersion. As previously pointed out, traces of those river systems are found at the top of reliefs and, sometimes, in the highest part of the present valley slopes.

Then, the persistent activity of transversal lines enabled most rivers to maintain their prior course (by antecedence) during the main period (Middle Pliocene) of compressional tectonics (Fig. 8b).

In spite of the extent of surface deformations, areal erosion, which likely was favored by arid climatic conditions and relatively slow rate of tectonic movements, succeeded in maintaining a gently undulated landscape. At the end of the compressional phase the Apennine ridge was completely emerged.

Upon the extensional tectonic phase, started in the Upper Pliocene, the early drainage systems were often interrupted by normal faults, mainly Apenninic trending. These interruptions diversed rivers producing lacustrine basins inside tectonic depressions.

The above said tectonics divided the older reliefs into blocks, displacing the summit paleosurface at different elevations.

Extensional tectonics was associated with a generalized uplift of the area, which triggered widespread selective erosion. Favored by a likely arid climate and by slow vertical movements, erosion gradually enhanced differences in height between outcrops of differently erodibile rocks.

The early surface was thus isolated and fragmented by flat-floored wide valleys, which were connected to a lower pedimentary surface, modeled in the terrigenous areas.

This evolution continued until the end of the Lower Pleistocene, when a new, wider-scale, significantly faster, areal uplift overlapped the first one. As a consequence, the prevailing areal erosion was sup-

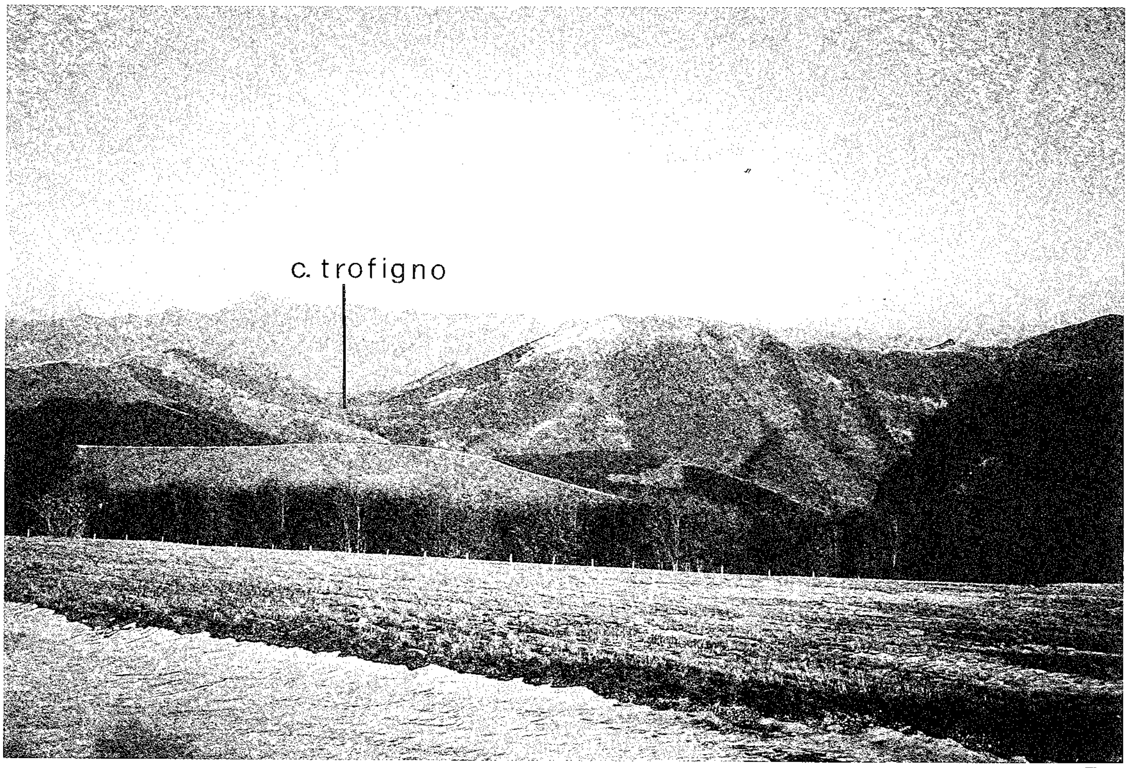

Fig. 4 - Case Trofigno palaeovalley (summit surface South of Fabriano).

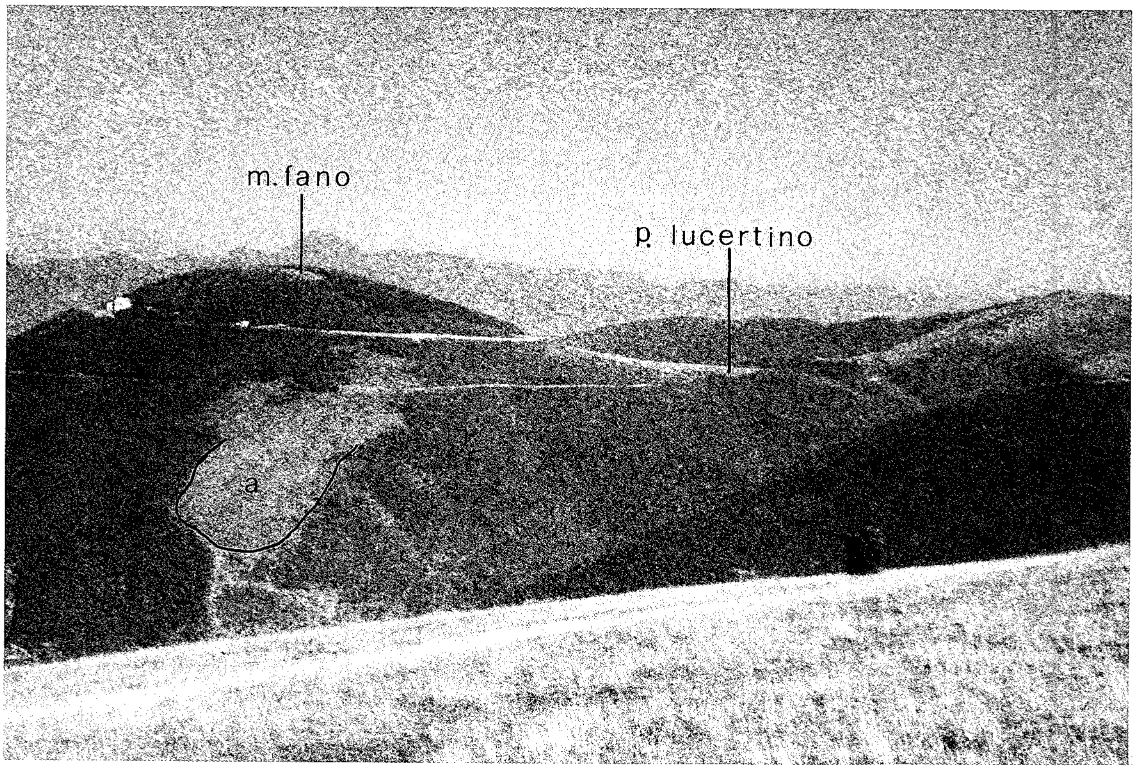

Fig. 5 - Piano Lucertino palaeovalley (summit surface South of Fabriano). a) fringe of orographic terrace (700 m a.s.l.) situated along the western side of Mt. Fano.

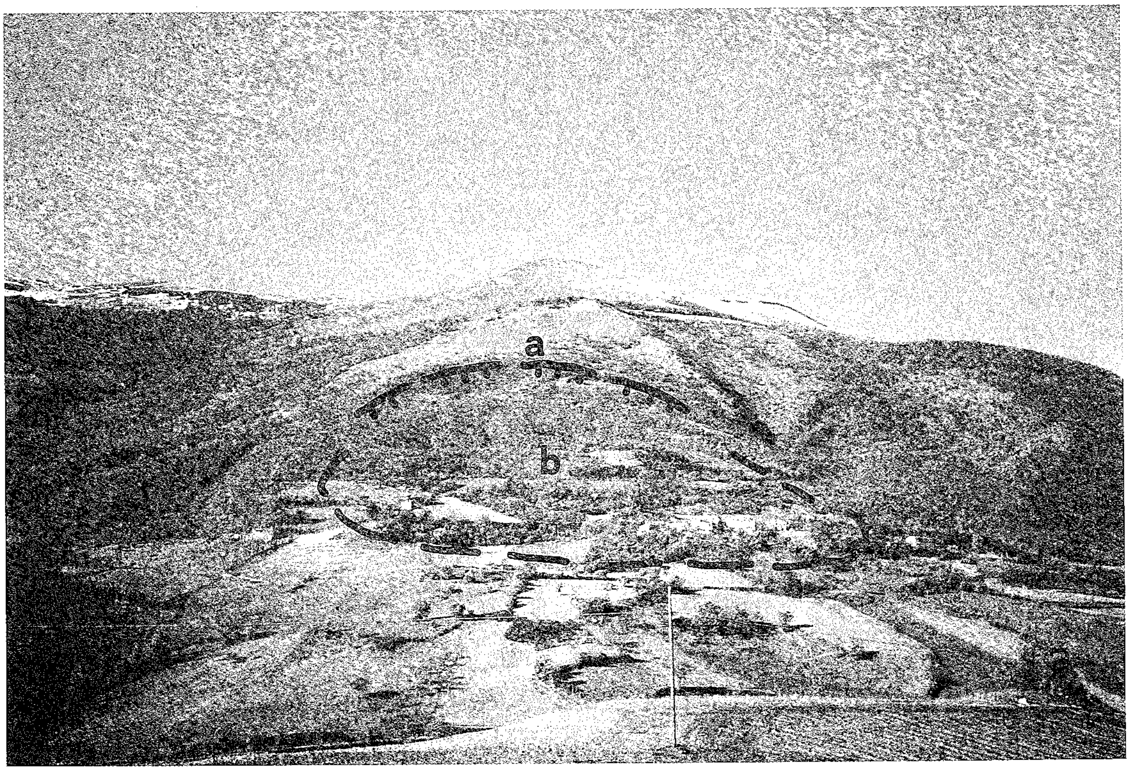

Fig. 6 - Ancient landslide at Sasso site (south of Campodonico). a) landslide edge; b) landslide body.

Fig. 7 - Fault in first order terrace, Matelica.

lanted by particularly active linear erosion (probably eased by a wetter climate). This erosion further downcut the valleys in both calcareous and terrigenous materials. The planated surface on terrigenous materials represents the last effect of the long pedimentary stage before cutting. The relicts of wide valleys cut into limestone, which were connected to the lower surface, correspond to the most elevated group of orographic terraces present along valley slopes in mountain areas.

Remains of lower orographic terraces are found inside both calcareous and terrigenous reliefs, sometimes evolving to entrenched pedimentary surfaces. These remains may identify a hiatus in deepening of erosion, consequent to a slower uplift or, more probably, to climatic changes.

During uplifting considerable changes occurred in the early hydrographic network and most of the wide transversal valleys were interrupted by the depeening of cataclinal ones along the terrigenous sinclines. Only the main rivers, characterized by greater erosive capacity and aligned along more active transversal tectonic lines, were able to maintain their course. Everywhere, the more recent Pleistocene uplift sped up deepening of drainage networks, generating narrow steep-sided valleys, especially in calcareous reliefs.

In the Middle-Upper Pleistocene, climate fluctuations complicated valley evolution; interaction between these fluctuations and tectonic uplift generated the three main orders of alluvial terraces and probably, as previously noted, the lower flat-floored wide valleys (Fig. 8c).

Most of the terraced pebbly materials were indeed emplaced during the main cold phases of the Middle and Upper Pleistocene. In these periods surficial water was overloaded by debris coming from bare slopes where gelifraction, slope-wash and solifluction were active (Coltorti *et al.*, 1983).

Consequently to the return of temperate climate and reforestation of the slopes, load-free waters deeply cut the previously deposited materials and then the underlying substratum. This process was favored by greater gradients resulting from the tectonic uplift which was still affecting the area.

Alternation of cold and temperate climates, combined with tectonic uplift, gave rise to the first three orders of terraces.

The origin of the fourth order terrace is instead different. Its materials were deposited above all as a result of anthropic deforestation (Biondi & Coltorti, 1982; Conti *et al.* 1983). On the other hand, cutting occurred in the past century as a consequence of human activities such as reforestation, construction of artificial reservoirs and, more recently (starting from the 60s), massive extraction of gravel materials from river beds (Conti *et al.* 1983).

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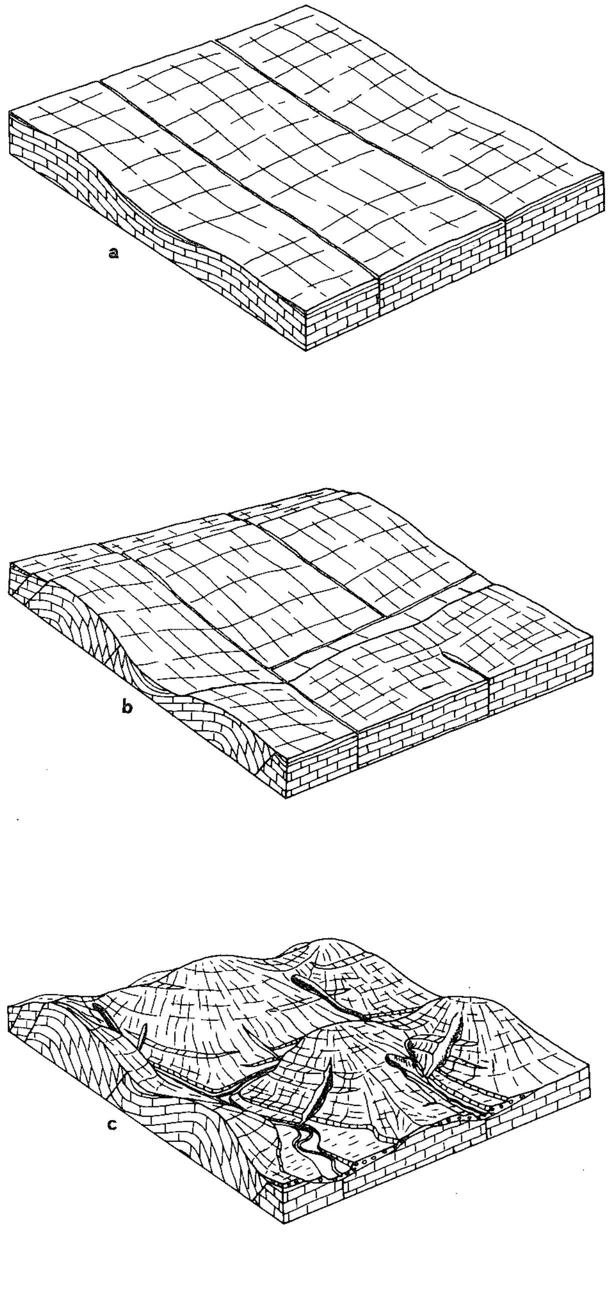

Fig. 8 - Sketch of relief evolution in the investigated area: a) Lower Pliocene; b) Mid-Upper Pliocene; c) Quaternary.

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