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MEMORIE E NOTE

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NEOTECTONIC EVOLUTION AND GEOMORPHOLOGY OF THE CASCIA AND NORCIA DEPRESSIONS (Umbria-Marche Apennine) (**)

ABSTRACT: CALAMITA F., COLTORTI M., DEIANA G., DRAMIS F. & PAMBIANCHI G., *Neotectonic evolution and Geomorphology of the Cascia and Norcia depressions (Umbria-Marche Apennine)* (IT ISSN 0084-8948, 1981).

The neotectonic and geomorphological evolution of the Norcia and Cascia depressions, which are part of a particularly important sector of the Umbria-Marche Apennine Arc, is illustrated. After the main compressive phase (end of the lower Pliocene-beginning of the middle Pliocene), which has determined a tectonic pattern consisting af three structural elements overlapping at least in part over one another (upper overthrust, lower overthrust, foredeep deposits), a long period of relative tectonic quiescence was established which lasted until the lower Pleistocene. In this area, during the above said time interval, a low relief energy landscape (« paleosurface ») was modelled, probably also in relation to climatic conditions favorable to areal erosion.

The above « paleosurface » has subsequently (lower-middle Pleistocene) been uplifted and dislocated by normal faults connected with the presence of a tensional stress field. The main new dislocations stretch with the Apennine trend and, together with other transverse faults (probably following previous strike-slip faults), have dismembered the previous structural pattern into blocks. The depressions of Norcia and Cascia correspond to two of these downthrown elements. The extensional tectonic phase has continued up to the present time as demonstrated by the direct faults, which dislocate the filling deposits of the depressions, and the seismic activity of the area, which fits very well the tensional type framework.

RIASSUNTO: CALAMITA F., COLTORTI M., DEIANA G., DRAMIS F. & PAMBIANCHI G., *Evoluzione neotettonica e geomorfologica delle conche di Norcia e Cascia (Appennino Umbro-Marchigiano)* (IT ISSN 0084-8948, 1981).

Viene illustrata l'evoluzione neotettonica e geomorfologica delle conche tettoniche di Norcia e Cascia, che fanno parte di un settore particolarmente importante dell'arco appenninico umbro-marchigiano, per l'evidenza della successione degli eventi neotettonici stessi. Dopo la principale fase di corrugamento (fine Pliocene inf.-inizio Pliocene medio) che ha determinato un edificio tettonico costituito da tre elementi strutturali almeno in parte sovrapposti tra loro (ricoprimento inferiore, ricoprimento superiore, terreni dell'avanfossa), si è stabilito un lungo periodo di relativa quiete tettonica perdurato fino al Pleistocene inferiore. In questo intervallo di tempo si è modellata una superficie a ridotta energia del rilievo (« paleosuperficie ») in relazione anche, probabilmente, a condizioni climatiche favorevoli all'erosione areale.

Detta « paleosuperficie » è stata successivamente (Pleistocene inf.-medio) sollevata e dislocata da faglie normali connesse con un campo di *stress* distensivo. Le principali dislocazioni di neoformazione hanno andamento appenninico ed insieme ad altre faglie trasversali (probabilmente impostate lungo precedenti linee trascorrenti) hanno scomposto il precedente edificio strutturale in blocchi. Le depressioni di Norcia e Cascia corrispondono a due di questi elementi ribassati. La Tettonica distensiva è proseguita fino ai tempi attuali, come dimostrano la ripresa delle faglie dirette che dislocano i depositi di riempimento delle conche e l'attività sismica dell'area che ben si inquadra in un campo di *stress* di tipo tensionale.

TERMINI-CHIAVE: Neotettonica, Geomorfologia, Appennino Umbro-Marchigiano.

FOREWORD

This paper is part of the integrated research of Geology and Geomorphology which the Institute of Geology of the University of Camerino has been carrying out for several years in the Umbria-Marche region, within the CNR (Italian National Research Council) Progetto Finalizzato Geodinamica. Such research, whose results have been published in part, have as their aim the reconstruction of recent tectonic events. Both geologic and geomorphologic methods are being utilized in the pursuit of this aim. The integrated use of such methods is, in fact, necessary for the study of an area whose neotectonic evolution has in large part occurred in a continental context.

The area examined in the paper, includes a sector of the Umbria-Marche Apennine which is particularly important in pointing up the succession of neotectonic events. The depressions of Castelluccio, Norcia and Cascia, located in this area, represent, in fact, a typical morphostructural element of the Umbria-Marche Apennine. The research has been carried out in the Norcia and Cascia areas, where the continental stratigraphic sequences are well exposed.

The surveys were planned and directed by DEIANA G. (geological aspects) and DRAMIS F. (geomorphological aspects). COLTORTI M. contributed by making the geomorphological survey and CALAMITA F. in making the geological survey. PAMBIANCHI G. surveyed some geologic sections controlling the correlation between faults and geomorphological evidences.

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(**) *C.N.R. - Progetto Finalizzato Geodinamica, pubbl. n. 457.*

GEOLOGICAL SETTING

The Umbria-Marche Apennine Arc is constituted by a system of folds with Adriatic vergence. Associated with the fold structures are reverse faults and overthrust which, in places, result in clearly visible tectonic doubling of the sedimentary cover. Transcurrent faults with anti-Apennine trend fragment this system into sectors with differentiated plicative deformation. Among such faults the « Line of the Valle del Chienti » seems to have considerable importance as the dividing element between a northern rather lightly folded area and a southern area characterized instead by widespread overthrusts and by severe shortening of the cover (DEIANA, 1979; AMBROSETTI & *alii*, in press). Moreover, various direct faults exist among which the Apennine and anti-Apennine trends are particularly important. The former is characterized both by the length (sometimes greater than 50 km) and the throw (often greater than 1 000 m) of the faults composing it and is especially developed in the southern part of the arc, where the tectonic depressions of Norcia and Cascia are located. The latter represents, in general, the reactivation of older transcurrent dislocations (AMBROSETTI & *alii*, in press).

STRATIGRAPHY

The stratigraphic sequence cropping out in the area shows, at the base, a carbonate platform thick formation (« Calcare Massiccio », lower Lias), underlying calcareous units with cherty and marly beds and calcareo-siliceous and marly-clayey units deposited in a pelagic environment from the middle Lias to the upper Miocene.

A disjunctive synsedimentary tectonic phase, occurred at the beginning of the middle Lias, dismembered the carbonate platform into several seamounts and basins which, during the Jurassic, became places for deposition respectively of condensed sequences (« Calcari Nodulari ») and complete sequences (« Corniola », « Calcari e Marne del Sentino » and/or « Rosso Ammonitico », « Calcari a Posidonia ». « Calcari Diasprini Umbro-marchigiani »). The pulsating synsedimentary tectonics acted, although attenuated, throughout the entire period, causing further sinkings of seamounts with the consequent enlargement of the basinal areas. In this way composite sequences were deposited consisting of units of the condensed sequences at the bottom, and of units of the complete sequence at the top (CENTAMORE & *alii*, 1971; CHIOCCHINI & *alii*, 1976).

At the beginning of the Cretaceous the pelagic environment became almost uniform and the same units were deposited everywhere, although with differing thicknesses (« Maiolica », « Marne a Fucoidi », « Scaglia Rosata », « Scaglia Cinerea », « Bisciaro » and « Schlier »). The pelagic conditions persisted until the upper Miocene when, with the turbidite sedimentation in the Laga basin to the East and in some minor basins to the North, the tectonic phases which led to the construction of this portion of the Apennine chain had their beginning.

It is to be noted that the pelagic units of the area differ, sometimes considerably, in their lithologic characteristic, from the classic ones of the Umbria-Marche domain due to the presence of numerous and at times thick calcareodetritic bedsets. These last ones derived mainly from the Latium-Abruzzi carbonate platform presently situated SSE of the Umbrian realm. Finally, we recall that in Umbria and northern Marche, upper Triassic dolostones and anhydrites (« Anidriti di Burano ») (MARTINIS & PIERI, 1964) have been drilled in bore holes (Fossombrone 1, Burano and Perugia 2) below the « Calcare Massiccio » formation. Such formation constitutes an incompetent level interposed between the sedimentary cover and the underlying crystalline basement. Neither does the latter crop out in the Umbria-Marche area, but it has been drilled by the Perugia 2 borehole even if for only a slight thickness.

TECTONIC PATTERN

The present structural setting of the area is the result of tectonic phases that have been active since the upper Miocene until today. Briefly, we can distinguish two successive periods of deformation, one compressive and the other extensional.

During the first period (divided into several episodes from the Tortonian to the middle Pliocene) folds, reverse faults and overthrusts (associated with transcurrent faults) have been formed which have determined severe shortening of the sedimentary cover, completely disharmonic with the underlying basement due to the probable interposition of the « Anidriti di Burano ».

In the studied area at least three structural elements connected with the mentioned compressional period, partly overlapping one another, have been identified (CALAMITA & *alii*, in press) (fig. 1).

1) Upper overthrust (whose root area is unknown) consisting of two structures differently displaced eastward, whose relation to each other is not observable at present.

2) Lower overthrust which constitutes the substratum underlying the preceding overthrust and which, in turn, was superposed over the units of the foredeep.

3) Foredeep units, which constitute the lowest element and are, in turn, folded and overturned eastward.

The relative stratigraphic sequence are represented respectively by columns A, B, C of fig. 2.

1) The highest structural element is constituted by two structures. One corresponding to the Mt. Macchialunga-Mt. Patino-Mt. Vetica range and located North and Northeast of the Norcia depression, represents an anticline overturned and overthrust eastwards over a substratum outcropping not only East of the overthrust front, but also on the side of the above said depression. The other, corresponding to the Mt. Pozzoni-Mt. Sassatelli-Castel S. Maria-S. Marco area and located South of the depression, also represents a fold overturned and overthrust eastward, divided by an E-W trending right transcurrent fault (Manigi-S. Andrea Fault).

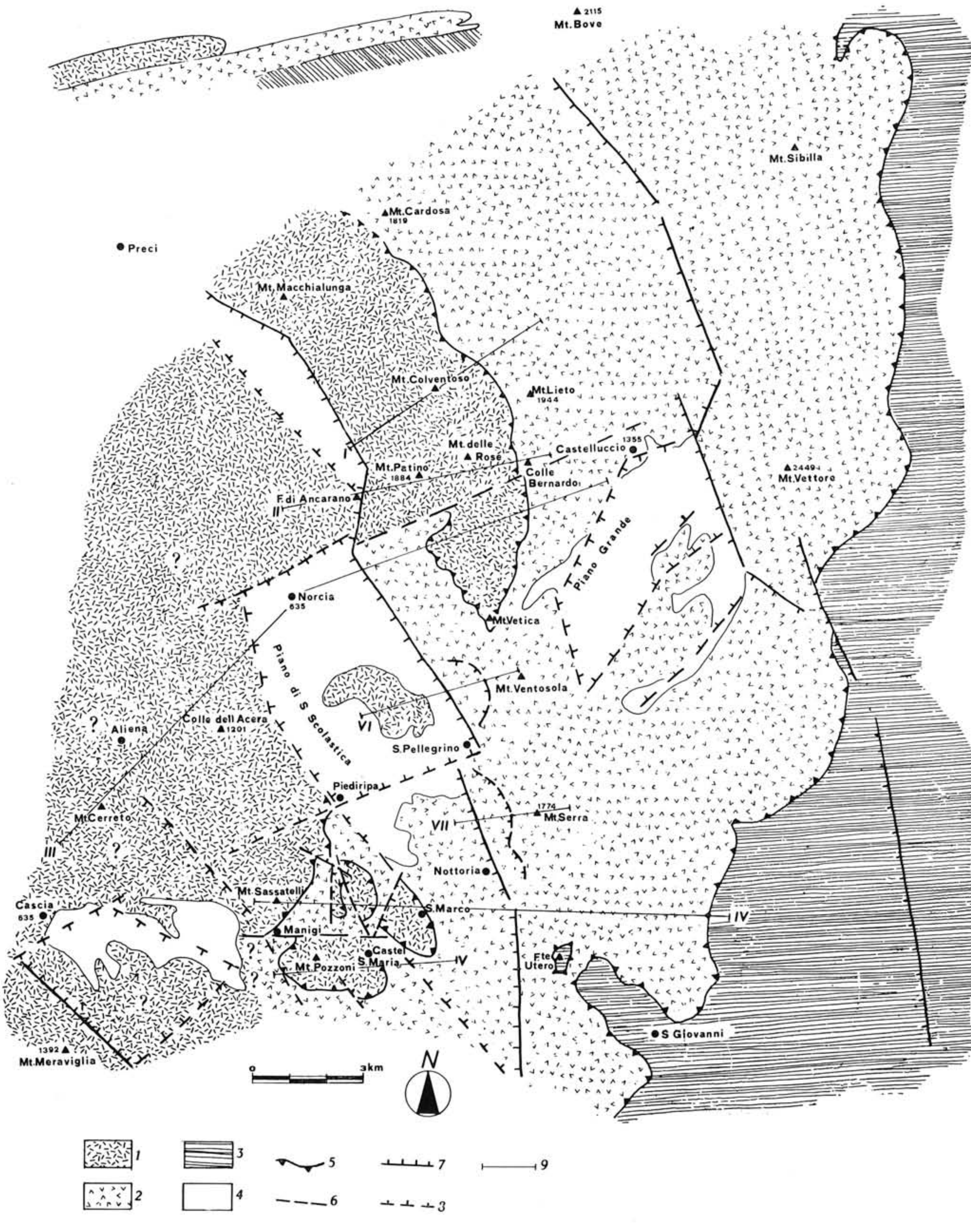

FIG. 1 - Structural scheme of the Castelluccio, Norcia and Cascia depressions: 1) upper overthrust units; 2) lower overthrust units; 3) foredeep units; 4) deposits filling the depressions; 5) trace of overthrust planes; 6) transcurrent faults; 7) main normal faults; 8) secondary normal faults; 9) trace of the geological sections.

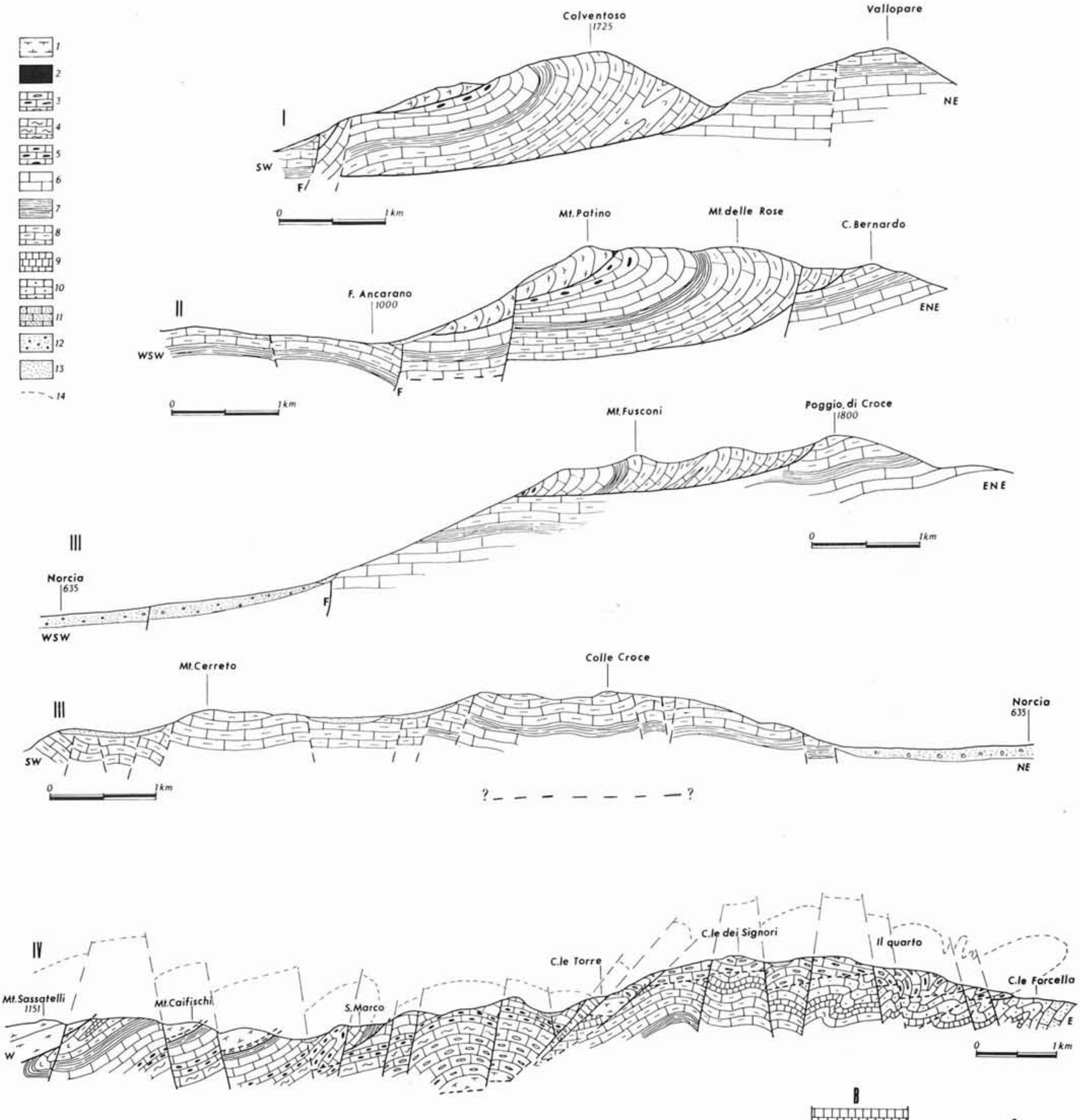

FIG. 2 - Geologic sections (I to V in fig. 1) and stratigraphic logs of the upper overthrust (A), lower overthrust (B), and foredeep units (C), in the southern part of the area: 1) « Calcare Massiccio » (lower Lias); 2) « Calcari nodulari del Bugarone » (middle Lias - lower Tithonian); 3) « Corniola » (middle Lias); 4) « Rosso ammonitico and Calcari e marne del Sentino » (upper Lias - Dogger *p.p.*); 5) « Calcari a Posidonia and Calcari diasprini umbro-marchigiani » (Dogger *p.p.* - lower Tithonian); 6) « Maiolica » (upper Tithonian - lower Aptian); 7) « Marne a Fucoidi » (Aptian *p.p.* - Cenomanian *p.p.*); 8) « Scaglia Rosata » (Cenomanian *p.p.* - middle Eocene); 9) « Scaglia Cinerea » (middle Eocene - Oligocene); 10) « Bisciaro », « Marne con cerrogna » and « Marne a Pteropodi » (Aquitanian - Messinian *p.p.*); 11) Turbidites of the « Laga Formation » (Messinian); 12) lacustrine and alluvial fan deposits (Quaternary); 13) slope debris (Quaternary); 14) probable trend of the « Maiolica » top (sect. IV and V).

The two structures seem to have shifted differently but their primary relationship is unknown, although it is likely that they had to be separated by transcurrent faults, one of which can be identified the Pierdiripa-S. Pellegrino Fault.

2) The units representing the substratum underlying the upper structural element constitute a complex structure largely overthrusted above the units of the foredeep. Section 4th of fig. 2 illustrates the structural pattern of the southern part of the area in which the overthrusted element essentially represents the normal limb of a recumbent anticlinal constituted almost exclusively by the « Corniola » formation.

3) The foredeep units can be well recognized under the lower overthrust in the area's southern part, along S. Giovanni Valley and, more to the West, they crop out in the Fonte Utéro Tectonic Window. These units have been folded, faulted and overturned above the « Laga Formation » turbidites.

The shortening of the sedimentary cover due to the compressive stage, South of the Norcia depression, excedes 50 %. The interpretative schematic profile of fig. 1 refers to this area and illustrates the structural setting at the end of the compressive stage.

During the tensional stage (probably started during the upper Pliocene-lower Pleistocene) several normal faults were produced, among which the most important show an Apenninic trend (SCARSELLA, 1941; DAMIANI, 1975; CENTAMORE, & *alii*, 1980). The present overall morpho-structural pattern of the area is due to two large Apennine trending normal faults (Mt. Vettore-Mt. Bove Fault eastward and Nottoria-Preci Fault westward [1]), which cut the axes of the plicative structures and determine three large blocks downthrown from NE to SW (CALAMITA & *alii*, 1979) (fig. 1). The highest block includes, among others, Mt. Vettore and Mt. Bove and is bordered on the West by the first of the above said faults which, in the vicinity of Mt. Vettore, dislocates the « Anzio-Ancona Line » *Auct.* The intermediate block includes, among others, Mt. Serra, Mt. Patino, Mt. Lieto and Mt. Cardosa and comprises the tectonic depression of Piani di Castelluccio. It is bounded by both the aforesaid tectonic lines. The western block includes reliefs of lower altitude than the foregoing and the two tectonic depression of Norcia (fig. 3) and Cascia (fig. 4), separated from each other by the Mt. Sassatelli-Colle dell'Acera ridge.

[1] These consist of a group of faults, sometimes with different trend, which on the whole stretch the Apenninic trend. Such faults are mostly neoformation faults, although sometimes they can reactivate older faults.

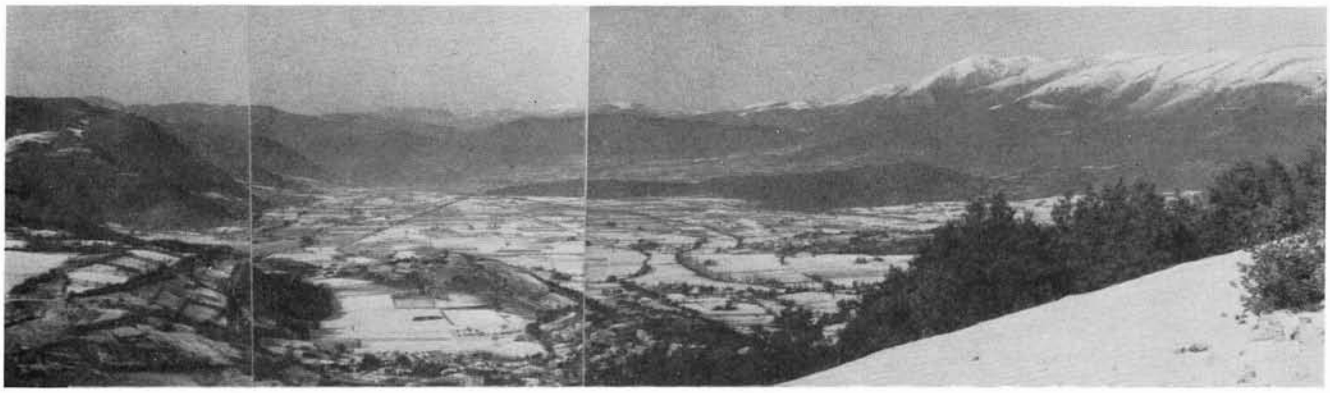

FIG. 3 - View of the Norcia depression on the western block, bounded to the East (right side of the picture) by the Nottoria-Preci normal fault.

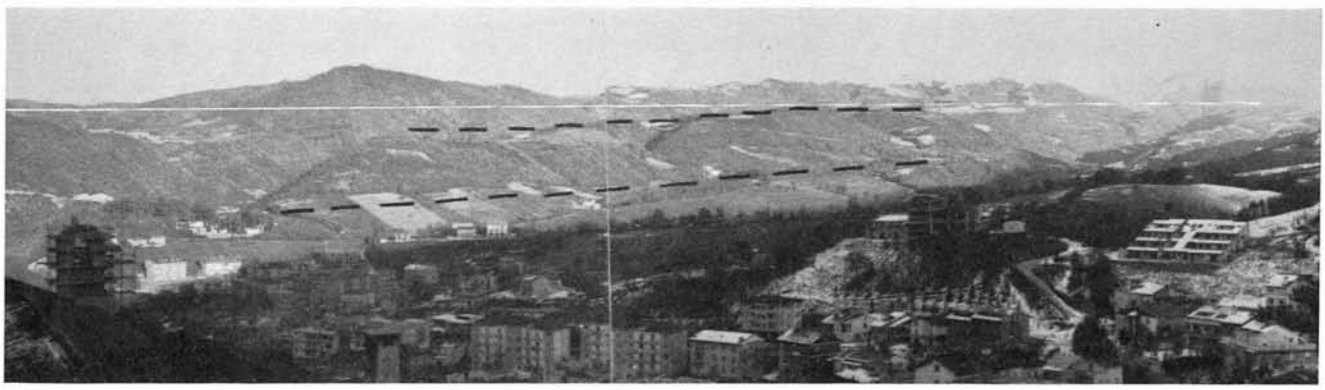

FIG. 4 - Partial view of the Cascia depression, bounded to the North-East by fault steps (in the background).

West of Cascia the Mt. Meraviglia-Mt. Maggio ridge, bounded on the side of the depression by important direct Apennine trending faults, can be recognized.

Along with the direct Apennine trending faults other anti-Apenninic trending normal faults exist, which together with the former, define smaller prismatic blocks. The depressions of Castelluccio, Norcia and Cascia correspond precisely to a number of these small structural elements inside the above mentioned large blocks.

FIG. 5 - Low dip normal fault in the slope of Mt. Serra (eastern side of the Norcia depression).

FIG. 6 - Apennine trending normal fault dislocating coarse deposits filling the Norcia depression (2nd unit).

Moreover, secondary low dip (40-45°) normal faults showing considerable morphological evidence (fig. 5), are connected with the main dislocations.

Sections 1st and 2nd of fig. 2 show the Mt. Vetica-Mt. Macchialunga overturned and overthrusted anticline (upper overthrust) truncated by the important Nottoria-Preci normal fault (F). The downthrown part represents the normal limb of the fold, eliminated by erosion in its uplifted part (Mt. Patino). The location and the depth of the plane of the overthrust are hypothetical and are drawn undefinied to the west of the fault whose throw largely exceeds 1 000 m.

Section 3rd of fig. 2 shows the southern part of the Mt. Vetica-Mt. Macchialunga structure thrust over the units of the lower overthrust along a subhorizontal plane cropping out on the eastern side of the Norcia depression. The sequence observed between the Norcia and Cascia depressions (represented in the western part of the profile) likely constitutes the normal limb of the fold, downthrown at least 1 000 metres with respect to the Nottoria-Preci Fault (F): under this sequence, therefore, the plane of overthrust should be found. The extension of this plane westwards, at the present stage of study, is very hypothetical. Hence the assignment of the sequence in the Cascia area as belonging to the upper overthrust is to be considered dubitative and provisional.

The role of tensional Tectonics appears evident in section 4th of fig. 2. It shows the structural setting of the southern area, constituted by the superposition of the structural elements above described, strongly fragmented by normal faults subsequent to the compressive phases. The present-day morphostructural setting is essentially due to the rigid more recent tectonics. One can observe a series of small blocks downthrown in steps at the sides of the major reliefs. Particularly interesting is the western portion of the section where both normal faults (which successively downthrow the blocks eastward) and the erosion allow the outcropping of the units of the lower over thrust (fig. 7).

Section 5th of fig. 2 has similar significance. It shows the effect of the tensional Tectonics on the units of the upper overthrust South of the Manigi-S. Andrea transcurrent fault.

The extensional Tectonics continued throughout the Quaternary as shown by dislocation of the continental sediments filling the Norcia and Cascia depressions (fig. 6)

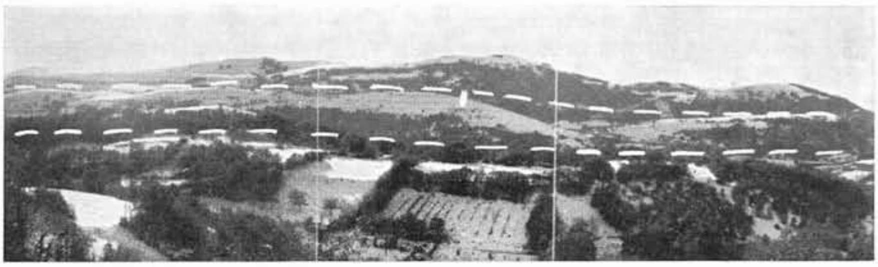

FIG. 7 - Stepped morphostructural setting West of San Marco (South of the Norcia depression). The upper part of the steps represent downthrown remnants of the « paleosurface ». The structural building consists of the upper and lower overthrusts.

FIG. 8 - Schematic geomorphologic map of the Norcia and Cascia area: 1) « paleosurface » edge; 2) erosional scarp; 3) main fault scarp; 4) faults and joints in surficial deposits; 5) nival circus; 6) landslide crown; 7) landslide body; 8) through floored valley; 9) V-shaped valley; 10) alluvial deposits of the 5th unit; 11) alluvial deposits of the 4th unit; 12) alluvial deposits of the 3rd unit; 13) alluvial deposits of the 2nd unit; 14) lacustrine deposits of the 2nd unit; 15) alluvial deposits of the 1st unit; 16) lacustrine deposits between the Norcia and Cascia depressions; 17) slope deposits correlable with the 4th alluvial unit; 18) slope deposits correlable with the 3rd alluvial unit; 19) cemented slope debris of Nottoria.

Mt. Patino
Mt. Ventosola
NORCIA
Sordo R.
Corno R.
CASCIA
Mt. Meraviglia
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
0
2 km
N

(dislocated alluvional fan of Mt. Patino and tilted and faulted lacustrine deposits of Cascia).

Present day extensional activity bears witness of the seismic phenomena involving the area: the solutions of the focal mechanism of such events indicate, in fact, a deep stress field of tensional type (RITSEMA, 1970; CAGNETTI & *alii,* 1978; WISE & *alii*, 1979; GASPARINI & *alii*, 1980). Also prevalently of tensional type is the stress field which is derived from overall picture of the solutions of the mechanism of recent seismic events in the Norcia area (DEIANA & *alii*, 1980; GASPARINI & *alii*, 1980).

As far as such recent events are concerned, it must be pointed out that the major part of the earthquake foci are located in the crystalline basement, that is, deeper than 5 km. Of these, those falling between 5 and 10 km (which are by far the most numerous) constitute a subvertical belt along the deep prosecution of the Nottoria-Preci tectonic line; those between 10 and 12 km are grouped along the Mt. Meraviglia-Mt. Maggio Line (DEIANA & *alii*, 1980).

Finally the recent tectonic evolution of the area is controlled by a persistent tensional stress field, to which the present-day morphostructural pattern is related. However, limited evidence of compressive structures (such as small folds and reverse faults affecting the lacustrine deposits of the 2nd unit, and small deformations of the overthrust planes) may suggest the occurence of compressive episodes in a tectonic framework controlled, in general, by tensional stress. Similar evidence has also been recognized in other partes of the Umbria-Marche Apennine (CENTAMORE & *alii*, 1978a; 1978b; COLTORTI, 1981; CENTAMORE & *alii*, in press).

GEOMORPHOLOGICAL ASPECTS OF THE AREA

The Norcia and Cascia depressions are located within the Umbria-Marche Apennine, immediately to the East of the highest part of the chain which culminates in Mt. Vettore (2 422 m). Consensus exists that their genesis may be attributed to tectonic phenomena (LOTTI, 1926; SCARSELLA, 1947; DAMIANI, 1975; CALAMITA & *alii*, 1979).

The area, as we have seen, is characterized by an essentially calcareous substratum which has undergone a complex tectonic evolution, the first evidence of which dates from the middle Liassic. Its present morphostructural setting is nevertheless due to the extensional Tectonics acting during the Quaternary, connected with a strong general uplift.

The forms and the deposits are the result of interaction between the neotectonic activity and climatic events, among which the variation in climate beginning from the lower-middle Pleistocene has had particular importance.

The principal geomorphological elements characterizing the area will now be illustrated (fig. 8).

« PALEOSURFACE »

The traces of an ancient landscape characterized in general by low relief energy (« paleosurface ») are evident on the summits of the area's reliefs.

The above mentioned morphological element is recognized throughout the Umbria-Marche region (DESPLANQUES, 1969; DEIANA & PIERUCCINI, 1976; CALAMITA & *alii*, 1979; CARRARO & *alii*, 1979) and has also been found in the nearby Abruzzi (DEMANGEOT, 1965), in Emilia Romagna (LIPPARINI, 1935; PANIZZA, 1968; BERNINI & *alii*, 1977; MARCHETTI & *alii*, 1979) and Tuscany (SESTINI, 1939; BARTOLINI, 1980).

The « paleosurface » is recognized by field observation, but mainly by the examination of aerial photographs from which a distinct contrast results between summit morphology, with low relief energy, and valley morphology, with noticeably steep slopes which, at times, delimit gorges. An old landscape in which, on the whole, areal erosion phenomena predominate is contrasted with a younger one affected prevalently by linear erosion.

This form is visibly dismembered by faults along which scarps more or less reshaped by erosion have been produced (fig. 7).

Erosional processes have broken the continuity of the « paleosurface », thereby reducing its outcrops to a few strips. Sometimes any evidence of the « paleosurface » disappear completely and the only clue to its existence could be represented by peaks of equal height.

The origin of the initial subaerial surface of the area is to be traced back to the first emersion phenomena likely started at the end of the Messinian (CENTAMORE & *alii,* 1975).

This surface has been subsequently more or less modified, especially in connection with the tectonic phase of the lower-middle Pliocene to which the formation of important orographic height differences must have been associated. We can suppose that the reduced relief-energy landscape has begun to be modelled starting from that moment, in coincidence with a period of relative tectonic quiet lasting until the lower-middle Pleistocene. The latter represents a new paroxysmal moment to which the faulting which dismembered the surface is tied. Tectonic quiescence is not meant to signify total cessation of deformation processes, but rather an interval of time between paroxysmal phases, during which the morphological effects of tectonic activity can be compensated by erosional action, in order to reach, moment by moment, a surface with low relief energy at relatively low altitudes above the general base level. Climatic conditions favourable to the areal erosion have probably contributed to the evolution of the surface in question.

Inasmuch as the basal deposits of the Norcia and Cascia depressions are attributable, as will be seen, to the lower-middle Pleistocene and inasmuch as the principal compressive phase is referable to the lower-middle Pliocene, the « paleosurface » ought to have been modelled during the time interval elapsed between these two moments.

ALLUVIAL AND LACUSTRINE DEPOSITS

Pebbly and sandy deposits (5th unit) are present in today's valley bottoms of the Corno River and its tributaries. Such deposits rarely exceed a thickness of 2-3 metres and overlie pebbly less coarse grained sediments characterized by subrounded imbricated clastics (4th unit) laterally connected to the debris deposits at the foot of the slopes, formed under periglacial conditions, likely during the last cold Pleistocene phase.

A first terraced unit, placed at 3-5 metres above the present talweg, consists of more or less angular, pebbly material intercalated with sandy levels (3rd unit). Often the material of this unit have undergone fair cementation and have been weathered by fersiallitic paleosols, and are somewhat truncated.

At heights over 20 metres above the talweg there are lacustrine and alluvial fan deposits (fig. 9) of an older terraced unit (2nd unit). In the Norcia depression the alluvial fan deposits constitute the uppermost portion of the last unit. The tips of such alluvial fans have generally been truncated by tectonic movements subsequent to their deposition and sometimes are cut by linear erosion. Sometimes they are covered by more recent deposits.

FIG. 9 - Alluvial fan cemented rudite deposits (2nd unit). They are faulted in the vicinity of Norcia.

The above said unit, in the vicinity of Nottoria, is constituted by strongly cemented subangular fragments which rest unconformably on stratified breccias of cryoclastic origin. Similar deposits, displaced by the Nottoria-Preci fault and correlable with the foregoing, are observed further upstream in the Fonte Utéro locality.

The oldest alluvial unit (1st unit) is constituted by pebbly deposits outcropping in small and suspended strips above the deposits of the 2nd unit. This has been found near Forca di Ancarano and Casali di Legogne, within wide valleys which cut about 200 m the « paleosurface ». Because the fault which limits to the North the Norcia depression has cut such valleys, it is probable that the materials of this unit are now located at the base of the depression's filling.

In the Cascia depression the deposits of the first three units are well represented and can be correlated with those illustrated above for the Norcia depression.

Moreover near the town there are clayey and silty lacustrine deposits, interbedded with pebbly level and cut for over thirty metres by the valley of the Corno River, in which deposits of the 3rd unit outcrop. Not far from the cemetery, the top of the lacustrine sequence is constituted by very distinct volcanoclastic silty and sandy deposits interbedded with blackish clayey levels (fig. 10). The pebbly deposits become progressively more abundant on the sides, toward the scarps of the faults that delimit the depression.

The last described deposits can be correlated, on a geomorphological basis, with those assigned at Norcia to the 2nd unit.

Above the fault scarps that delimit the depression to the northeast and southwest, other depositional elements can be recognized on terraces lying as high as 200 metres above the valley bottom. These medium to coarse grained subrounded, at times imbricated, gravel deposits are interbedded with sandy levels. The observable thickness of the deposits is several tens of metres in some cases such as, for example, along the road from Cascia to Leonessa.

Near the village of Colmotino, built on one of the above said terraces, a recent excavation at the top of the deposits shows the outcropping of a truncated paleosol whose observable profile is approximately two metres.

FIG. 10 - Lacustrine deposits consisting mainly of volcanoclastics in the vicinity of Cimitero di Cascia. A slump level can be observed in the central part of the picture.

The pebbly deposit is totally leached and inside the argillic horizon the framework is constituted essentially by siliceous and pyro-clastic fragments. The colour of some levels is in the order of 5 YR reddish-brown and reddish and is due to the high concentration of iron oxides. It is a leached fersiallitic soil which has evolved under dry climate conditions marked by sharp seasonal contrasts, lasting a long time (BIRKELAND, 1974; DUCHAUFOUR, 1977). Soils of such degree of evolution have been noted in the Abruzzi (DEMANGEOT, 1965) and in the Po area (FERRARI & MAGALDI, 1968; CREMASCHI & PAPANI, 1975; COLTORTI, 1979; COLTORTI & *alii*, in press) and have been referred at least to the « Mindel »-« Riss » interglacial.

Soils showing a comparable evolution have also been observed in the Norcia depression, both at the top of the 2nd unit alluvial fans (Madonna Bella, C. Angeloni, Nottoria) and on the bedrock (Valcaldara).

The presence of faults and the absence of sections which satisfactorly demonstrate interfingering among the various filling deposits is a hindrance in estabilishing the relationship among the various dislocated elements. It is possible, however, that the units lying at higher elevations represent the equivalent of the deposits located at the northern edge of the Norcia depression (1st unit).

Lacustrine deposits with scanty pebbly deposits and pyroclastic levels outcrop in a number of smaller tectonic depressions such as the Fogliano and Avendita ones, situated within the « paleosurface » between Norcia and Cascia. The estabilished presence of a number of paleolithic finds (scrapers, arrows, nucleous etc. of Levallois *facies*) at the top of such deposits confirms their age as dating from at least the middle Pleistocene. Considering the geomorphological continuity between the depositional surfaces of Colmotino and Fogliano, and the tectonic dislocations which separate the latter from that of Avendita, it seems reasonable to assume that their deposits are contemporary.

PERIGLACIAL FORMS AND DEPOSITS

Pleistocene periglacial morphogenesis has largely modelled the area's landscape. The limestone slopes, devoid of their vegetation cover because of the cold periods, were the site of generalized frost shattering which produced large quantities of waste material, probably also favored by concomitant tectonic activity. Such materials were then transported downwards by various processes such as sliding on snow or ice, pipkrake, solifluction and, above all, the widespread slope-wash fed by snow melting. They were deposited in characteristic and thick stratified accumulations (*éboulis ordonnés*) (fig. 11) at the foot of slopes or in small valleys which at times were completely obliterated. On the higher slopes such processes produced extensive forms of rectification.

FIG. 11 - Stratified slope deposits (*éboulis ordonnés*) along the Corno Valley.

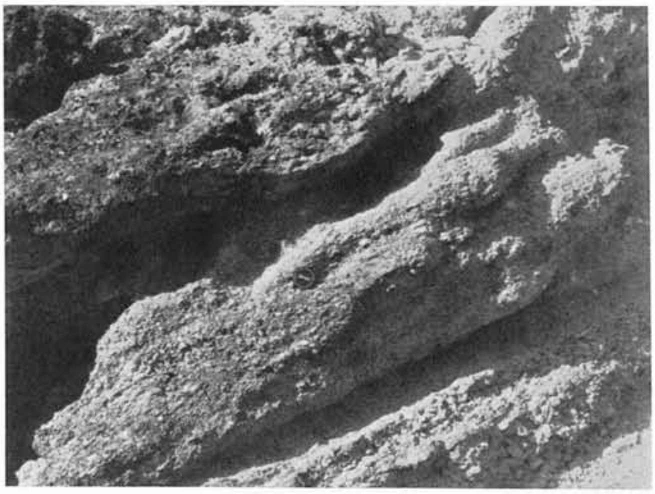

FIG. 12 - Bedded breccias at the base of the 2nd unit deposits, near Nottoria.

As observed throughout the Umbria-Marche Apennine (COLTORTI & *alii*, 1979; DRAMIS & *alii*, 1980) also in the Norcia and Cascia area several generations of stratified debris are recognized which, at times, interfinger with the alluvial deposits of the 4th and 3rd units. An older deposit of this type is represented, as has been said, by the breccias of Fonte Utéro and Nottoria, the latter being found at the base of the alluvial deposits of the 2nd unit (fig. 12). Smaller forms connected with Pleistocene periglacial morphogenesis are represented by small nivation hollows cut at the top of the slopes, which bound the Norcia depression at the East, and on the reliefs South of Cascia.

CHRONOLOGY OF THE DEPOSITS

The chronological attribution of the deposits in the Norcia and Cascia depressions is rather difficult inasmuch as for the time being fully satisfactory reference data are lacking.

However a close analogy has been observed between the main local phases of erosion and accumulation and those which have been found in various localities of the Marche region. Here, four terraced alluvial units have been noted which are situated at progressively increasing altitudes from the bottom of the valley. Geomorphological and pedostratigraphic evidence as well as radiometric dating and paleo-ethnological findings (DAMIANI

& Moretti, 1969; Alessio & *alii*, 1979; Coltorti & *alii*, in press) have caused these units to be attributed respectively to the Holocene and to the main cold phases of the upper Pleistocene (« Würm ») and middle Pleistocene (« Riss » and « Mindel »).

Among the main analogies observed, particular importance is attributed to the interstratification of the alluvial materials with slope-wash deposits dating back to periglacial conditions (4th, 3rd and 2nd unit) and fersiallitic paleosols showing an increasing degree of alteration at the summit of the 3rd and 2nd unit deposits.

It seems possible therefore to attribute the alluvial deposits of the 5th unit to the Holocene, those of the 4th to the upper Pleistocene and the ones of the 3rd and 2nd units to the middle Pleistocene. These chronological references obviously also apply to the stratified slope deposits wich correlate to the alluvial units.

Finally, the deposits of the 1st unit can be correlated with the deposits observed at comparable altitudes in the neighbouring area of Rieti and in Umbria and referred to the lower-middle Pleistocene (Raffy, 1979).

THE AREA'S NEOTECTONIC AND GEOMORPHOLOGICAL EVOLUTION PATTERN

The following steps illustrate the area's neotectonic and geomorphological evolution:

1) Modelling of a « paleosurface » during a period of relative tectonic quiescence over an already plicated substratum (middle Pliocene to lower-middle Pleistocene) (fig. 13a).

In our Apennine a long time interval is interposed between the principal fold phase (end of the lower Pliocene-beginning of the middle Pliocene) and the most important moment of the tectonic extensional activity (lower-middle Pleistocene). The former is clearly documented in the foredeep by the middle Pliocene transgressive deposits above older folded ones. Differences of level between the Apennine proper and the foredeep are attributable to the plicative phases, as is demonstrated by the presence and abundance of limestone pebbles at the base of the transgressive deposits. The extensional phase associated with general uplift may be deduced from the first appearance of abundant calcareous clastics (likely derived from the erosion of the uplifted areas) in the intra-Apennine tectonic depressions, as well as by the presence of the same clastics in the late-Calabrian sediments in the more external areas of the foredeep. Such clastics were transported from the Apennine uplifted areas.

It is probable that, during the above said time interval of tectonic relative quiescence, the Apennine Arc may have suffered the incipient extensional activity which reached its acme later. This is demonstrated by the fact that in several cases the throws of the normal faults are considerably greater than the fault scarps height dislocating the « paleosurface » remnants.

In this framework the moment in which the stress-field changes (from compressive to extensional) is of little relevance to the modelling of the « paleosurface », the time interval elapsed betwen paroxysmal phases, of a different type, counting much more. Considerable importance is attributed, on the other hand, to the climatic conditions which must have favoured the areal erosional processes.

2) Rapid uplifting of the area and first geomorphological and sedimentary evidences of tectonic extensional activity which dislocates the « paleosurface ». The uplift-

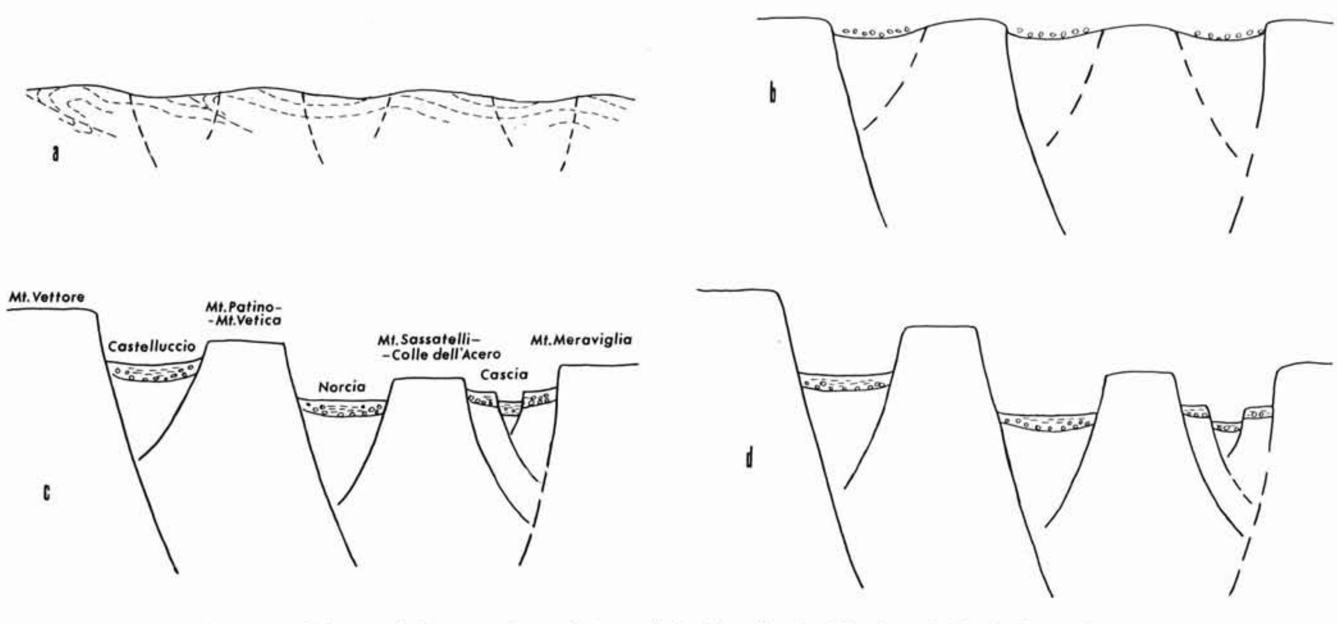

Fig. 13 - Scheme of the tectonic evolution of the Castelluccio, Norcia and Cascia depressions.

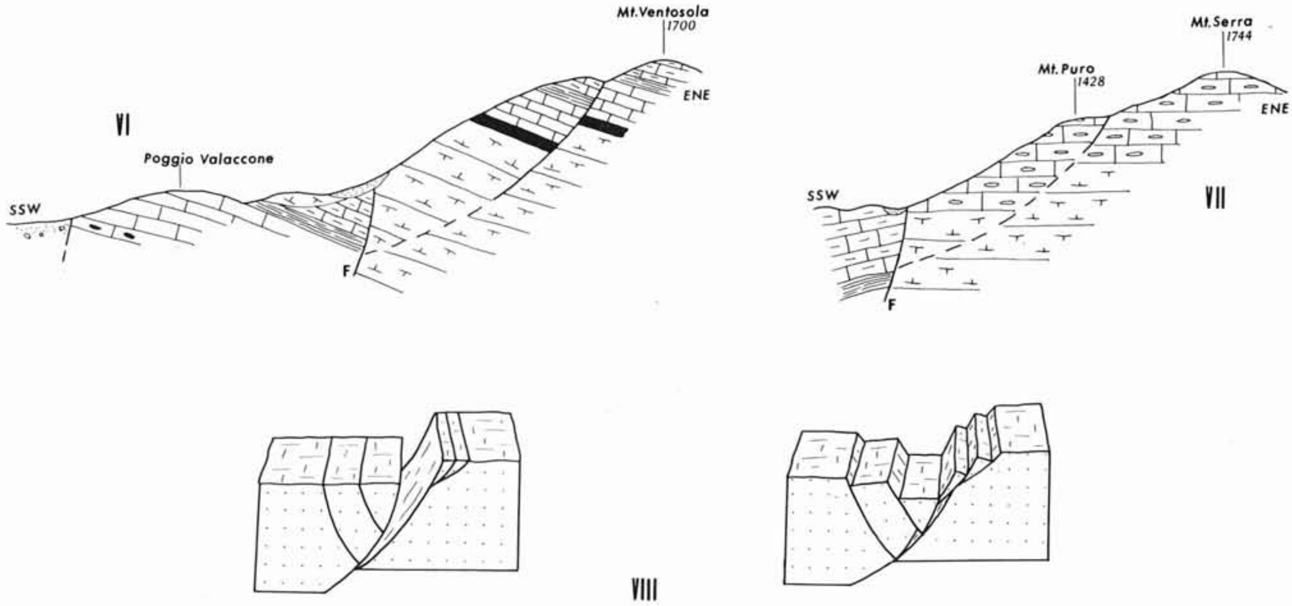

FIG. 14 - Geological sections (VI and VII in fig. 1) crossing the Mt. Ventosola and Mt. Serra low dip normal faults and possible genetic scheme (VIII). As to the legend see fig. 2.

ing causes a strong intensification of the linear erosion, to which the deep stream valleys which break the continuity of the same « paleosurface » can be referred. The tectonic activity is expressed particularly along the Mt. Vettore-Mt. Bove faults, but also along the minor faults within the downthrown areas. The oldest continental clastic deposits (lower-middle Pleistocene) are connected to that drainage network (fig. 13b).

3) The extensional process is fully in action. The Apennine faults (the main ones, in particular) are still acting. But also anti-Apennine normal faults are activated which, together with the former, create the tectonic depression of Castelluccio, Norcia and Cascia (fig. 13c). Several tens of metres of lacustrine and alluvial fan sediments (2nd unit deposits) were deposited in such depressions.

4) The Apennine and anti-Apennine faults are still acting and dislocate, sometimes notably, the older deposits (2nd and 1st units) (fig. 13d) and, although less strongly, the more recent ones, as it is clearly observable in the Norcia depression (fig. 8). Present day tectonic activity is documented, as has been said, by the seismic events which have continue to affect the area.

With reference to the interpretative sketches of fig. 13 it is evident that the Mt. Vettore-Mt. Bove and Nottoria-Preci faults (eastward respectively of the Castelluccio and Norcia depressions) and the Mt. Meraviglia-Mt. Maggio Fault (to the West of the Cascia depression) are considered to be master faults (synthetic faults) which reach considerable depths (as the seismological data relative to the recent seismic period involving the area seem to confirm). The others, dipping in the opposite direction, have instead been interpreted as minor, antithetic faults.

A particular category of normal fault is represented, as has been seen, by a number of dislocations with a low inclination angle (40°-45°), along the Nottoria-Preci scarp fault, which borders the Norcia depression (fig. 14 - sect. 6th and 7th). They dislocates the units of the lower upthrust downthrowing them several hundred metres towards the depression.

The genesis of these minor faults is perhaps to be explained by assuming a concave upward shape of the master fault. During the extensional movement, this leads to the downthrown block being moved away from the uplifted one: in this way a void space is generated in the back part of the downthrown block. This space can be compensated not only by the antithetic faults, such as the one bordering the western edge of the depression (TREVISAN & GIGLIA, 1974), but also by low angle faults located on the edges of the structure's uplifted side. Fig. 14 - sect. 8th schematically shows the possible genetic mechanism of these last ones connected, to the overall evolution of tensile structures, such as the intra-Apennines examined depressions. It is only to be noted that the above said faults are characterized by a considerable quantity of cataclasites which contrasts with the limited nature of the movement and the small volume of the rock bodies involved. This fact does not exclude the possibility that such faults could be old reverse faults (the reduced inclination of fault planes seem to confirm this fact) which have subsequently behaved like normal faults (NIJMAN, 1971), according to mechanism illustrated above.

The concomitance of uplifting and extensional effect has been illustrated by CENTAMORE & *alii* (1980) in a study on the recent tectonics of the Umbria-Marche Apennine Arc. The foregoing Authors consider the arc itself as the eastern margin of a rift (the Tuscany-Latiumwestern Umbria area under tension by the effect of the opening of the Tyrrhenian Sea) which is therefore characterized by the association of the two phenomena. In particular, the investigated areas, affected by the mentioned large Apennine faults, mark the present position of the Tyrrhenian rifting front. This front, in time, has undergone a migration from West to East.

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