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QUATERNARY DEPOSITS AND GEOMORPHOLOGICAL EVOLUTION OF THE TELESINA VALLEY (SOUTHERN APENNINES)

ABSTRACT: MAGLIULO P., *Quaternary deposits and geomorphological evolution of the Telesina Valley (Southern Apennines)*. (IT ISSN 1724-4757, 2005).

In this paper, we outline the results of a geologic and geomorphologic survey carried out in a sector of the Calore River basin (Telesina Valley), located in the Benevento Province (Southern Apennines, Italy). The data analysis conducted allowed to reconstruct the morpho-evolutionary sequence of events that occurred in the study area during the Quaternary.

The pre-Quaternary substratum of the Telesina Valley is made of tectonically deformed carbonatic, pelitic and arenaceous terrains, whose ages range from Late Triassic to Early Pliocene. A gentle erosional landscape (Paleosuperficie, *Auct.*) was cut on these terrains between the Late Miocene and the upper Early Pleistocene. Most probably 1.3 My B.P., a first tectonic phase disrupted the Paleosuperficie and a subsident depression was formed in the study area. It was bounded by morphostructural highs subject to severe erosional processes which led to the emplacement of large amounts of detritus in the morphostructural depression. During the same phase, in the northern part of the valley, a glacia developed partly on the detritus and partly in the underlying substratum. A new tectonic phase, probably dating about 700 ky B.P., disrupted the glacia and enlarged the valley floor, which was subsequently filled by a thick succession of alluvial deposits. The dating of an ignimbrite interbedded in the upper part of the alluvial succession allows the end of the valley-infilling to be fixed at ~540 ky B.P. The alluvial deposits were then terraced in three orders by phases of downcutting and lateral erosion of the Calore River. Afterwards, the valley was partly filled by Campanian Ignimbrite, (~39 ky B.P.) and then affected again by deep downcutting and lateral erosion which led to an almost complete removal of the Campanian Ignimbrite from the valley-axis and, finally, to the formation of a fourth order of erosive terraces in the Early Holocene. During the Middle and Late Holocene, the Calore River experienced a new phase of downcutting, followed by an aggradation of a few decametres of silt-sand alluvial deposits and to the forming a V order of depositional terraces. The current a notable instability of the valley sides appears to be strongly related to recent and still ongoing deepening of the drainage network.

KEY WORDS: Geomorphology, Southern Apennines, River terraces, Paleosols, Quaternary.

RIASSUNTO: MAGLIULO P., *Depositi quaternari ed evoluzione geomorfologica della Valle Telesina (Appennino meridionale)*. (IT ISSN 1724-4757, 2005).

Nel presente lavoro, vengono illustrati i risultati di un rilevamento geologico e geomorfologico di dettaglio condotto nella bassa valle del Fiume Calore (Valle Telesina), nell'Appennino meridionale. I dati raccolti hanno permesso una ricostruzione della successione degli eventi morfoevolutivi che hanno interessato la valle durante il Quaternario.

Il substrato pre-Quaternario della Valle Telesina è costituito da litotipi carbonatici, pelitici ed arenacei fortemente tettonizzati, di età compresa tra il Trias superiore ed il Pliocene inferiore. Tra il Miocene superiore e l'inizio del Pleistocene inferiore, su tali terreni si modellò un paesaggio erosionale a debole pendenza (Paleosuperficie, *Auct.*). Una fase tettonica, forse databile a 1.3 Ma B.P., disarticolò tale paesaggio, individuando una depressione subsidente bordata da alti morfostutturali soggetti ad intensa erosione che produsse cospicui volumi di detrito che si accumularono nella depressione. Contemporaneamente, nel settore settentrionale della valle si modellava un glacia in parte su substrato ed in parte su detrito. Una successiva fase tettonica, avvenuta probabilmente ~700 ka B.P., dislocò il glacia ed ampliò la valle che venne successivamente colmata da una spessa successione di depositi alluvionali. La datazione $^{39}\text{Ar}/^{40}\text{Ar}$ di un'ignimbrite non segnalata in letteratura ed intercalata nella parte alta della successione alluvionale ha consentito di fissare a ~540 ky B.P. il termine del riempimento della valle. Successivamente, le alluvioni vennero terrazzate in tre ordini da fasi di incisione e planazione laterale del Fiume Calore. La valle fu quindi parzialmente colmata dall'Ignimbrite Campana (~39 ka B.P.) ed, in seguito, nuovamente sede di processi di profonda incisione e planazione laterale del corso d'acqua principale che asportarono quasi completamente l'Ignimbrite Campana e portarono, nell'Olocene inferiore, alla formazione del terrazzo erosionale di IV ordine. Nell'Olocene medio-superiore, si registrò una nuova fase di incisione ad opera del Fiume Calore, cui seguì l'aggradazione di poche decine di metri di alluvioni prevalentemente limoso-sabbiose con formazione del terrazzo deposizionale di V ordine. Attualmente, la valle è sede di intensi processi erosivi che sembrano essere fortemente correlati all'approfondimento, tuttora in corso, del reticolo idrografico.

TERMINI CHIAVE: Geomorfologia, Appennino meridionale, Terrazzi alluvionali, Paleosuoli, Quaternario.

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INTRODUCTION

The Telesina Valley is located in the Campanian Apennines (fig. 1), on the W border of the Benevento Province.

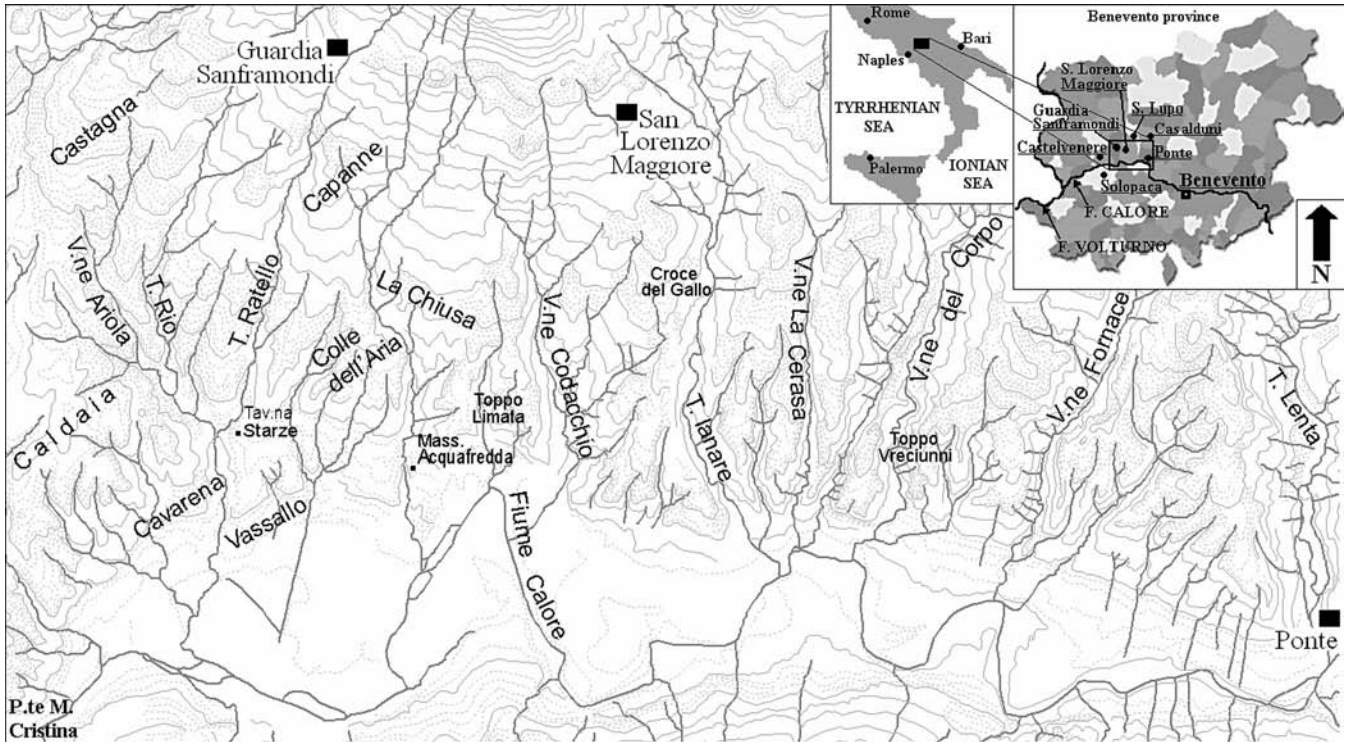


FIG. 1 - Location of the study area and main localities and toponyms cited in the text.

It is the lower portion of the valley drained by the Calore River, the principal tributary of the Volturno River. The study area covers a portion of the Telesina Valley which is approximately comprised between the villages of Ponte, Guardia Sanframondi and Solopaca, with a total area of ~63 km². In this sector, the Calore River flows in a wide, E-W elongated morphostructural depression bordered in the S by the M. Camposauro massif and in the N by the M. Croce massif. The geomorphology of the Telesina Valley and its Quaternary evolution have previously been the subject of two studies (Malatesta, 1959; Di Nocera & *alii*, 1995), offering strongly contrasting data. In particular, Malatesta (1959) found only two orders of alluvial terraces in the study area (at ~100 m and 15-40 m above the Calore riverbed) that he dated respectively to the Riss and to the Würm. Di Nocera & *alii* (1995) on the other hand recognised five orders of terraces between 120 m and 5 m above the riverbed, and attributed them to ages between the Riss and Holocene. Moreover, they hypothesized about the existence of an erosional glacia, which was not found by Malatesta (1959). However, the authors of the two papers agree about the morphostructural origin of the valley and about the absence of the oldest terrace orders in the southern side of the basin.

The present study wants to shed light on the more controversial aspects of the geomorphological history of the Telesina Valley. To this aim, an accurate description of the outcropping Quaternary deposits is given and their geo-

morphological significance in the evolution of the valley is discussed. The data in this paper have been obtained through analysis of aerial photos and detailed cartographic maps and through accurate field surveys.

The study of this valley sector is connected to a line of research which, through geomorphologic analysis of significant areas of the southern Apennines (Russo, 1990; Santangelo, 1991; Brancaccio & *alii*, 1991, 1994, 1997; Russo & Schiattarella, 1992; Romano & *alii*, 1994; Schiattarella & *alii*, 1994; Bosi & *alii*, 1996; Bianca & Caputo, 2003), aims to determine elements that can clarify the general morphoevolutive model for this sector of the chain.

GEOLOGIC BACKGROUND

The study of the geological bibliography of the area can give insight into the tectonic origin of the Telesina Valley. According to Aprile & *alii* (1980), the valley structurally evolved in three successive phases: 1) ~1.3 My B.P., the area had a sudden general uplift with the activation of a distensive fault system; 2) ~700 ka B.P., while the surrounding area was still uplifting, a few sectors of the valley began to subside; 3) at the end of the Middle Pleistocene, the more depressed sectors experienced alternating phases of uplift and subsidence. In partial agreement with the authors previously cited, Cinque & *alii* (2000) identify a definite activity of the main faults of the Calore Valley in the

late Middle Pleistocene. The activity was connected to a regional deformative event, with a NE-SW direction of extension. In one hypothesis, these tectonic movements occurred thanks to the reactivation of a pre-existing fault system (Caiazzo, 2000); in another, the movements were presumably related to the activation of new systems, some of which with an evident regional significance: these systems would have experienced multiple deformative activities including also some transcurrent ones (D'Argenio, 1967; Ortolani & *alii*, 1994).

From the work of Bergomi & *alii* (1975) it can be deduced that the pre-Quaternary substratum of the study area is made of:

- 1) ?Late Triassic to Senonian dolomites, dolomitic limestones and limestones. These deposits are considered by D'Argenio & *alii* (1973) as part of the Matese-Monte Maggiore structural-stratigraphic Unit, which elsewhere extends from Middle Trias to Late Miocene.
- 2) Campanian to Oligocene calcarenites and calcilutites with marly intercalations, part of the Coltre Sannitica terrains (Selli, 1962) and, more precisely, of the «Flysch Rosso» Unit.
- 3) Aquitanian to Oligocene dark red or greenish argillites and scaly marls, with intercalations of greenish or light brown limestones, of calcarenites and of cherty limestones, all considered to be part of the Argille Varicolori Unit.
- 4) Puddingstones, breccias and an overlaying or partly heteropic «arenaceous-pelitic unit» of unknown age; Di Nocera & *alii* (1993) consider these terrains as part of the Caiazzo Unit (Tortonian - Early Messinian) and distinguish a basal calcareous-pelitic member and a top arenaceous member.

Besides the mentioned deposits, Di Nocera & *alii* (1993) found in the study area clastic deposits related to the Altavilla Unit (D'Argenio & *alii*, 1973), Messinian to Early Pliocene in age (De Castro Coppa & *alii*, 1969).

The relations between the above listed units are described by Di Nocera & *alii* (1993) as tectonic. In particular, the tectonically lowest unit is the Matese-Monte Maggiore Unit, which is overlaid by the Argille Varicolori Unit and the Caiazzo Unit, both tectonically cut by the Coltre Sannitica terrains. The Altavilla Unit deposits lie with an angular discordance above the last three units.

According to Bergomi & *alii* (1975), on this complex and highly tectonized substratum, lie, with an angular discordance, the following Quaternary deposits:

- (a) Cemented calcareous breccias, reddened by the presence of a pedogenized matrix, and tentatively ascribed to the glacial Mindel.
- (b) Terraced fluvial-lacustrine deposits of the Calore River (Riss) overlaid, on the southern side of the basin, by
- (c) Alluvial fan deposits of the Würm I-?II, followed by
- (d) Late Pleistocene and Holocene pyroclastic deposits as well as
- (e) Holocene colluvial slope deposits.

Holocene-subcurrent alluvial deposits of the Calore River, which are mostly of sandy texture, complete the lithologic framework given in the literature.

GEOLOGICAL CHARACTERISTICS OF THE AREA

THE PRE-QUATERNARY SUBSTRATUM

The detailed geo-lithological survey carried out in the study area (fig. 2) shows that in the north-western sector the most common terrains are part of the calcareous-pelitic member of the Caiazzo Unit (Di Nocera & *alii*, 1993), tectonically overlaid by the calcarenitic-marly deposits of the «Flysch Rosso». In the north-eastern sector there are terrains of both the calcareous-pelitic member and the arenaceous member of the Caiazzo Unit, but also Argille Varicolori deposits. Clastic deposits of the Altavilla Unit lie with an angular discordance on both these terrains.

In the northwestern sector, between Loc. Castagna and the V.ne La Cerasa (fig. 1), the calcareous-pelitic member of the Caiazzo Unit is characterized, at the bottom, by a few meters of silty lead-grey clays, incorporating largely fractured blocks of fine micaceous sandstones and whitish or dark red marl clasts. Above this, there are 1 to 10 dm thick layers of whitish marls, which, in the upper part, are intercalated with thin layers of coarse arkosic-lithic yellowish-grey sandstones. The layers appear strongly tectonized, as shown by narrow folds and by the presence of spathic calcite in the fractures. Laterally, the marls interfinger with silty green clays with an abundant soft concentrations of calcium carbonate. The calcareous breccias found in Loc. La Chiesa are tentatively referred to as part of the Caiazzo Unit. These breccias are a few decametres in thickness and made up of heterometric clasts of white calcarenite and greyish calcilutite which have angular edges and contains veins of microcrystalline calcite. To the W side of the T. Ratello tributary valley, the deposits of the calcareous-pelitic member of the Caiazzo Unit are in tectonic contact with those of the arenaceous member (fig. 2); the latter are made of gradated yellowish lithic sandstones, medium and coarse-grained, in layers and levels of variable thickness. White calcarenites with intercalations of red marls and red-cemented calcareous breccias complete the lithological picture of the northwestern sector. They outcrop N of the Guardia Sanframondi and San Lorenzo Maggiore and they are part of the «Flysch Rosso» Unit.

In the north-eastern sector, between V.ne La Cerasa and T. Lenta, the calcareous-pelitic member of the Caiazzo Unit is mainly made of a complex sequence of heteropic lithofacies, consisting of (i) reddish clays incorporating largely fractured blocks of calcarenite, (ii) yellowish-green marl clays and (iii) quartzose, lightly cemented sandstones. They are stratigraphically overlaid by the deposits of the arenaceous member that have similar characteristics to the deposits observed in the northwestern sector. In the small tributary valleys of V.ne del Corpo and T. Lenta, the substratum is made of clays and red or green scaly marls that are part of the Argille Varicolori

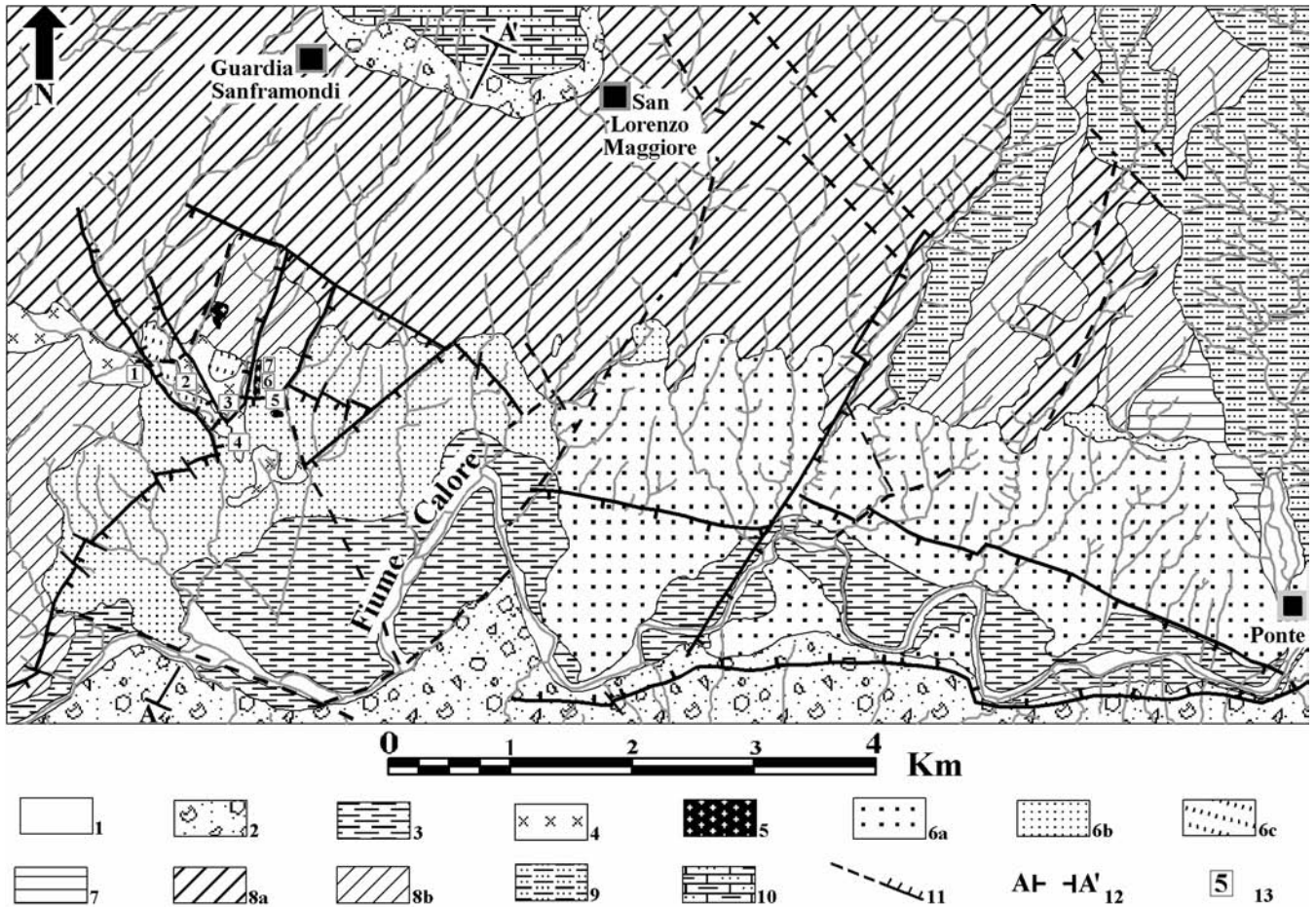


FIG. 2 - Geolithological map of Telesina Valley. 1) Current heterometric-gravelly and sandy alluvial deposits; 2) coarse-gravelly colluvial slope deposits (Holocene); 3) alluvial sands, silty-sands and gravels (RECRAD: Recent Calore River Alluvial Deposits; Holocene); 4) greyish ignimbritic tuff (CI: Campanian Ignimbrite; ~39 ka B.P.); 5) reddish ignimbritic tuff (IGS: Ignimbrite of Guardia Sanframondi; ~560 ka B.P.); 6) polygenic and heterometric alluvial gravels in a sandy matrix and swamp silts and clays (OCRAD: Old Calore River Alluvial Deposits; Middle Pleistocene): a) gravelly member, b) sandy-gravelly-pelitic member, c) silty-clayey member; 7) conglomerates, sandstones, sands and clays (Altavilla Unit; Messinian - Lower Pliocene); 8) clays, marly clays with calcarenitic olistolites, calcareous breccias, marls and sandstones (Caiazzo Unit; Tortonian - Lower Messinian): a) calcareous-pelitic member, b) arenaceous member; 9) polychrome scaly marls and clays (Argille Varicolori Unit; Cretaceous - Miocene); 10) calcarenites and calcilutites with marly interbeddings («Flysch Rosso» Unit; Upper Cretaceous - Oligocene); 11) fault (dotted lines indicate uncertain and buried faults); hatching on downthrown side; 12) trace of the geological cross-section shown on fig. 10; 13) location of stratigraphic logs.

Unit (Bergomi & *alii*, 1975). To the NW of Ponte, on top of the Caiazzo Unit and the Argille Varicolori, lie with an angular discordance polygenetic conglomerates, yellowish sands, sandstones and clays. These deposits, in agreement with Di Nocera & *alii* (1993), can be considered part of the Altavilla Unit (De Castro Coppa & *alii*, 1969; D'Argenio & *alii*, 1973).

On this complex substratum lie, with an angular discordance, alluvial and Quaternary pyroclastic deposits, whose characteristics will be subsequently discussed. In particular, the contact between the Middle Pleistocene alluvial deposits of the Calore River («6a», «6b» and «6c» in fig. 2) is erosive and often marked by a level of alteration, as thick as ~10 cm, with frequent coatings of iron-manganese oxides and soft concentrations of calcium carbonate.

QUATERNARY DEPOSITS

Pyroclastic deposits

Within the Telesina Valley, the pyroclastic deposits occur only to the west of Vallone Codacchio (fig. 1). They include a reddish ignimbrite, to which we will refer to as the «Ignimbrite of Guardia Sanframondi» (IGS) (Magliulo, 2004), and the Campanian Ignimbrite (CI). Moreover, there are pumice and/or ash deposits of both fall and flow types, whose age and origin are uncertain (Bellucci & *alii*, 2003).

A) Ignimbrite of Guardia Sanframondi (IGS) and associated paleosols - The Ignimbrite of Guardia Sanframondi (IGS) (Magliulo, 2004) was found in four different outcrops (fig. 3) in the westernmost sector of the study area.

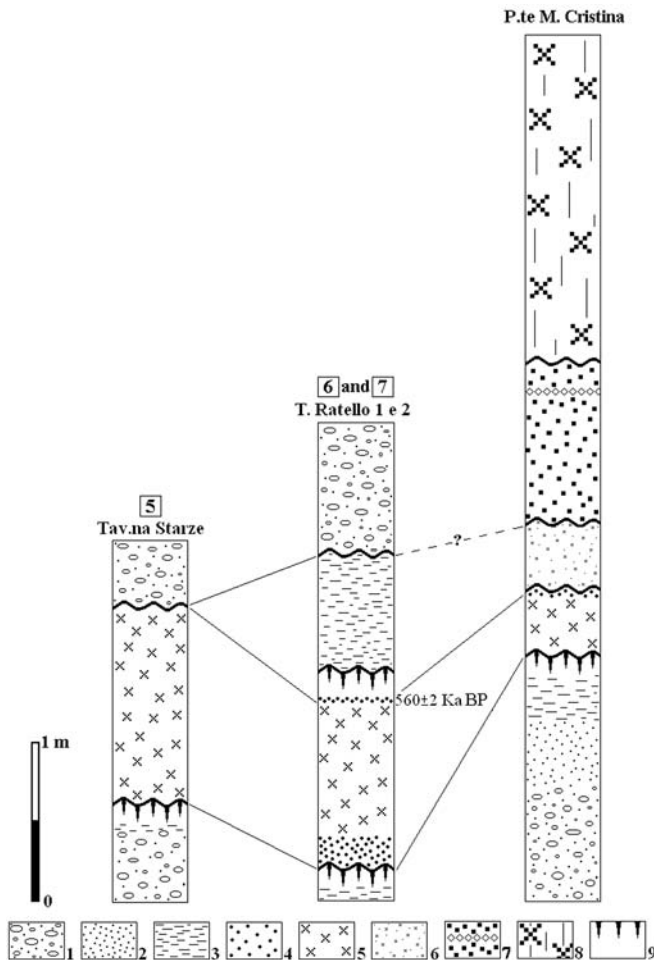


FIG. 3 - Stratigraphic logs of Ignimbrite of Guardia Sanframondi, with associated deposits. 1) Alluvial gravels; 2) alluvial sands; 3) greenish palustrine silts and clays; 4) pumiceous levels; 5) Ignimbrite of Guardia Sanframondi: reddish tuff with levels and pockets of whitish pumices; 6) volcanoclastic silty-sands; 7) coarse-sands with gravelly levels (alluvial fan facies); 8) Campanian Ignimbrite; 9) paleosols. For locations of outcrops schematised in the stratigraphic logs, see fig. 2.

The first two outcrops are to the E side of T. Ratello tributary valley, the third to the NE of Taverna Starze and the fourth in the proximity of Ponte Maria Cristina (fig. 1).

The IGS appears as a compact ash-rock, with a prevalent reddish-brown colour sometimes with a slight gradation towards an olive-brown colour (fig. 4); in places, it gradually becomes green, probably because of zeolitization processes. The deposit is characterized by prismatic columnar fissuring, which is not particularly pronounced. The fissuring separates blocks with the major axis of ~40 cm. At varied heights, layers and compact pockets of white filamentous pumices can be distinguished. They are argillitified and their size is 1÷100 mm. Towards the top, the pumices become more and more dispersed in the matrix, before passing to a level of practically solely pumices, consisting of heterometric pumices with a diameter of

~0,5÷2,5 cm. These pumices are little weathered and rich in lithics and sanidine crystals. They are immersed in a light-yellow brown ash matrix that becomes strongly prevalent towards the top. At the bottom of the IGS, a coherent and strongly argillitified level of white pumices is sometimes present («A» in fig. 5); it is characterised by an inverse graded bedding and the maximum diameter of the pumices is ~2 cm while the frequent lithics that can be found in this level have a medium diameter of ~0,5 cm.

On the top pumice level of the IGS, a radiometric $^{39}\text{Ar}/^{40}\text{Ar}$ dating with laser-fusion on single sanidine crystals was carried out, revealing an absolute age of 560 ± 2 ka B.P. (fig. 6). The absolute age of the IGS is of high interest because, as it will be better clarified progressively, it constitutes an important upper chronological constraint to the deposition of the Old Calore River Alluvial Deposits (OCRAD).

The IGS is constantly overlaying paleosols; the contacts between the IGS and the paleosols are always of a clear erosive nature (fig. 3). A first paleosol, found in the outcrops of the T. Ratello («B» in fig. 5) and of the Taverna Starze, develops from clay and swamp silt rich in carbonates. It is characterized by a dark greenish-grey colour, and by a strong de-carbonation and well-expressed vertic features (slickensides, wedge-like aggregates, cracks). In the lower part of the profile, there are sometimes weakly carbonated sandy pockets. The pre-IGS paleosol found near Ponte Maria Cristina appears more evolved than the previous one. It shows a thickness of ~90 cm and is rich in organic matter, often oxidized, which seems to suggest that it comes from silty swamp sediments. It has a strongly developed coarse prismatic structure; there are frequent slickensides, wedge-like aggregates and evidences of clay illuviation. At the bottom of the paleosol, there are laminated and gradated silty sands which lay on the pebbles of the OCRAD.

In the section of the T. Ratello, it was possible to observe the soil overlaying the IGS and developed from the alteration of the ignimbrite itself (fig. 3). This paleosol is characterized by a reddish-brown colour, by a weakly-developed prismatic to angular blocky structure and by Fe and Mn concretions having a maximum diameter of ~8cm.

On top of this last paleosol, ~1,5 m of green clays are found («3» in fig. 3). They come from a swamp environment and are rich in organic matter and Mn oxides. With an erosive contact, the clays are overlaid by a few meters of pebbles and alluvial sands («1» and «2» in fig. 3) that are very similar in lithology, size and facies to those of the OCRAD, whose lithologic upper border was found only 250 m uphill from the outcrop. The IGS is thus intercalated in the high portion of the alluvial succession and it represents an important chronological constraint to the deposition of the OCRAD.

B) *Campanian Ignimbrite and associated fall deposits* - Outcrops of the Campanian Ignimbrite (CI) and/or associated fall deposits have been found on the W side of the V.ne Ariola tributary valley, on the W side of the T. Rio basin, on the E side of the T. Ratello basin and E of Taverna Starze (fig. 7). The largest thicknesses have been



FIG. 4 - Detail of the Ignimbrite of Guardia Sanframondi (eastern side of T. Ratello basin).

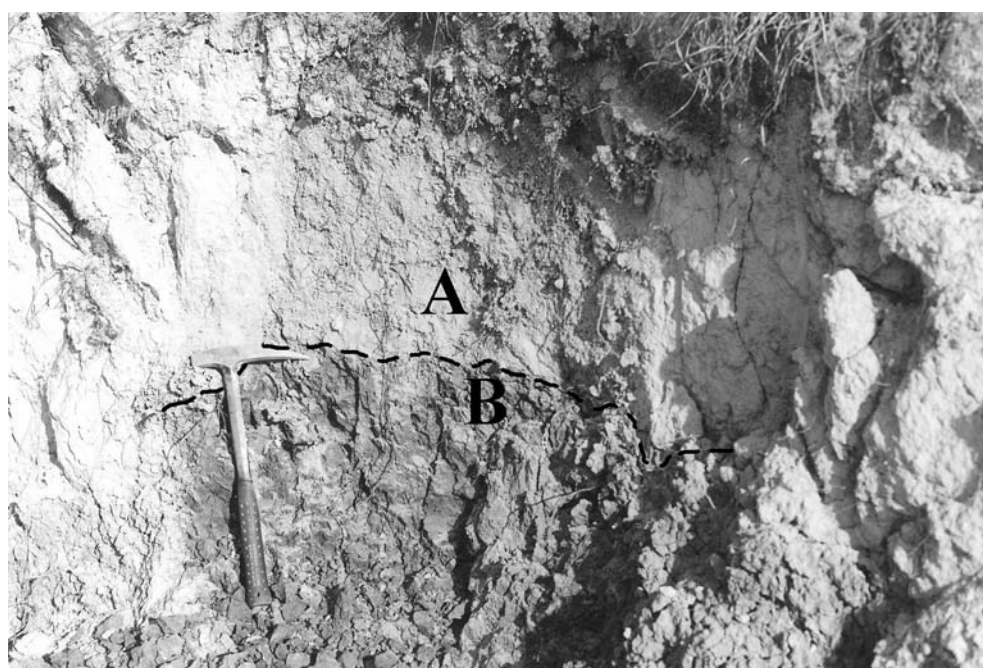


FIG. 5 - Stratigraphic contact between argillitified whitish pumices (A) underlying the Ignimbrite of Guardia Sanframondi and a greenish-grey paleosol with vertic features (B) developed on palustrine clays and silts. Eastern side of T. Ratello basin.

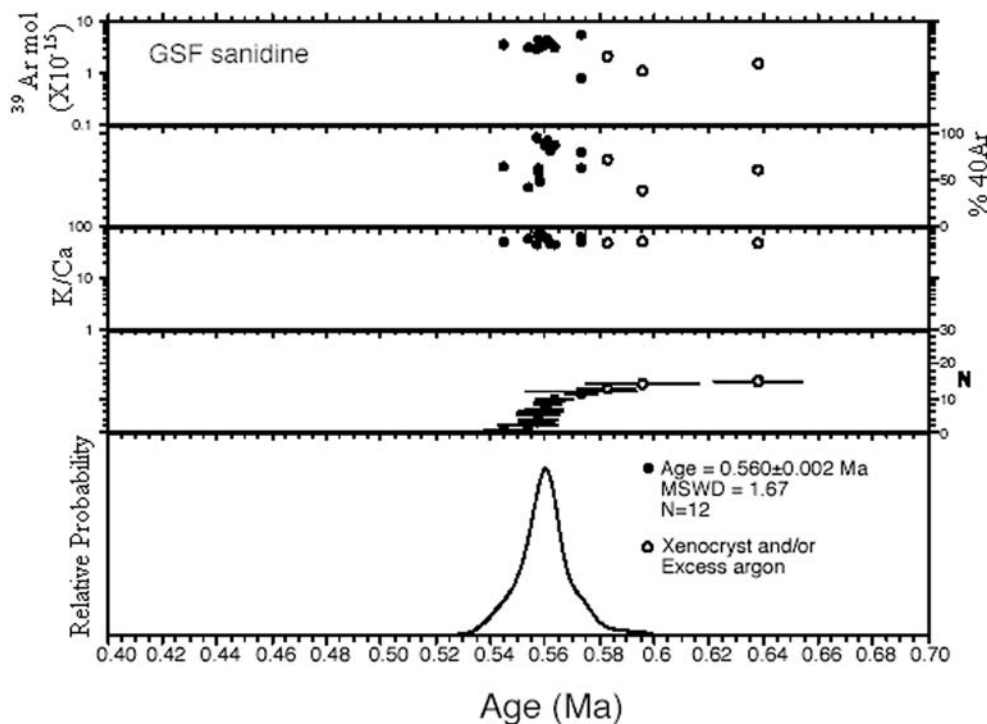
found where the ignimbritic deposit has filled pre-existing incisions.

This deposit was recently dated to the absolute age of ~39 ka B.P. (De Vivo & *alii*, 2001).

In the studied outcrops, the Ignimbrite is made of a grey compact ash deposit. Moving upward, the deposit gradually becomes a violet-grey growing progressively

darker and is characterized by prismatic column fissurings. The pumices, whitish or orange, are rare, dispersed in the matrix and almost always 1÷10 mm in size. Sanidine crystals and volcanic glass are very frequent; the volcanic scoriae are flattened and have a maximum diameter of ~2 cm along the longest axis. At the bottom, the CI gradually assumes a red-yellow or orange coloration. The CI here is

FIG. 6 - Radiogenic yield, K/Ca, signal size and age probability diagrams for single crystal laser fusion results from sanidine of the upper pumiceous level of Ignimbrite of Guardia Sanframondi (New Mexico Geochronology Research Laboratory - NMGR).



characterized by a reduced amount of pumices and scorias than in the upper part. Several authors interpreted the colour variations as due to secondary mineralisation processes (zeolitization).

Below the ignimbrite deposit, an ash deposit of a dark bluish-grey colour («2» in fig. 7) can be distinctly recognised. It is rich in white pumices, 1÷10 mm in size, and in out-gassing vacuoles. The deposit is loose or weakly cemented, probably related to a previous eruptive event. It is overlaying, with a gradual contact, a very-light brown level, with a thickness of ~10 cm, that fossilizes a white pedogenetic horizon (both with «3» in fig. 7). The horizon is weakly structured, with orange coloured mottles, and it has evolved from pumices and white ash occasionally cemented. The weak signs of pedogenesis in this horizon and the sporadic presence of pockets strongly pedogenized at the contact with the overlaying CI imply a certain time gap between the deposition of the pumiceous parent material and that of the CI itself. It seems thus plausible to attribute these pumices to a pre-CI eruptive event. The pumices and the white ash are likewise constantly overlaying, through erosive contact, buried paleosols («4» in fig. 7), which are generally weakly developed and come from the alteration of clays and swamp silts. The paleosols rest, often with an uncertain contact, on the OCRAD («5» in fig. 7).

The Calore River Alluvial Deposits

The Calore River Alluvial Deposits represent the most common Quaternary deposit in the study area. They outcrop between 45 and 215 m a.s.l. and have been subdivid-

ed into two groups denominated respectively Old Calore River Alluvial Deposits (OCRAD), Middle-Pleistocene in age, and Recent Calore River Alluvial Deposits (RECRAD), Holocene or, maybe, Late-Pleistocene in age.

A) Old Calore River Alluvial Deposits (OCRAD) - The Old Calore River Alluvial Deposits (OCRAD) outcrop almost all along the central portion of the study area (fig. 2), at an elevation of 60÷210 m a.s.l. The visible thickness is more than 150 m.

An erosional surface (fig. 8) recognised to the E of Toppo Vreciunni (fig. 1) could represent the contact between two distinct alluvial successions of the paleo-Calore. Nevertheless, surfaces of this type have never been observed in the other sectors of the valley, leaving the hypothesis that the erosive event, witnessed by the above-mentioned surface, has actually been rather contained. Apart from the origin of the surface in question, the OCRAD are very homogeneous everywhere in both lithology and facies, thus making it possible to consider the whole Middle-Pleistocene alluvial succession of the Calore River as an independent stratigraphic unit.

The OCRAD lie with an angular discordance and a clearly erosive contact on the different units of the pre-Quaternary substratum. Likewise, the OCRAD are the substratum where the deposits of the Recent Calore River Alluvial Deposits (RECRAD) rest with an angular discordance (fig. 9).

Although gravels are clearly prevalent in the OCRAD, on the basis of the relative particle-size variability of these deposits it has been possible to subdivide them into three members, which are in probable heteropic contact: a grav-

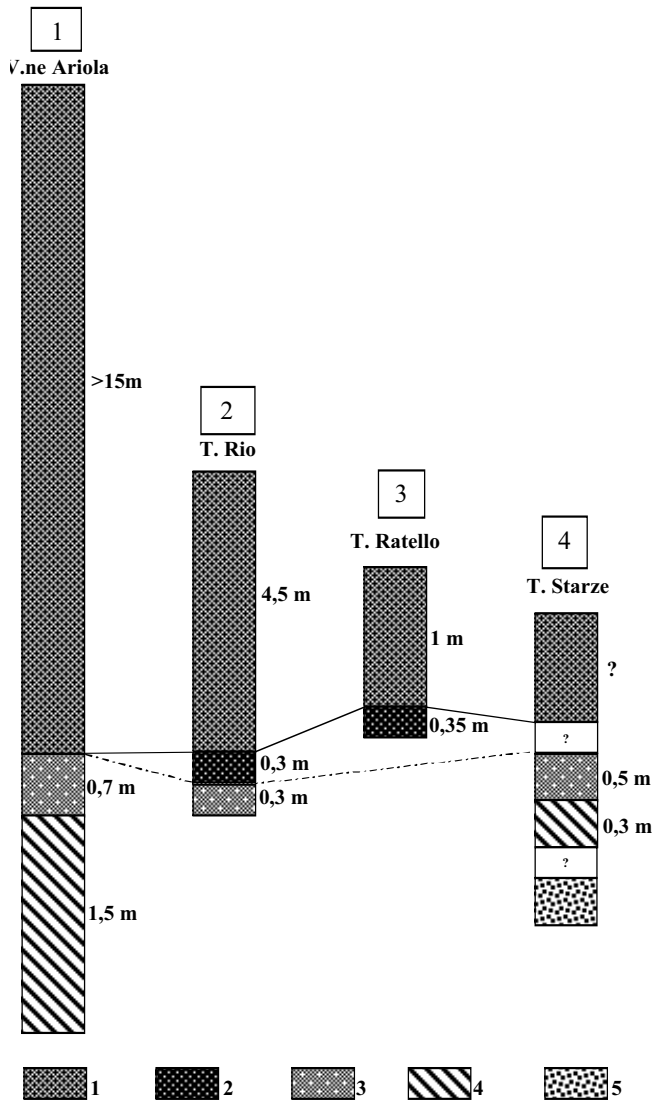


FIG. 7 - Schematic stratigraphic logs of Campanian Ignimbrite with associated fall deposits. 1) Campanian Ignimbrite; 2) bluish-grey ash deposit; 3) whitish pumiceous level, in places weakly pedogenized; 4) greyish-brown paleosol developed on alluvial clays and silts; 5) alluvial gravels and sands (OCRAD). For location of the outcrops schematised in the stratigraphic logs, see fig. 2.

elly member (OCRADg), a sandy-gravelly-pelitic member (OCRADs) and a silty-clayey member (OCRADI).

Gravelly member (OCRADg). The deposits of the gravelly member of the OCRAD outcrop in the central-eastern sector of the study area, between the Vallone Codacchio and the T. Lenta (fig. 1 e 2), at an elevation of 65÷200 m a.s.l. The pebbles are rather elaborate and always have a medium diameter lower than 10 cm. The lithology of the clasts is extremely variable: carbonate (limestone, calcarenite and calcilitite) and sandstone clasts are the most common ones, while the chert and marl ones are less frequent. The degree of cementation of these deposits is generally low, with the

exception of those outcropping to the NW of Ponte. The matrix is relatively rare and consists of coarse yellowish sands. The matrix tends to spontaneously diminish in percentage moving toward the eastern sector of the valley. A peculiar characteristic of these deposits is the presence of frequent levels of iron and manganese oxide accumulation with a reddish-brown and black colour respectively. The oxides are related to the existence of fluctuating water tables, probably due to the presence of more cemented and less permeable pebbly levels. The OCRADg is characterised by the sporadic presence of massive yellowish sand intercalations, prevalently concave in shape and with a thickness generally lower than 1 m. The intercalations are constantly bordered by erosive surfaces marked by pebbly levels with strong accumulations of Fe and Mn oxides: these sediments represent the filling of old channels. W of Ponte, some of these concave structures are filled with alternate clinostratified levels of pebbles and sands, possibly related to meander pebble bars (Ori, 1982). In some of the outcrops, it was possible to notice how the majority of the flattened pebbles showed the maximum axis dipping E-SE. This makes it possible to hypothesize a prevalent flow direction of the paleo-Calore more or less analogous to the current one.

Sandy-gravelly-pelitic member (OCRADs). This member outcrops in the central-western sector of the study area, at an elevation of 60÷150 m a.s.l. It was also found along the northern border of the area where the OCRAD outcrops, at an elevation of 160÷210 m a.s.l. (fig. 2). Even though pebbles analogous in dimension and lithology to those of the OCRADg are still prevailing, this member is different from the previous one for the higher frequency and thickness of the sandy intercalations; the matrix, sandy as well, is much more abundant and, in general, the pebbles are less cemented. Moreover, silty-clayey levels and paleosols not present in the OCRADg have been found in this new member. The facies of the deposits often denotes a strong canalisation of the hydric flow.

The frequent, mostly sand based, intercalations in the alluvial succession of the OCRADs almost always have a thickness of more than 2 m and concave or tabular shapes. They are made up of greyish or yellowish sands with strong accumulations of carbonates that are prevalently in the form of soft concentrations, but sometimes they are found as very hard calcareous crusts. In places, compact silty levels have also been observed in the OCRADs. These levels have a thickness of more than 80 cm, a greenish-grey colour and evident settling laminas. The silts have a series of sub-vertical fissures that could represent the signs of an embryonal pedogenesis, which began with a first attempt of internal reorganisation of the primary particles, which was almost immediately stopped by the arrival of new alluvial material (van Breemen & Buurman, 1998).

In the OCRADs, three buried paleosols have been found, placed respectively in Loc. Colle dell'Aria, on the E side of T. Ianare tributary valley and S of Toppo Limata (fig. 1); in this last site, the paleosol is fossilized by a white level with a thickness of about 15 cm and made up of strongly argillitified pumices. The paleosols always develop from the fine intervals intercalated in the succession

FIG. 8 - Erosional surface in the OCRAD alluvial succession at Toppo Vreciunni locality. Caterpillars in the lower part of the picture for scale.

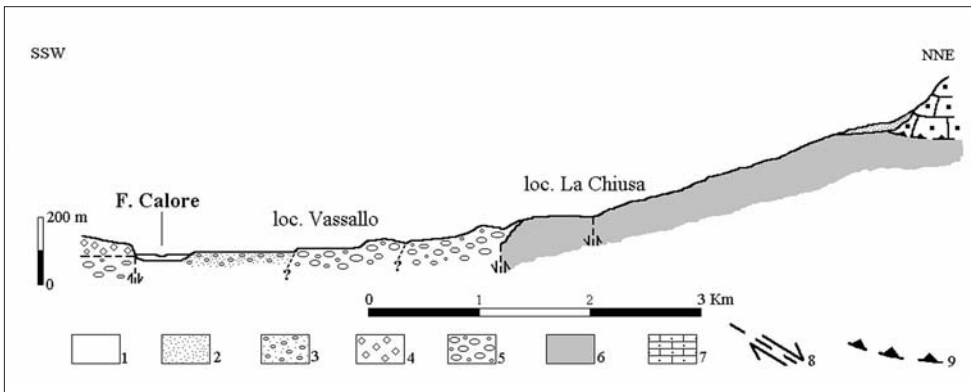
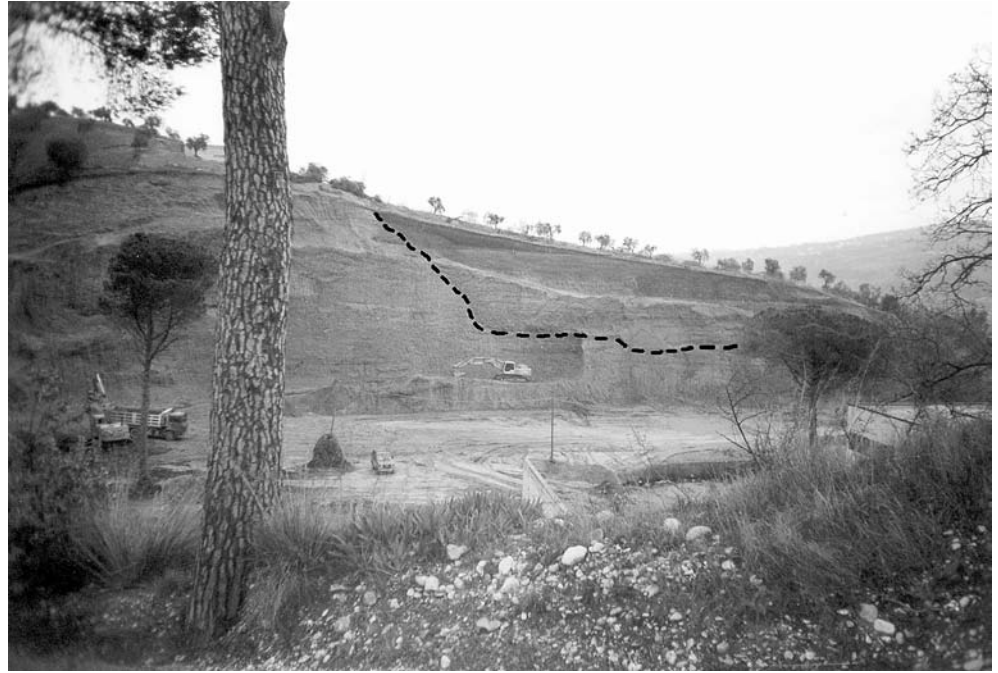


FIG. 9 - Geological cross-section of the western sector of the Telesina Valley (the trace of the cross-section is shown in fig. 2). 1) Current heterometric-gravelly and sandy alluvial deposits. 2) Coarse-gravelly colluvial slope deposits (Holocene). 3) Recent Calore River Alluvial Deposits (RECRAD; Holocene). 4) Gravelly deposits in alluvial fan facies. 5) Old Calore River Alluvial Deposits (OCRAD; Middle Pleistocene). 6) Caiazzo Unit (Tortonian - Lower Messinian). 7) «Flysch Rosso» Unit (Upper Cretaceous - Oligocene). 8) Fault. 9) Thrust.

and they are cut by erosive surfaces. The paleosols are characterized by a structure either prismatic or angular blocky, a weak rubefaction, greenish-grey mottles, a low CaCO_3 content, slickensides and wedge-shape aggregates. Even though specific studies are lacking, it is possible to hypothesize that the evolution of these paleosols have come about in a hydromorphic environment and with a climate characterized by marked alternations of dry and humid seasons (Sumner, 2000).

Silty-clayey member (OCRADl). On the far eastern border of the study area, between V.ne Ariola and Masseria Acquafredda (fig. 1), silty-clayey deposits of alluvial origin were found. The colour of these deposits varies from a greenish-grey to a whitish colour. The deposits have frequent coatings and levels of Fe-Mn oxides and horizons with concretions and soft concentrations of CaCO_3 . The organic levels are absent, probably because of oxidizing

processes connected to phases of subaerial exposure. Rare and lightly-reworked calcarenite clasts are also found in the OCRADl. On the whole, these silty matrix-supported deposits seem to come from a lacustrine and/or swampy alluvial environment of very low energy. The energy was not enough for the clasts to undergo a strong re-elaboration, while made it possible for the silt to settle. An exact evaluation of the thickness of the OCRADl is not possible because its base has never been found. Nevertheless, it must be higher than 10-15 m. The stratigraphic relationships between these deposits and the OCRADs have been observed in few, not very significant outcrops. They seem to show an heteropic relationship between the two members.

B) Recent Calore River Alluvial Deposits (RECRAD) - Because of a) the very scarce fluvial downcutting, b) the artificial levees that border the Calore River and c) the thick vegetation, no one significant outcrop of these de-

posits has been found. Therefore, it has only been possible to describe them by studying cores that have been drilled for public works. The data are summarised by the stratigraphic column of fig. 10.

In terms of the RECRAD thickness, through cores study it was obviously not possible to distinguish the deposits of the different deposition cycles by looking at the contact between the different alluvial bodies. The deepest core shows the presence of alluvial deposits of over 30 m in depth. Nevertheless, it is likely that the thickness of the RECRAD is in between the ground surface level and the top of the underlying grey-blue silts, placed between 9 and 15,5 m in depth (fig. 10).

From the cores, it appears evident that there is a lateral change in size of the RECRAD moving farther from the current thalweg. This justifies the subdivision of the RECRAD in a gravelly-sandy proximal member (RECRADp) and in a silty-clayey distal member (RECRADd), probably heteropic with one another.

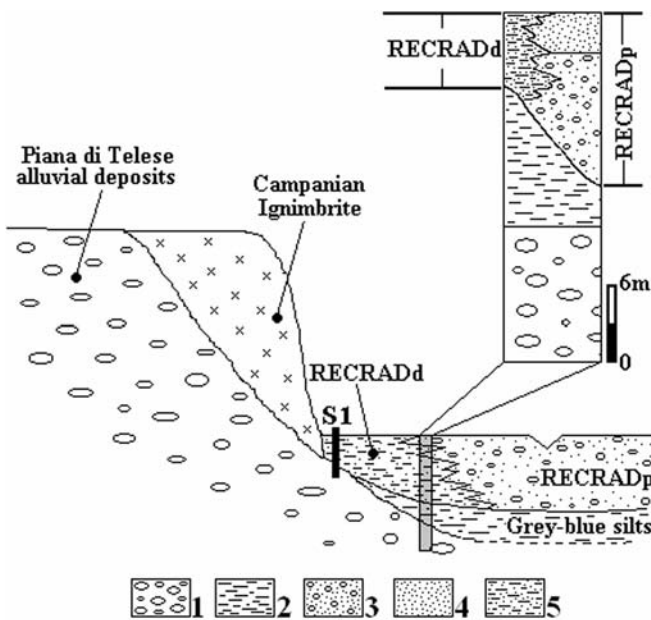


FIG. 10 - Schematic morphostratigraphic sketch (not in scale) and synthetic stratigraphic log showing, respectively, stratigraphical relationships between RECRAD and the underlying deposits and features and thickness of RECRAD. Both figures are gathered by unpublished boreholes data. Legend: 1) polygenetic, rounded and, in places, cemented gravels and pebbles having average diameters <math><3-4\text{ cm}</math> in a sandy-silty or silty-clayey matrix; coarse quartzose sands of a yellowish-light brown or reddish colour with rare calcareous or cherty pebbles of

The RECRADp begins with calcareous gravels, which are

The RECRADd has a thickness of

The surface deposits found in a core (core S1 in fig. 10) drilled at the bottom of the fluvial erosion paleo-scarp incised in the CI are doubtfully related to the RECRADd. In this core, the grey-blue clayey silt levels were not found. The substratum here is directly made up of sandy-gravelly deposits related to a previous alluvial cycle, stratigraphically overlaid by the clayey silts. They extensively outcrop in the adjacent Piana di Telese (Aiello & alii, 1989). Most of the surface deposits found in the core are strongly influenced by the location of the drilling itself, as shown by the frequent reworked pyroclastic levels and by ignimbrite block inclusions. These are mostly the product of the erosion of the scarp, successively reworked by the main river during the aggradation of the RECRAD.

As regards the relations between the RECRAD and the Campanian Ignimbrite (CI) the analysis of the cores shows the absence, down to a depth of around 30 m, of deposits to be directly correlated to the CI, which is on the contrary exposed in more than 15 m high scarps (fig. 10) that border the outcropping area of the RECRAD. These scarps are the result of a downcutting phase of the river that occurred after the emplacement of the CI and before the deposition of the RECRAD which must therefore be considered sensibly younger than

Fan deposits

These deposits widely outcrop along the southern side of the valley, which is at the bottom of the carbonatic M. Camposauro massif (fig. 2). Moreover, two non-mappable outcrops have been found on the northern side of the valley, namely on the W side of T. Rio basin and the E side of V.ne La Cerasa basin (fig. 1).

The fan deposits at the bottom of the Mt. Camposauro are made of heterometric calcareous clasts, with a dark brown matrix prevalently of volcanic nature (Bergomi & alii, 1975). In agreement with Malatesta (1959), the same

Authors attributed these deposits to the Würm I-?II, while Iacobacci & alii (1959) dated them at the upper Middle Pleistocene. The fan sediments are covered by few meters of Holocene colluvial slope deposits, made up of coarse calcareous pebbles in a pyroclastic matrix too.

The T. Rio and the V.ne La Cerasa paleofan deposits are made up of little-weathered clasts. The lithology of the clasts is mainly calcarenitic and calcilititic, and subordinately marly and arenaceous. Because of the presence of these rocktypes, it is possible to infer that the fans were originally supplied by the calcarenite-marl hillslopes of the «Flysch Rosso». This area is now located N of Guardia Sanframondi and it is completely separated from the fan area. The diameters of the clasts vary widely, shifting from 2-3 mm to more than 25 cm in the case of the T. Rio fan and up to 60-70 cm in the V.ne La Cerasa. The grade of roundness is extremely variable too, with a prevalence of sub-rounded pebbles. The matrix, made up of calcareous sands, is abundant. In the V.ne La Cerasa outcrop, the sandy elements show evident flux structures and become the parent material of dark coloured pedogenized levels. These levels are characterized by a prismatic structure, slickensides and, probably, by clay coatings. They are always cut by erosion surfaces often marked by accumulations of Fe-Mn oxides and carbonates.

Sub-current fan deposits have been found also at the bottom of valley dissecting the alluvial terraces. The deposits of these fans are obviously made up of reworked alluvial pebbles, lithologically analogous to the outcrops in the supplying basin. These pebbles are immersed in an abundant brown sand matrix, prevalently of volcanoclastic origin.

GEMORPHOLOGY

As a whole, the Telesina Valley is highly asymmetric, the southern side being characterised by a mean slope of ~70% while the right side is only ~17% inclined (see the attached Geomorphological Map). From a morphogenetic point of view, the study area can be divided into four large sectors: (i) the valley floor, where the Calore River flows E-W on its own alluvial deposits; (ii) the northern piedmont area, between the villages of Guardia Sanframondi, S. Lorenzo Maggiore, S. Lupo, Casalduni and Castelvenere (fig. 1), characterized by Miocene flysch formations; (iii) flanks of the southern limestone relieves and (iv) the foothill scree taluses area. Nevertheless, the geomorphological study has exclusively focused on the first two Units (i and ii), characterized by larger extensions and more complexity than the last two ones (iii and iv).

GEMORPHOLOGY OF THE VALLEY FLOOR

The geomorphology of the S side of this sector is different from that of the N side. To the S, the morphological boundary of this sector is quite evident everywhere, being marked by a clear increase in slope when it meets

the adjacent Geomorphological Unit of the foothill scree taluses area of M. Camposauro massif. Two widespread orders of river terraces can be recognized here. On the other hand, to the N side, the border between the Calore R. valley floor and the adjacent piedmont area is not marked by any clear change in slope. The morphology here is much more various, characterized by the presence of river terraces, often highly reworked. The oldest orders are in the OCRAD, while the lowest terrace is on the RECRAD. In addition, there are the sub-current flooding terraces of the Calore R., that will be referred to as the «0-order terraces».

The geomorphological study was aimed to find the exact number of terrace orders by analysing aerial photographs and 1:5000 cartographic maps and by constructing a longitudinal profile of the alluvial terraces (fig. 11). It turned out to be very difficult, especially for the oldest orders that are very small almost everywhere and no longer flat (see the attached Geomorphological Map). Such a situation is the product of different factors:

- The OCRAD are poorly conservative;
- The ancient surface where the terraces were formed was already very irregular because of lateral fans;
- The terraces are tectonically fragmented by faults of uncertain vertical displacement, which often are no longer morphologically evident. Nevertheless, their presence has often been hypothesized through indirect evidence such as subsequent incisions and tilting of strata, made evident by the anomalous immersion toward the N of the sandy layers intercalated within the conglomerates;

The lower terraces also, which are generally better preserved than the higher ones, were not easy to recognise because of the following factors:

- The erosional fluvial scarps separating the different orders are scarcely evident. These scarps always have a height of less than 6 m and are mappable only on a 1:5000 cartographic map. Moreover, the scarps are often lowered thanks to the high erodibility of the sediments they are formed in. The lowering of these scarps is also increased by the presence of human activities, the area being highly cultivated. In several cases, the fluvial scarps have been partially dismantled by the successive lateral migration of the river. Finally, some of them have been covered by the aggradation of new alluvial sediments;
- Recent fault activity. Although the displacement of these faults is generally of only a few meters, the faults could have highly altered the relative mean elevations of such short terraces, thus making it difficult to decide the order of each terrace patch. In the proximity of these faults, both the river gradient and the Index of Sinuosity (Schumm, 1963) (fig. 12) increase. The faults are also highlighted by the presence of rapids in the river due to the change in elevation of the riverbed and anomalies in the geometry of the Calore River, such as straight-angled bends and/or alignments with the terminal straight portions of minor tributaries.

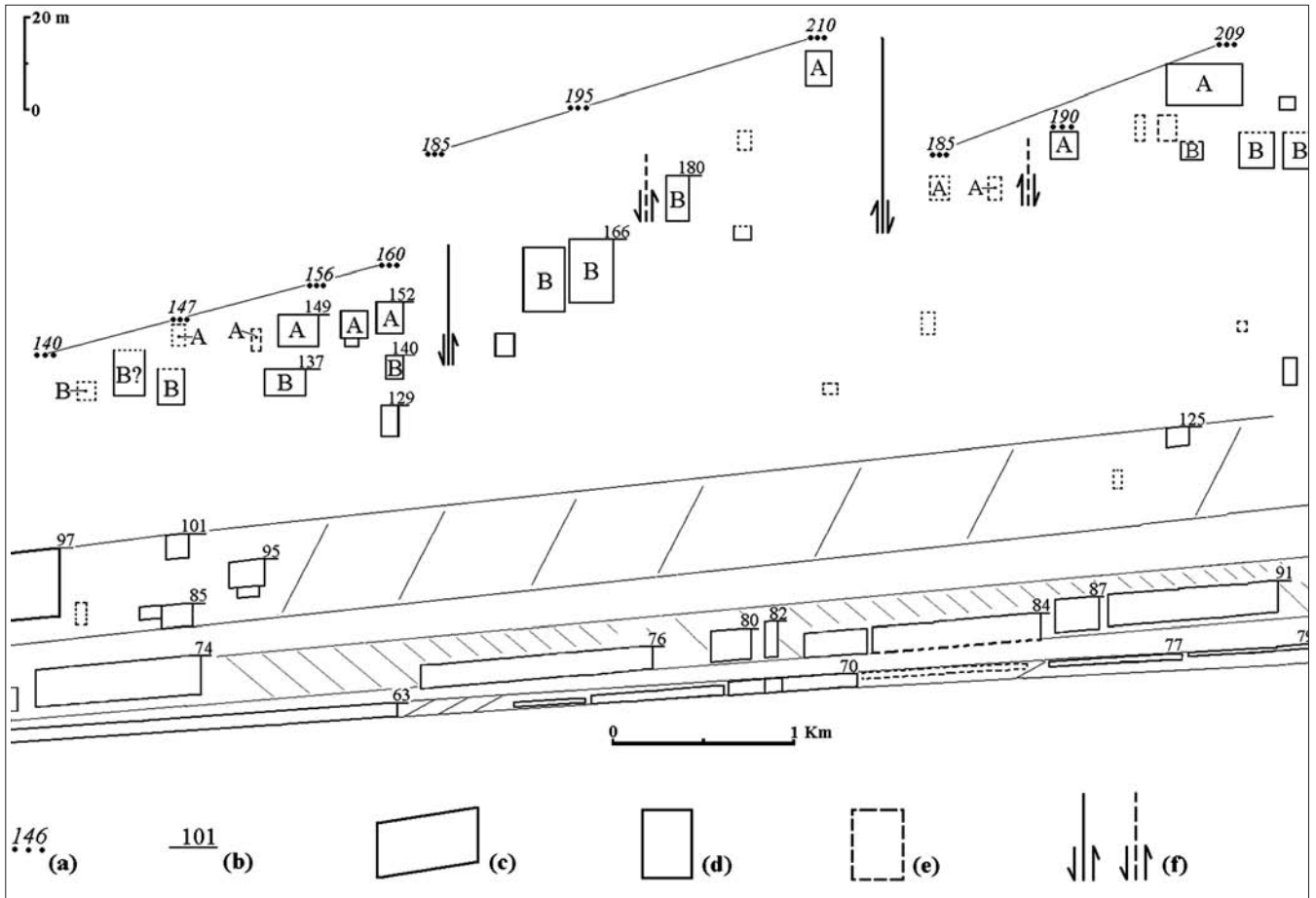


FIG. 11 - Longitudinal profile of the Calore River alluvial terraces (elevation on axis of ordinate, distance on axis of abscissas) in the valley sector between Vassallo locality and the village of Ponte. The ordinate of the upper vertexes of each polygon indicate the maximum elevation of the relative terrace patch. The few «0-order» terraces (see text) are not showed in the profile due to their small dimensions. Note the intense fragmentation of the older terraces (A and B), due to tectonics and/or erosion; the patches of the older terraces which are believed to be correlated are marked with the same letter. In fig. 11 are not showed the faults elongated longitudinally to Calore River.

Legend: a) lithological boundary of OCRAD and relative altitude (m a.s.l.); b) maximum elevation of terrace patches (m a.s.l.); c) well preserved terrace patch; d) badly preserved terrace patch; e) very badly preserved terrace patch; f) major certain and uncertain faults elongated sideways to the Calore River.

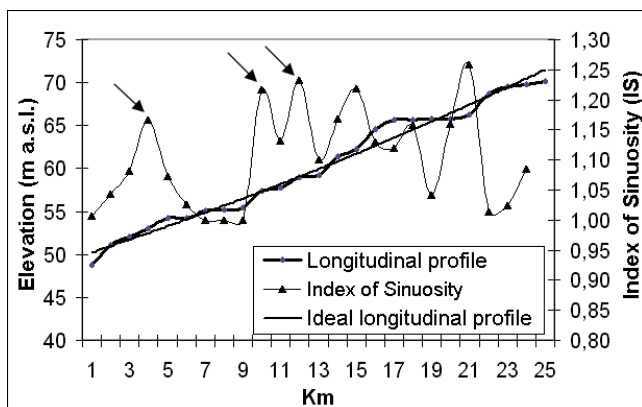
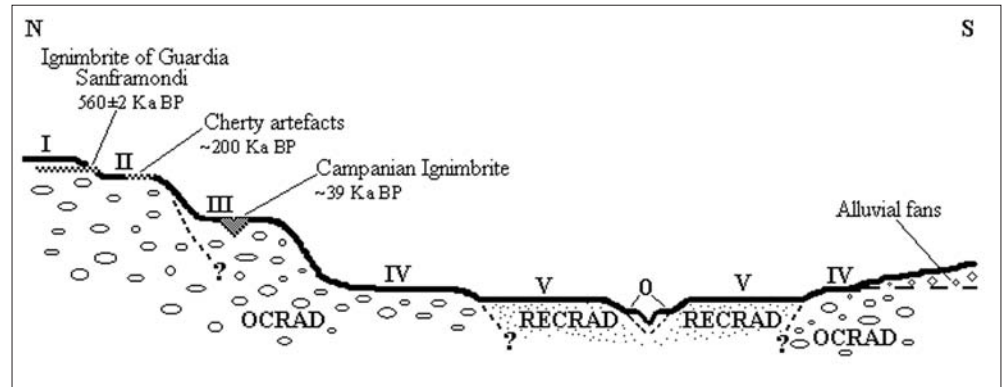


FIG. 12 - Longitudinal profile, ideal longitudinal profile and Sinuosity Index curve (Schumm, 1963) of the Calore River in the study area. Arrows indicates points in which signs of recent tectonics (simultaneous increase of Sinuosity Index and fluvial gradient coupled with rapids indicating changing in elevation of the riverbed) occur.

Notwithstanding the above difficulties, a detailed analysis made it possible to recognise 5 orders of river terraces. The first 4 terraces are formed in the OCRAD, while the V order is in the RECRAD (fig. 13). The whole sequence can only be seen NW of Ponte. The terraces of the I and V order have a depositional origin, while those of the II and IV orders have an erosional origin. The III order terrace is likely to have an erosional origin too. The terraces of I, II and III order are not present on the southern side of the valley.

I ORDER TERRACES. The highest and oldest order in the study area has been found between the Loc. Caldaia and the village of Ponte (fig. 1). The mean elevation ranges between 140 and 210 m a.s.l. The original surface of the I order terrace is today subdivided into several small and poorly preserved patches by the erosive action of the Calore River tributaries. The reduction of the original surface of the terrace is still occurring, mostly thanks to slope

FIG. 13 - Schematic morphostratigraphic cross-section of the different orders (0-I-V) of alluvial terraces of Telesina Valley, also indicating the main geochronological constraints.



undercutting processes operated by the tributaries at the base of the sub-vertical scarps that border the relict patches. These processes cause the progressive withdrawal of the scarps themselves through consecutive falls. In some cases (T. Ianare, V.ne Codacchio), undercutting is facilitated by the outcrop of soft Tertiary pelites underneath the OCRAD pebbles. The relict patches are diversely dislocated by faults that crucially favoured the reduction of the original surface of the terrace.

II ORDER TERRACES. There are relict patches of this order between the Loc. Colle dell'Aria and the T. Lenta (fig. 1), at an average elevation between 130 and 190 m a.s.l. A paleo scarp of fluvial erosion marks the border between the I and the II order. The scarp, 10 to 15 m in height, is highly regularized and can only be seen in the easternmost portion of the area. The lateral continuity of the alluvial succession (OCRAD), at the passage from I and II order terraces highlights the erosional origin of the II order.

III ORDER TERRACES. III order terraces have been found in the westernmost portion of the N side of the valley, between the Loc. Cavarena and Mass. Acquafredda (fig. 1), at an elevation between 80 and 100 m a.s.l. They have also been found as small patches in the easternmost portion of the area, at 110 and 125 m a.s.l. In the central portion of the N side of the valley, there are no terraces of the III order.

The paleo-scarp of fluvial erosion, that separates the II order terraces from the III order ones, has completely lost its morphological «freshness». In fact, it is deeply incised by tributary streams and gullies. Nevertheless, the morphological border between the two terrace orders is quite evident all over, because the relative change in elevation is never lower than 40 m.

The erosional terrace of the III order was mostly formed within the OCRADs and, similarly to the two older terraces, it has completely lost its original characteristics. In particular, what was originally a continuous, E-W elongated surface, has been subdivided into many relict patches by both the tributaries of the Calore River and the activity of several faults. In general, however, these terraces appear better preserved than the two previous and older ones.

IV ORDER TERRACES. These are the lowest terraces that developed in the OCRAD at elevations between 60 to

80 m a.s.l. In the western portion of the valley, they are formed in the OCRADs, while in the eastern sector they formed within the OCRADg. Unlike the previous two orders, the terraces of the IV order are found both on the N and S side of the valley. The only area where they are missing is S of Toppo Limata (N side of the valley), where they have been bank-eroded by a recent migration of a meander of the Calore River. The morphological border with the upper terraces of the III order is evident everywhere, being marked by fluvial erosion paleo-scarps declined to gradients of 10÷25%. In the valley portion between the V.ne Codacchio and the T. Lenta, the regularity of the surface is interrupted at the base by rectilinear sub-vertical scarps. These scarps have a very «fresh» morphology and a height usually lower than 5 m; they can be considered recent fault scarps. Reaches of streams with an anomalous geometry interrupt the lateral continuity of these scarps. Laterally to these anomalous reaches, the scarp is shifted either uphill or, more often, downhill: it is thus likely that these streams are flowing along transcurrent faults.

The absence of erosional surfaces between the terraces of the III and IV order, coupled with the fact that they are both resting on analogous alluvial substratum, confirm the hypothesis of an erosional origin of the IV order terraces.

V ORDER TERRACES. Unlike the previous 4 orders, the terraces of the V order are found in the RECRAD. They have a depositional origin and an elevation between 55 and 78 m a.s.l. These terraces are the largest and most continuous ones: they are interrupted only by the final portion of the Calore River tributaries that incise sub-vertical scarps with a height generally lower than 2 m.

The border between the terraces of the V and IV order is everywhere characterized by scarce morphological evidence and it has been recognized solely by analysing detailed cartographic maps (1:5000). The border is marked by gentle scarps of a height between 4 and 6 m, often covered by fan deposits. The scarce morphological evidence of the border between the IV and V order terraces can be explained assuming that, after the OCRAD was incised, the rise of the local base level and the related RECRAD aggradation reached an elevation very close to that of the upper IV order terraces (fig. 9 and fig. 13).

The aerial photo analysis made it possible to recognise, over the top flat surfaces of the V order terraces, well-preserved traces of the last fluvial paths, characterized by small curvature radius meanders.

Downvalley, the terraces of the V order are sometimes bordered by sub-vertical scarps of a height lower than 2 m. At the bottom of these scarps there are the 0-order terraces, which represent active Calore River terraces and are made of sub-current pebbles and alluvial sand. Where there are no 0-order terraces, the V order terraces are directly bordered downvalley by the main river through ~5 m sub-vertical scarps.

GEOMORPHOLOGY OF THE NORTHERN PIEDMONT AREA

This area can only be found in the northern side of the valley and it is bordered towards the N by the Toppo Capomandro fault scarp hillslope. The slope is on marly calcarenites of the «Flysch Rosso» unit and the village of Guardia Sanframondi is at the bottom. Towards the S, the piedmont area is bordered by the valley floor, which meets the piedmont area without any evident change in steepness (see attached Geomorphologic Map).

In this sector, whose slope never exceeds 15%, several sub-planar surfaces have been noticed. They are usually very small, less than 2% inclined and of clear erosional origin. This is particularly evident on the E side of V.ne Fornace tributary valley (fig. 1), where one of such surfaces cuts, with a clear angular discordance, the arenaceous layers of the Caiazzo Unit (fig. 14). The geomorphological analysis has clearly shown signs of intense morphodynamics, which has highly reworked these surfaces after their formation. The poor level of preservation

of these landforms is due to the high erodibility of the rocktype they were formed in, mostly clays and marls. This rocktype causes the surfaces to be particularly vulnerable to the action of surface wash processes and of gravitational movements (see attached Geomorphologic Map). These planar surfaces are connected through sub-rounded irregular ridges, often cut by more or less developed gullies and still incising lateral landslide channels. E of the V.ne del Corpo, where the most lithoid members of the Caiazzo Unit outcrop, the morphology generally becomes steeper and more regular. The ridges here are much sharper than those of the western sector and the area, together with flows and rotational slides, experiences falls as well.

The erosional origin of these surfaces, together with evidences of retreating of Toppo Capomandro fault scarp hillslope, have suggested that these landforms can be considered relict patches of a wide pediment glacis. An indirect proof of the retreating of the fault scarp is given by the paleo-fan deposits previously described (see par. «fan deposits»): in fact, the very proximal facies of these deposits, witnessed by the presence of slightly rounded blocks and boulders, is absolutely not consistent with the present location of the foothill, located more than 2.5 km north. The identification of the source area of these alluvial fans with the Toppo Capomandro relief is confirmed by the lithological nature of the clasts, consisting of calcarenite and calcilutite gravels and boulders: Toppo Capomandro is in fact the only structure of the area whose bedrock is made up of such rocktypes.

Alluvial fan deposits have never been observed on the surfaces upvalley from the described outcrops, those surfaces being directly cut in the substratum (fig. 14).



FIG. 14 - Sub-planar erosional surface (A) cut in the arenaceous member of Caiazzo Unit. Note the clear angular discordance between the surface and the underlying arenaceous strata, clearly dipping towards the left side of the picture (350°N dipping, with an angle of 25°). Eastern side of V.ne Fornace basin.

The main factors that influenced the hillslope retreating can be summed up as:

- The presence of low-erodible terrains («Flysch Rosso») over other easily erodible ones (Arenarie di Caiazzo and Argille Varicolori), that caused extended processes of slope undercutting by differential erosion of the pelitic-arenaceous rocktypes.
- Lithologic disuniformity of the slope itself, made of calcarenites with marl intercalations, with prevalent erosion of these latter and consequent «lack of support» for the upper calcarenites.

In order to reconstruct the spatial and altimetric relationships among the glacia patches, a longitudinal profile of the piedmont sector of the study area has been completed. Along the profile, some information about the lithology of the substratum was added (fig. 15). By looking at fig. 15 it is possible to notice, first of all, how the distribution of the relict patches of the glacia is highly correlated to that of the more conservative terrains of the Caiazzo Unit (lithoid sandstones, breccias, calcarenites). Indeed, there are no patches for ~2 km in the valley portion immediately W of Croce del Gallo (fig. 1) where the substratum is mostly made of pelitic deposits. On the contrary, to the W and to the E of this sector of the valley, where the relict patches are relatively more frequent, the Caiazzo Unit is mostly made of sandstones, cemented breccias and calcarenites. Fig. 15 also highlights the possible presence of two different «orders» of glacia, separated by steps of ~50-60 m.

In the western sector, S of Guardia Sanframondi, aerial photo analysis made it possible to recognise, between the two «orders» of glacia, a linear feature with a SSE-NNW direction and a length of over 3 km. This feature is per-

fectly aligned with an anomalous portion of the river that is W of Mass. Acquafredda (fig. 1). Similar features to this one, less morphologically evident than the former but still associated to streams with an anomalous path, have been observed between the two orders of glacia in the easternmost sector. The landforms have been interpreted as due to faults, suggesting that the two orders of glacia represent a tectonic duplication of only one original surface.

The gentle surface of the pediment area is often interrupted by large blocks of calcarenites (up to ~100 m³) that emerge from the top of the surface itself (see attached Geomorphologic Map). According to Di Nocera & *alii* (1995), these «calcareous humps» would have come off from the retreating scarp of Toppo Capomandro and slowly slid downvalley on a ductile rocktypes, becoming similar to «floating olistolithics». For the larger blocks, the same Authors hypothesise that the formation may have been due to large-scale lateral spreading processes.

CURRENT MORPHODYNAMIC PROCESSES

From a morphodynamic point of view, the study area appears dominated by much active erosional processes. The most unstable areas are those of the secondary small valleys in the piedmont area, which are characterized by high steepness and a prevalently clayey substratum (calcareous-pelitic member of the Caiazzo Unit and the Argille Varicolori Unit). Here, the instability is related not only to the poor mechanical characteristics of the rocks, but also to the current tendency to incision of the minor streams, which have seasonal discharge and appears confined by sub-vertical scarps up to 3 m high. The hillsides of these secondary small valleys evolve mainly through

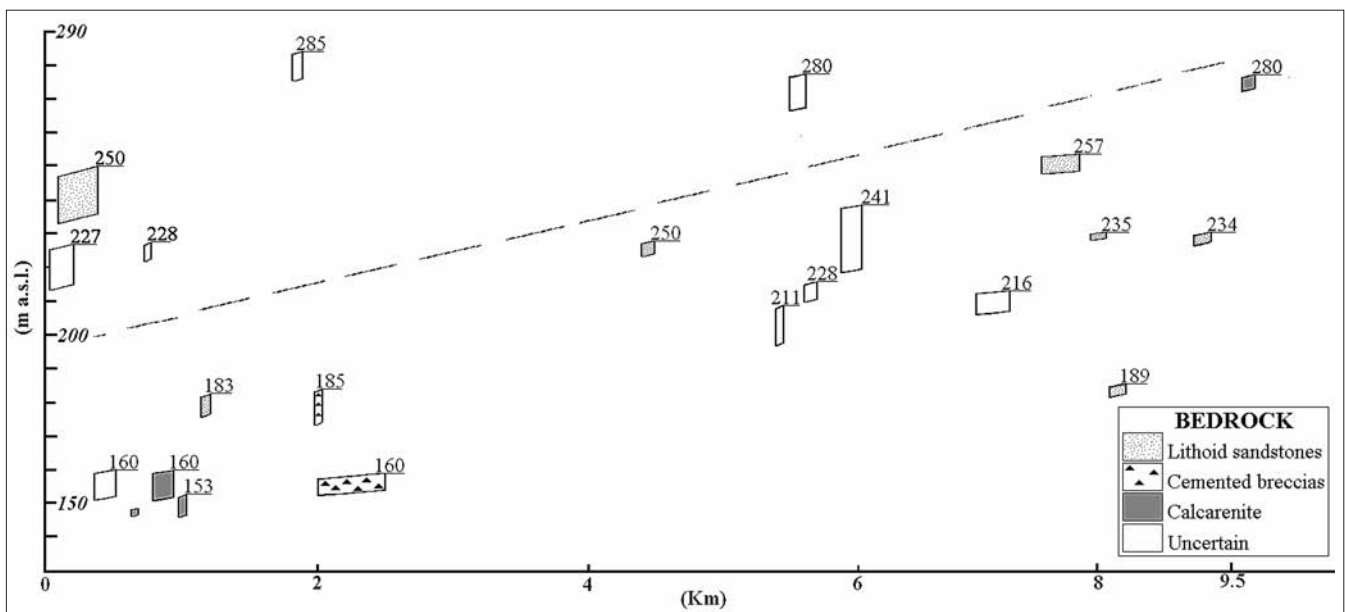


FIG. 15 - Longitudinal profile of sub-planar relict patches of glacia. Dotted line indicates the boundary between the two «orders» of surfaces; numbers indicate the maximum elevation of each patch. Note the intense fragmentation of the paleo-surface.

landslides, next to which there is evidence of slow regolith movements (solifluction, soil creep, etc.), which are sometimes very intense. Together with these, there are surface wash processes, both areal (sheet wash) and linear (rill and gully erosion). Evidence of rill erosion and sheet wash are particularly clear in the portions of the hillsides that are cultivated with grapevines, with rows along the slope («rittochino» ploughing). Incising gullies have mostly been noticed along the hillsides of small valleys with a OCRAD substratum; nevertheless, the largest gullies have been found in the lower portion of the glaciais patches and of the alluvial terraces.

Landslides are particularly frequent in the tributary valleys of V.ne Codacchio, T. Ianare and T. Lenta (fig. 1 and attached Geomorphological Map). In the V.ne Codacchio, the substratum of these incisions is made of led-grey clays of the calcareous-pelitic member of the Caiazzo Unit, while in the other two places they are mostly formed in the Argille Varicolori Unit. Most landslides are earthflows. In the secondary valleys of the NW sector of the study area, together with several earthflows, many rotational flows have been noticed, with the landslide front sometimes evolved in a pure flow.

The incisions on the OCRAD are often characterized by sub-vertical head slopes that frequently tend to evolve through successive falls. The retreat of these walls is more rapid where the incising drainage network has downcut to more erodible levels, consequently triggering slope-undercutting processes. In several cases, these levels are made of incoherent alluvial sands: this situation is mostly found in the OCRADs, where the frequency and thickness of the sandy intercalations are higher than those of the gravel member. In the cases of the most evolved valleys (V.ne Codacchio, T. Ianare), the weak basal levels of the OCRAD are directly made of the Tertiary pelitic substratum instead.

On the oldest sub-planar and sub-flat surfaces (glaciais and terraces of the I and II order) the current erosive processes are not as evident as on the previous described areas. Nevertheless, clear erosional surfaces involving the substratum have been found in several outcrops. The detrital material is continuously being transported downvalley by gravitational processes and running waters. An indirect evidence of this comes from the characteristics of the clasts found on the surface: independently from the parent material of the soil, the coarse fragments are always and almost completely calcarenitic, with angular edges; since the only structure evolved on that rocktype in the study area is the Toppo Capomandro hillside, it appears certain that the clasts are the product of the degradation of that slope, which have later moved downvalley through areal processes such as sheet flood and creep. Any case, it cannot be excluded that such materials could derive from reworked surficial deposits of the glaciais.

While the incisions and top surfaces of the glaciais and terraces of the I and II orders appear to be erosive environments, the sub-flat areas at the top of the lower terraces are normally acting as accumulation areas. In particular, the IV order terraces are the substratum of several active fans, supplied by short but highly erosive incisions

developed along the scarps that join the surfaces of different orders. On the whole, all the concavities at the base of the old fluvial scarps can be considered of depositional origin. Instead, incision is the most common process along the minor streams that laterally incise the most recent terrace patches. It is nonetheless likely that the minor drainage network directly drains most of the conspicuous volumes they erode into the Calore River.

INTERPRETATION OF THE DATA AND PRINCIPAL MORPHOEVOLUTIVE STEPS OF THE TELESINA VALLEY

The geological and geomorphological data we collected make it possible to reconstruct the geomorphological evolution of the Telesina Valley, at least during the Quaternary.

The principal steps in such long-term evolution can be synthesised as follows:

- The formation of a gently rolling erosional landscape (Paleosuperficie *Auct.*) (fig. 16-A), probably at regional scale: in fact, relicts of such a paleolandscape are documented in several sectors of the Apennines by several authors (for example: Ortolani & Pagliuca, 1988; Brancaccio & Cinque, 1988; Amato & Cinque, 1999). In our case, this low-energy landscape is represented by the gentle surfaces at the top of the carbonatic reliefs (M.te Camposauro and Toppo Capomandro), just outside the study area (fig. 16-B). Its age can be framed between the Late Miocene and the beginning of the Early Pleistocene.
- An infra-Pleistocene tectonic phase of tectonic fragmentation of the Paleosuperficie, possibly coinciding with the one dated 1.3 My B.P. by Aprile & *alii* (1980). It activated the main fault at the base of the Mt. Camposauro massif and others with minor displacements that are found on the opposite side of the valley (fig. 16-B). These faults are considered direct left-transcurrent faults by D'Argenio (1967) and by Ortolani & *alii* (1994).
- A phase of modelling of the hillslopes (fig. 16-C), which had different consequences on the two sides of the Telesina Valley. On the southern side of the basin (M.te Camposauro), the inherited fragmentation of the carbonate rocks enabled the production of large volumes of detritus, which is nowadays represented by cemented calcareous breccias outcropping immediately outside the study area, along the E-W trending fault scarp that bounds the Mt. Camposauro massif. It is also plausible to hypothesise that a first phase of alluvial sedimentation along the Calore River also occurred during this phase. The presence of a subsiding depression bounded by the main fault created much accommodation space for the produced detrital volumes and therefore for the development of sedimentary masses of considerable thickness. On the northern side of the basin (Toppo Capomandro), the overlapping of a rigid plate («Flyscht Rosso») over mostly-pelitic soft deposits (Unità di Caiazzo) caused large slope undercutting episodes and the retreat

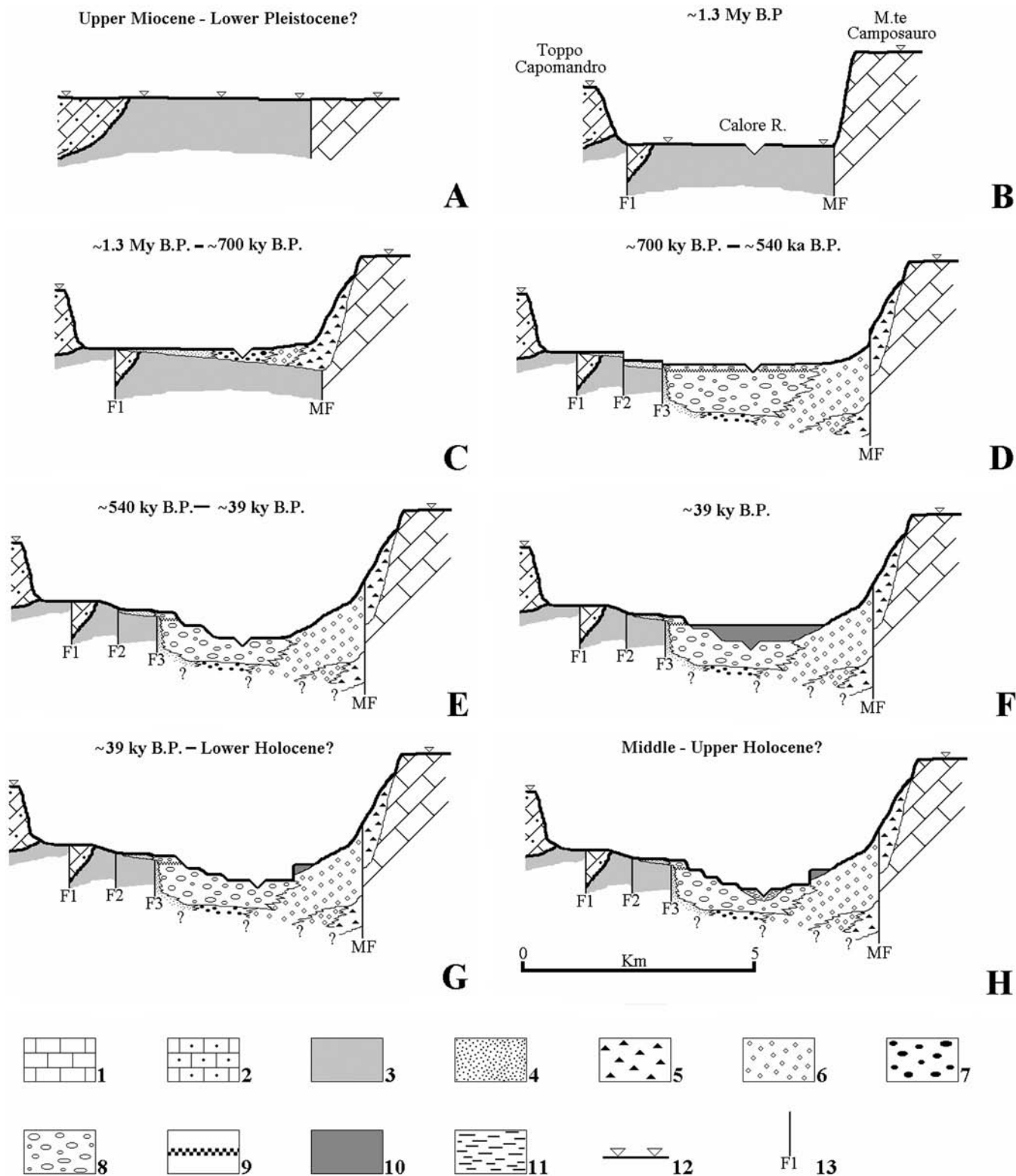


FIG. 16 - Schematic morphostratigraphic cross-sections illustrating a possible succession of the main morphoevolutive steps of Telesina Valley. Legend: 1) carbonatic sediments of Matese-Monte Maggiore Unit; 2) marly-calcarenitic sediments of the «Flysch Rosso» Unit; 3) terrigenous sediments of the Caiazzo Unit and of the Argille Varicolori Unit; 4) slope and alluvial fan deposits; 5) calcareous breccias; 6) alluvial fan deposits; 7) deposits of the first alluvial cycle of Calore River; 8) Old Calore River Alluvial Deposits (OCRAD); 9) Ignimbrite of Guardia Sanframondi with associated paleosols; 10) Campanian Ignimbrite (CI); 11) Recent Calore River Alluvial Deposits (RECRAD); 12) Paleosuperficie *Auct.*; 13) Fault (MF = main fault; F1, F2, F3 = tectonic phases).

of the fault scarp. This was also favoured much by the lithological disuniformity of the retreating scarp, which exposed alternations of calcarenites and marl and was then subject to repeated rockfalls of the calcarenitic blocks. Downslope of the retreating scarp, a glacia slightly dipping towards the valley axis was formed. The flank degradational deposits can only be found on the most distal sectors of glacia: thus, in the distal sectors the glacia probably developed entirely in detritus («bahada» *sensu* Tator, 1953). On the contrary, the most proximal portions of the glacia could have been in part cut in the substratum (interfan areas) and in part of depositional origin (fan areas). The patches cut in the substratum worked as «transporting slopes» (Young, 1972). However, we believe that the fans must have had a reduced thickness, probably because the whole glacia was mainly a by-pass zone between the northern relieves (Toppo Capomandro) and the subsiding zone at the base of Mt. Camposauro. The present scarcity of fan sediments can be also due to successive phases of erosion that remodelled the glacia.

The exact age of this morphoevolutive phase and of the correlative deposits is not known. Nevertheless, the attribution of the Mt. Camposauro calcareous breccias to the Mindel, as proposed by Bergomi & *alii* (1975), seems unrealistic. In fact, the breccias at issue are stratigraphically overlaid by the OCRAD formation, which is to be framed between ~700 ka B.P. and ~540 ka B.P. for reasons that will be given later in this paper.

- A tectonic phase with displacement of the Mt. Camposauro basal breccias, duplication of the glacia and formation of an alluvial basin (fig. 16-D), bordered to the W by a tectonic threshold made of a resistant calcarenite block (outcropping SE of Solopaca). This basin was aggraded by the Old Calore River Alluvial Deposits (OCRAD) which are mostly made of pebbles and must therefore be ascribed to a high energy fluvial environment. In proximity of the threshold, however, the energy of the river was lower because of a reduction of its longitudinal gradient caused by lateral detrital supply higher than elsewhere. This was due to the presence of more erodible rocktypes in the tributary valleys, whose terminal fans were probably able to produce partial damming of the Calore River. The latter deposited here sands, gravels and pelites passing on the margins of these sectors to swamp and/or lake areas where a silty-clayey deposition occurred.

The end of this morphoevolutive phase can be chronologically constrained by the Ignimbrite of Guardia Sanframondi (IGS), which is intercalated in the uppermost part of the OCRAD and it is dated 560 ± 2 ka B.P. This age results absolutely coherent with archaeological data as well, relative to cherty artefacts found within the alluvial succession and said to be from the old Paleolithic period (pers. com. of Prof. F. Fedele).

The beginning of the OCRAD aggradation phase still remains uncertain. Nevertheless some comments can be made. In the first place, the remarkable thickness of

these alluvial deposits strongly suggests a link with a period of strong detrital supply from the adjacent relieves that is reasonably to be related with a cold (glacial) climatic phase. Considering that the emplacement of the IGS occurred during the cold OIS-14 and that the IGS covers paleosols developed under warm-humid conditions, (OIS-15?), it appears reasonable ascribe to the OIS-16 the OCRAD portion underlying the IGS which ended ~620 ka B.P. (Karner & *alii*, 1999). Nevertheless, the pre-IGS portion of OCRAD is more than 150 m thick and it appears difficult to explain such huge formation by invoking only the action of the climate. Probably, such aggradation was favoured also (and perhaps mainly) by conditions of tectonic instability consisting in a notable uplift of the horsts bounding the subsiding Calore Valley. A situation of this type would have been realized, according to Aprile & *alii* (1980), about 700 ka B.P. It appears then reasonable that the OCRAD aggradation and thus the morphoevolutive step in question began at the beginning of the Middle Pleistocene.

- The terracing in three orders of the OCRAD, probably due to complex interactions between climatic changes and some minor tectonic events (fig. 16-E), which are testified by the intense grade of fragmentation and by some evidence of tilting affecting the older alluvial terraces. After the formation of the depositional surface of the I order terraces, which ended, as previously mentioned, ~540 ka B.P., the Calore River entered a period of downcut. This was either accompanied or followed by lateral planation phenomena that caused the formation of the erosional surfaces of the II order terraces. The exact age of this order cannot be evaluated precisely. The only chronological constraint is actually represented by the presence, on a few relict patches, of lithic artefacts of the Early Musterian age, datable 200 ka B.P. (pers. comm. of Prof. F. Fedele). Thus, the II order terraces must have formed between 540 and 200 ka B.P. The fact that they have a degree of conservation very similar to that of the I order terraces leads to prefer the oldest part of this time span.

After the formation of the II order terraces a new incision phase began, with lateral planation of the Calore valley floor and the formation of the III order terraces, which are absent both in the area between the T. Ianare and the V.ne Fornace, and S of Toppo Limata (fig. 1). In the first case, the course of the OCRAD boundary suggests that the gap is probably due to the narrowing of the paleo-valley in this sector (fig. 2): if any III order terrace formed in this reach of the valley, they would have had limited extension and, thus, they went easily dismantled during the following events. S of Toppo Limata, we believe that the III order terraces have been dismantled by bank erosion connected to the recent northward migration of the Calore R. in this part of the valley. This hypothesis is confirmed by the presence of sub-parallel traces of abandoned meanders observed on the aerial photos. Sub-parallel migrations of this kind

represents a frequent type of fluvial response to tilting processes (Keller & Pinter, 2002); an explanation that – in our case – is supported by the anomalous dipping of the alluvial deposits towards the N.

The exact age of these III order terraces is still undetermined. Nevertheless, the fact that the tributary valleys dissecting this orders contains outcrops of the Campanian Ignimbrite (CI) indicates that ~39 ka B.P. the III order terrace was already deeply incised. The erosive origin of the II and III order terraces suggests that the studied valley sector was uplifting with respect to sector located further downstream, as already hypothesised by Aprile & alii (1980).

During this phase of progressive, even if not continuous, lowering of the local base level it is likely that both the dissection of the old glacis and the removal of its original alluvial cover underwent their highest boost.

- A partial filling of the valleys by the CI (fig. 16-F). The age of this morphoevolutive step is ~39 ka B.P.
- A phase of intense incision by the Calore River, which was followed by lateral planation processes. This resulted in the almost complete removal of the CI from the axial sector of the valley, which was deepened down to the underlying OCRAD. It resulted also in a successive modelling, on the same OCRAD, of a new erosional surface (IV order terrace; fig. 16-G). The incision on the CI is witnessed by the fluvial erosion scarps, sometime more than 15 m high in the study area and even more evident in the sector of the Telesina Valley that is immediately W of the study area. The CI today is preserved solely in paleo-valleys that dissect the I, II and III order terraces and, on the S side of the valley, on top of the ancient alluvial fans.

The existing knowledge does not permit to exactly date the morphoevolutive phase during which the CI was dissected and the IV order terraces formed. Nevertheless, the large extension and the excellent degree of preservation of those terraces suggests that it lasted till a quite recent times (Early Holocene?).

It was probably in this phase that the steep fault scarps clearly visible on both sides of the valley (see attached Geomorphological Map) formed, possibly as reactivation of pre-existing discontinuities. On the N side of the valley, these scarps cut the OCRAD deposits and run at the base of the slope descending from the III to the IV order terraces. On the S side, the scarps cut the basal fan deposits of the Mt. Camposauro massif. On both sides, portions of streams with an anomalous geometry interrupt the lateral continuity of these scarps. Here, lateral to these anomalous streams reaches, the scarp is shifted either uphill or, more often, downhill. It is thus likely that those stream reaches are flowing along transcurrent faults. The fault scarps are obviously younger than the IV order terraces that, as mentioned before, are reasonably of Early Holocene in age. The recent age hypothesized for these faults is coherent with their morphological «freshness» in spite of the high erodibility of the alluvial deposits in which they are cut.

- A phase of lowering of the local base level followed by a last period of valley floor aggradation. This latter corresponds to the deposition of the Recent Calore Alluvial Deposits (RECRAD) and the formation of the depositional surface of the V order terrace (fig. 16-H). The border between the IV and the V order terraces is not morphologically well evident, proving that the RECRAD aggradational event went all the way up to an elevation quite similar to that of the IV order terraces, so that the scarps that originally delimited the IV order terrace downvalley were totally or largely buried (fig. 9 and fig. 13). The RECRAD are mostly characterized by silty-sand overbank deposits, while coarser riverbed deposits occur only near the current thalweg. This indicates a much less energetic environment than OCRAD event.

Analysed on the aerial photos, the V order terraces showed the presence of very well preserved traces of paleo-riverbeds. This circumstance, coupled with the very good grade of preservation of the terraces and the reduced degree of pedogenesis of the overlying soils, suggests that the V order terraces formed during the last millennia (?Middle-Late Holocene).

- Nowadays, the fluvial dynamic of the Calore is characterized by prevalent incision and by local aggradation of new alluvial deposits, with discontinuous formation of very low-lying terraces of the 0-order along the Calore River. Similarly, the minor drainage lines are progressively downcutting and their valley sides are experiencing intense morphodynamic processes, with prevalent evolution through landslides and intense surface wash.

CONCLUSIONS

This study has made it possible to geomorphologically characterise a little-known sector of the southern Apennines: the Telesina Valley. The local record of past geomorphic stages is often made ambiguous and/or incomplete by the low conservative power of the rocks and sediments in which the relict landforms are cut. However, the main steps of the Quaternary evolution of the area were delineated. Moreover, the dating of a till now unknown pyroclastic deposit (herein named Ignimbrite of Guardia Sanframondi) together with the study of the relations of the Campanian Ignimbrite with the younger alluvial terraces, made it possible to fix some geochronological constraints to the evolution of the Telesina Valley, which can be synthesised as follows:

1. Formation of an erosive surface (Paleosuperficie *Auct.*) between the Late Miocene and the Early Pleistocene.
2. A tectonic phase in the Early Pleistocene (possibly 1.3 My B.P.) with consequent displacement of the Paleosuperficie and the formation of a E-W elongated depressed area.
3. A phase of intense modelling of the valley sides with accumulation, on the southern side, of breccias and alluvial deposits and with the formation, on the northern side, of a partly erosive and partly depositional glacis (Early Pleistocene).

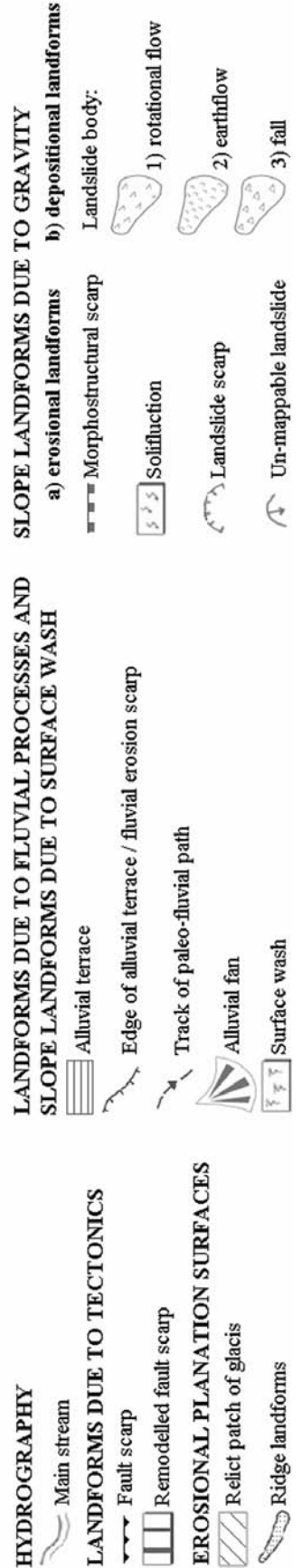


FIG. 17 - Geomorphological map of Telesina Valley.

4. A new tectonic phase with displacement of the breccias, duplication of the glacis and formation of an axial depression that was aggraded by the Old Calore River Alluvial Deposits (~700 ka B.P. - ~540 ka B.P.), which carry intercalated in its upper part the Ignimbrite of Guardia Sanframondi (~560 ka B.P.).
 5. Terracing in three orders of the Old Calore River Alluvial Deposits due to alternating processes of downcutting and lateral planation (~540 ka B.P. - Late Pleistocene).
 6. A phase of dissection followed by the emplacement of the Campanian Ignimbrite (~39 ka B.P.).
 7. A phase of incision and lateral planation of the Calore River with erosion of the Campanian Ignimbrite and formation of the IV order terrace (~39 ka B.P. - ?Early Holocene).
 8. Phase of lowering and successive rising of the local base level with aggradation of the Recent Calore River Alluvial Deposits and the formation of the depositional terrace of the V order (?Early Holocene - Late Holocene).
 9. Current drainage network deepening and an intense erosive morphodynamic of the hillsides mostly through landslides and surface wash processes.
Worthy to note is the possible correlations of the OCRAD alluvial phase with the paleoclimatic data given in Karner & alii (1999) and Russo Ermolli (1995). These papers are based respectively on $\delta^{18}\text{O}$ and pollen data regarding the Vallo di Diano area, which is not too far from our study area and has a geomorphological context very similar to that of the Telesina Valley. Both curves show the presence of a cold peak, more or less corresponding to the OIS-14 of Imbrie & alii (1984), which falls between ~540 and ~580 ka B.P. At least the portion of the OCRAD which lies above the IGS can be reasonably referred to a phase of increased detrital production promoted by that cold stage. The relatively small thickness of OCRAD alluvium overlying the ~560 ka tephra suggests that the aggradation phase stopped in concomitance with the end of the cold stage at issue. Other than a notable increase of the detrital production and, therefore, of the fluvial aggradation, the rexic static conditions that began around 580 ka B.P. caused an intense erosion of the soils that had been formed in a previous climatic phase. This intense erosion is confirmed by the presence of erosive surfaces that constantly separate the paleosols underlying the IGS from the ignimbrite itself. The vertic features, the strong decarbonation and the evidence of clay illuviation found in these paleosols all indicate a pedogenesis in warm and humid climatic conditions with a strong seasonality. A temperate climatic phase (OIS-15) that occurred before the deposition of the IGS was found by Karner & alii (1999) and by Russo Ermolli (1995) in the interval between ~580 and ~620 ka B.P. It is thus reasonable to link the formation of the fossilised paleosols with this climatic phase. The presence of that paleosols indicates also a phase of general stability of the geomorphological surfaces before the onset of the following alluvial phase.
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