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HOLOCENE FLUVIAL DYNAMICS IN MOUNTAIN AREAS: THE CASE OF THE RIVER ESINO (APPENNINO UMBRO-MARCHIGIANO)

ABSTRACT: CILLA G., COLTORTI M. & DRAMIS F., *Holocene fluvial dynamics in mountain areas: the case of the River Esino (Umbria-Marche Apennines)* (IT ISSN 0391-9838, 1994).

On the basis of detailed morphological, sedimentological and stratigraphical investigations the Early Holocene evolution of the source area of the River Esino (close to Esanatoglia, Umbria-Marche Apennines) is outlined. Particularly important in this framework was the emplacement of thick deposits of phytohermal and phytoclastic travertine, favoured by the presence in the waters of a greater amount of CO_2 deriving from densely vegetated slopes. Beginning from 3.500 y. B.P., the travertine deposition underwent a progressive reduction and than ceased possibly connected with anthropic deforestation.

KEY WORDS: Fluvial dynamics, Travertine, Holocene, Apennine, Italy.

RIASSUNTO: CILLA G., COLTORTI M. & DRAMIS F., *Dinamica fluviale olocenica in aree montane il caso del Fiume Esino (Appennino Umbro-Marchigiano)* (IT ISSN 0391-9838, 1994).

Sulla base di dettagliate indagini morfologiche, sedimentologiche e cronostratigrafiche, viene delineata l'evoluzione del tratto montano del fiume Esino (nei pressi dell'abitato di Esanatoglia, Appennino Umbro-Marchigiano), durante la prima parte dell'Olocene. Particolare importanza ha avuto in questo ambito la deposizione all'interno delle valli, di potenti corpi di travertino fitoermale e fitoclastico, favorita dalla maggiore quantità di CO_2 nelle acque legata alla rioccupazione dei versanti da parte di una fitta vegetazione boschiva. A partire da 3.500 A.C. la sedimentazione di travertino subisce una progressiva diminuzione, fino a cessare probabilmente in seguito all'incremento della presenza antropica nell'area ed a conseguenti attività di disboscamento.

TERMINI CHIAVE: Dinamica fluviale, Travertino, Olocene, Appennino.

INTRODUCTION

The evolution of the middle-lower reaches of the valleys in the Umbria-Marche area during Holocene has been the subject of numerous studies in recent years (COLTORTI, 1981, 1991; BIONDI & COLTORTI, 1982; GENTILI & PAMBIANCHI, 1987; CALDERONI & *alii*, 1989; COLTORTI & *alii*, 1991). After a period, lasting up to the Middle Ages, of generally slow deepening of the river bed by meandering streams, which in the case of some minor valleys is still going on, these reaches were subject to aggradational processes. A first phase, occurring before the 3rd Century B.C., which has left few traces in the valley morphology, is well documented in the coastal areas and locally at the junctions with secondary side valleys. The most evident aggradational phenomena in the river beds occurred after the 11th and 12th Centuries; like the previous phenomena, these have been associated with soil erosion due to anthropic activity on the slopes. This phase can be identified in the majority of Marchean and Italian watercourses (ROVERI, 1964; CANUTI & *alii*, 1991; BISCI & *alii*, 1992) and lasted until the end of the 19th Century and locally up to the first half of the 20th. Subsequently, due to the abandoning of agriculture, to embankment works, the building of reservoirs, and the extraction of gravel from the beds, the first important erosional processes were seen; these continued until the bedrock was locally reached and channeled into (GENTILI & PAMBIANCHI, 1987; VITTORINI, 1991).

The research conducted in the upper reaches of the Esino river has evidenced that the source areas have been subject to somewhat different processes, and that evolutionary analogies are characterized by marked differences in chronology. The study of the area supplies useful data for reconstructing the fluvial dynamics and their variations in time and space over the whole hydrographic basin.

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THE GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The River Esino rises in the Umbro-Marchean Apennines on the eastern side of the Umbro-Marchean Ridge; after initially running northeastwards, transversally to the structures, it turns to NNW following the Camerino synclinorium. Then it transversally cuts the Marchean Ridge and the Periadriatic Basin, to enter the Adriatic to the north of Ancona. On the ridges, the bedrock is prevalently composed of limestone and marly-limestone sediments, Jurassic to Oligocene in age (CENTAMORE & *alii*, 1986), while in the Camerino Basin characterized by terrigenous sedimentation, Miocene sandstone, pelitic, and, more rarely, gypsum sediments crop out (CANTALAMESSA & *alii*, 1986b). In the peri-Adriatic basin, the marine sedimentation, at first terrigenous and then littoral, extends from Lower Pliocene to Middle Pleistocene (CANTALAMESSA & *alii*; 1986a).

The structural framework of the area is connected to the evolution of the Umbro-Marchean Apennine Arc. This was characterized by deformations of the Triassic-Pliocene sedimentary multilayer, which from Upper Miocene to Lower Pliocene was subject to large-scale eastward-trending folds and overthrusts (BALLY & *alii*, 1986; BOCCALETTI & *alii*, 1986; CALAMITA & DEIANA, 1986; CALAMITA & *alii*, 1991). The Apennine area began to emerge in Miocene and, after a period of relatively quiescent tectonics, underwent differentiated uplifting; from the Middle Pleistocene the whole external Marchean Basin was involved (AMBROSETTI & *alii*, 1982; COLTORTI & *alii*, 1991; DRAMIS, 1992).

The geomorphology of the area has been strongly influenced by the structural framework, the difference in stiffness of the outcropping rocks, the recent tectonic evolution, and by the various modelling processes connected with Quaternary climatic variations.

On the ridges, the relief goes up to and over 2.000 m and is characterized by summit surfaces with flat morphology and with vast slightly undulating portions. The latter represent the remains of an ancient flattened surface modelled during a period of relatively quiescent tectonics (COLTORTI, 1981; CICCACCI & *alii*, 1985; DRAMIS & *alii*; 1991, DRAMIS, 1992). The summit surfaces are deeply cut by narrow valleys trending anti-Apenninically, that become gorges where the lithology has greater stiffness. The modelling of these landforms is correlated with vertical erosion processes due to the Middle Pleistocene uplifting (DUFAURE & *alii*, 1988; DRAMIS, 1992).

During the cold phases of Middle and Upper Pleistocene, this general tendency to vertical erosion was slowed down by the intense degradation of the slopes, a phenomenon leading to the emplacement of several generations of stratified debris deposits (CASTIGLIONI & *alii*, 1979; COLTORTI & *alii*, 1983; COLTORTI & DRAMIS, 1987, 1988). Inside the valleys, the emplacement of various alluvial units occurred, mainly due to braided streams and presently they are preserved at progressively higher altitudes on the thalweg (CHIESA & *alii*, 1990; CALDERONI & *alii*, 1991; COLTORTI & *alii*, 1991). These units underwent terracing during the interglacial phases as a result of the enhanced erosive power of the streams, which were no longer obstructed by debris and were generally formed of single meandering channels. Similar processes characterized the evolution of most of the marchean valleys during Early Holocene, and are still today active in the neighboring areas.

During recent Holocene, the practice of agriculture and grazing on the slopes, together with deforestation, have activated intense erosive processes connected with rapid aggradation in the middle-lower stretches of the valleys (COLTORTI, 1981, 1991; CALDERONI & *alii*, 1989; COLTORTI & *alii*, 1991).

THE GEOMORPHOLOGY OF THE AREA

The study-area of the upper basin of the River Esino lies on the eastern slope of the Umbria-Marche Ridge, between the source and the town of Esanatoglia a few kilometers downstream (450 m asl). The folds and thrusts of the ridge have been deeply cut along an anti-Apenninic fault, giving rise, where the rocky outcrops with greatest stiffness occur, to narrow gorges, small hanging valleys and waterfalls (fig. 1). Downstream from Esanatoglia where the rocks with lesser stiffness crop out, the valley widens to over 500 m. The basin is bordered by narrow sharp ridges and, where marls outcrop, complex landslide phenomena of limited extension can be observed involving both the bedrock and the overlying colluvial sediments.

The upper parts of the relief are at times modelled by small nival niches mainly exsposed to N and NE. Along the slopes, two main generations of slope waste deposits are present, sometimes reaching the valley floor. The older generation, at times covered by the successive one, is characterized by strong cementation and the presence in its summit part of remnants of reddish-brown clayey horizons which evolved during the last Interglacial (COLTORTI & DRAMIS, 1987, 1988; CHIESA & *alii*; 1990); the second debris generation accumulated during the Upper Pleistocene.

On the south facing slopes, where anthropic activity such as forestry and grazing have led to considerable scarcity of tree cover, processes of slope-wash, gullying and solifluction are active remobilizing ancient debris and causing the formation of small fans on the valley floor.

The surface waters are the main agent in the modelling of the basin. The area at the head of the valley is remarkably steep (over 30%) and, for a few hundred meters from the source, is characterized by the presence of numerous small waterfalls on which travertine deposits are found. The average angle of slope of the lower portion varies approximately from 5.3% upstream from Esanatoglia to 2.4% downstream. At Conceria Ottolina, the profile displays a series of steps representing an overall dislevel of more than 30 m. These steps were built during the Middle Ages to prevent expansion of the regressive and lateral erosion processes particularly active in this part of the valley. Between the source and the town of Esanatoglia, the river bed is straight (sinuosity index 1.1), is 2-4 m

FIG. 1 - Geomorphological map of the Esanatoglia area: 1) Limestone, 2) Marls and marly limestone, 3) Alluvial deposits (Middle Pleistocene), 4) Alluvial deposits (final Middle Pleistocene), 5) Alluvial deposits (Upper Pleistocene), 6) Alluvial deposits (Holocene), 7) Travertine (Holocene), 8) Travertine (present-day), 9) Slope debris (Middle and Upper Pleistocene), 10) Colluvial deposits (Upper Pleistocene - Holocene), 11) Alluvial fans and debris (Holocene), 12) Landslide deposits, 13) Structural escarpment, 14) Rounded crests, 15) Crests with sharp edges, 16) Fluvial erosion scarp, 17) Paleochannels containing phytoclastic sand; 18) Gullies, 19) Concave valley floor, 20) Slope-wash, 21) Outcrops of bedrock in riverbed, 22) Landslide crown, 23) Reverse fault, 24) Thrust, 25) Normal fault, 26) Buried fault, 27) Layering: a) subvertical, b) subhorizontal, c) 5-45°, d) 45-80°, e) overturned, 28) Location of Sections: 1, S. Pietro; 2, C. la Valle; 3, 4, 5, 6, 7, Crocefisso; 8A e 8B, C. Fornaro; 9, Autorimessa Binni; 10, Conceria Zampini; 11, C. S. Marco.

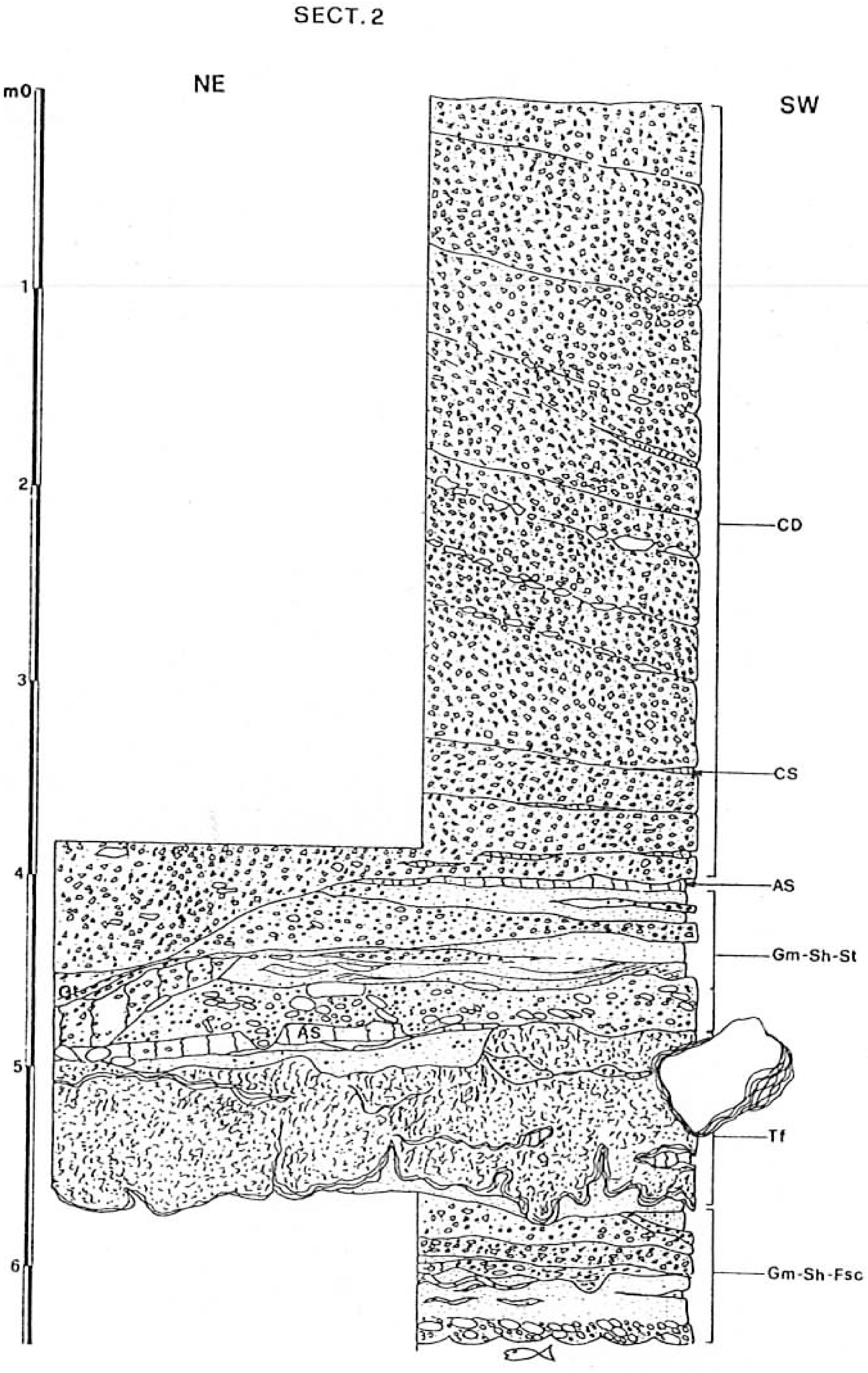

FIG. 2 - Section 2 (Casa La Valle) (for localization, cf fig. 1); the symbols used for the fluvial deposits, except for the phytohermal and stromatolithic ones, are taken from MIALL (1977, 1985): CD, colluvial debris deposit; AS, alluvial soil; CS, colluvial soil; Tp, phytohermal travertine.

wide and at certain points is on the limestone bedrock. Holocene alluvial deposits, of limited thickness and extent, are present at the sides of the river bed, which has been cut to a depth of 1-3 m by the present-day stream. Until relatively recent times, before downcutting processes, these deposits were covered by fluvial waters during heavy floods.

Downstream from Esanatoglia, the alluvial plain becomes progressively wider and the watercourse remains deeply entrenched within the Upper Pleistocene alluvial sediments. In this stretch, the river is about 3-5 m wide, and still follows a straight course (sinuosity index 1.3) entrenched in its own alluvia. The stream tends to become more sinuous, causing on the convex side the formation of small gravelly, sandy bars, whereas the concave side displays lateral erosion with the formation of pools 1-2 m wide and 50-80 cm deep. Since the river is entrenched 2-3 m in the deposits of the alluvial plain below the present one, flood phenomena are very limited.

Two terraced alluvial units, attributed respectively to the Middle-Late and Upper Pleistocene (SERVIZIO GEOLOGICO D'ITALIA, 1987; CALDERONI & *alii*, 1991) are present in the outermost part of the ridge, downstream from Esanatoglia, at progressive heights above the present-day bed. The lower unit, located above the present channel and the recent alluvial plain, is the more extensive one and can be observed continuously along the valley. The depositional surface is approximately 15-20 m above the thalweg and displays a flattened morphology, now considerably cut into by the present-day deepening of the river bed. Where the erosion was more intense, steep scarps have formed up to ca 20 m in height. Proceeding upstream, the height of these scarps progressively decreases. The base of the deposit rests on the bedrock, which is shaped into mounds and paleochannels modelled by the fluvial dynamics preceeding the aggradation phase. The sediments forming the body of this 15-25 m thick unit evidence a complex depositional history embracing the Middle and Upper Pleniglacial (CHIESA & *alii*, 1990; CALDERONI & *alii*, 1991). During the stadials, braided channels developed, prevalently with aggradation of gravelly sediments; in the Hengelo and Denekamp-Arcy Interstadials, gravels, silt, and clays with peat were deposited inside anastomosed channels, while silty and sandy alluvial plains evolved during the Kesselt and Tursac Interstadials. The upper part of the unit, emplaced during Late Glacial, displays more complex characteristics with gravelly sediments deposited by relatively sinuous channels and flood silt preluding the development of more stable channels in a phase of gradual deepening (CALDERONI & *alii*, 1991).

The finding of artefacts in the summit part of this unit (COLTORTI, 1981; SILVESTRINI & PIGNOCCHI, 1987), allows one to establish that the deposition was concluded approximately with the end of Upper Pleistocene. The summit appears to be altered by brown soils and vertisols that evolved from the end of the last Glaciation. Inside these soils, lithic artifacts and neolithic ceramics apparently not reworked (CILLA, unpublished) were frequently observed, similar to what was found at the Maddalena di Muccia site and dated by the ^{14}C technique to between 5.760 and 5.225 B.C. (LOLLINI, 1965).

The higher of the two terraced units, the summit of which is at about 35-45 m above the thalweg, is found in extensive limbs along the valley. It is separated from the underlying alluvial unit by steep scarps up to 20 m high with rounded edges. The 15-20 m thick deposit is made up of gravelly sediments, mostly deposited by braided channels. In the area of Esanatoglia, these sediments locally rest directly on the bedrock, which also consists of mounds and paleochannels. Silty-clayey deposits of lacustrine origin have been observed in the lower part of these sediments. (COLTORTI, 1981; GENTILI & PAMBIANCHI, 1988). The upper part of this unit is weathered by reddish clay borizons of fersiallitic paleosoils, sometimes containing Middle Paleolithic artifacts (COLTORTI & *alii*, 1980; CILLA, unpublished).

THE FLUVIAL MODELLING DURING HOLOCENE

The sequence of Casa la Valle (Section 2, fig. 2) illustrates the events that have occurred upstream of Esanatoglia.

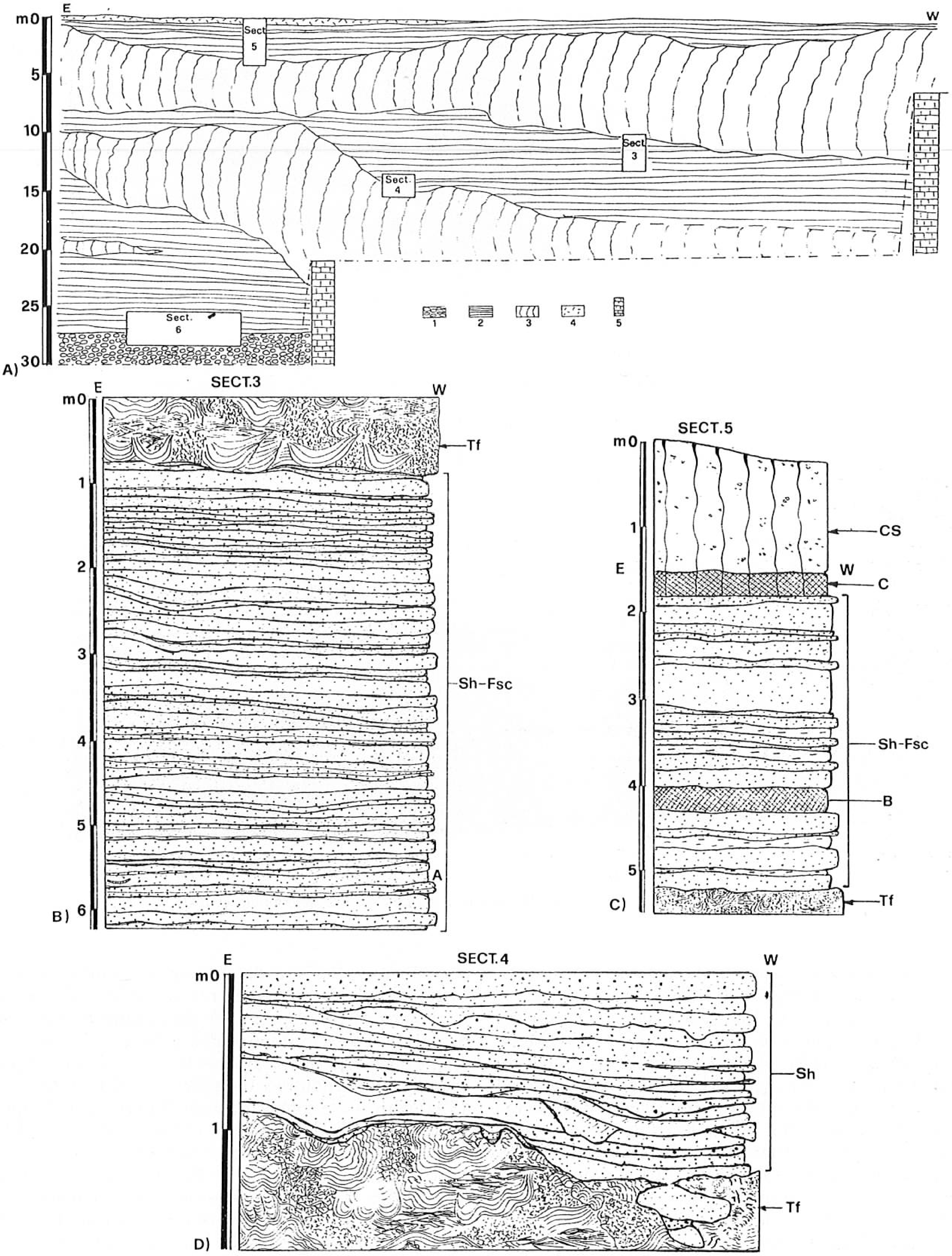

FIG. 3 - A: General framework of the Esanatoglia deposit (Crocefisso) with location of Sections (3, 4, 5, 6): 1) Alluvial gravels (Upper Pleistocene), 2) Phytoclastic sand deposits (Holocene), 3) Phytoherrnal travertine (Holocene), 4) Colluvial deposits, 5) Small check dams. The hatched line indicates the longitudinal profile of the Esino watercourse; B: Section 3 (Crocefisso); C: Section 4 (Crocefisso); D: Section 5 (Crocefisso): A and B represent archaeological levels; for description, cf text.

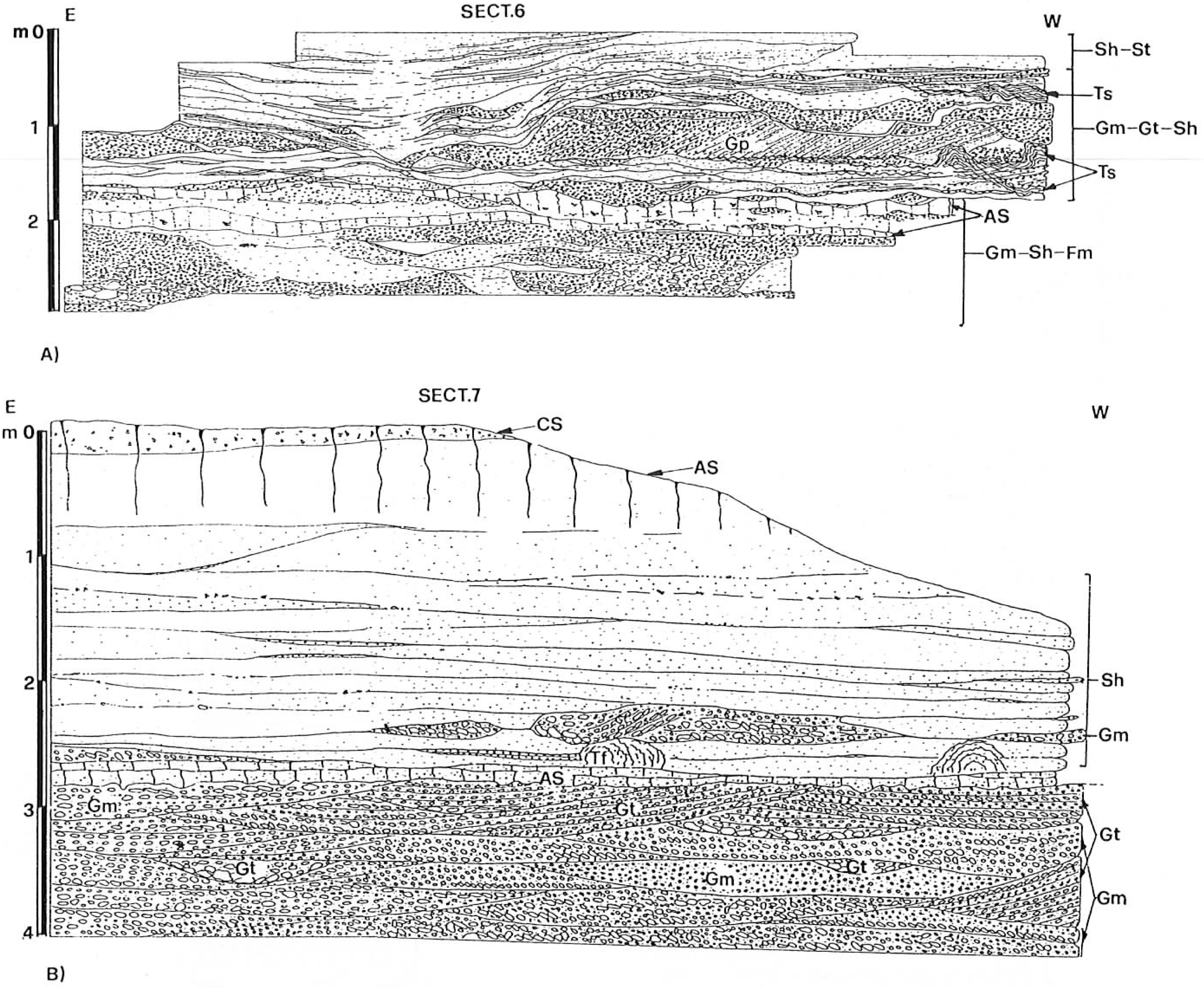

FIG. 4 - A: Section 6 (Crocefisso); B: Section 7 (Crocefisso): for description, cf text.

At the base of the outcrop, medium to coarse gravels, sometimes embricated (the Gm lithofacies of MIALL, 1977; 1985), are overlaid by fine and coarse travertine, phytoclastic sands (Sh) and again, by subangular gravels (Gm). Upwards, a layer of phytohermal travertine (Tp) containing gravelly lenses, phytoclastic sands and isolated blocks, weathered at the top by a thin layer of alluvial soil (AS; sandy loam; wet, 5YR 3/4 dark reddish brown). This is again followed by decimetric gravelly layers (Gm), phytoclastic sandy lenses (Sh) cut by a small channel filled with gravelly sediments (Gt) and buried by bar gravels and sands (Gm, Sh) altered by a thin layer of alluvial soil (sandy loam; wet, 10 YR 3/3 dark brown). These sediments are covered by more than 4 meters of colluvial debris deposits (CD) containing charcoal lenses and ceramic fragments from historical periods.

About 200 m upstream from this section above the phytohermal deposits, ceramic material of the Bronze Age (2.000 years B.C.) apparently not reworked has been found; this probably represents a chronological reference to the end of the deposits for the analogous sediments of Section 2. These sections evidence the associations of sediments deposited in shallow pools, affected periodically by gravelly sedimentations (lithofacies 1 of GOLUBIC & *alii*, 1993) with those connected with the presence of rapids or small waterfalls (lithofacies 3 of GOLUBIC & *alii*, 1993).

Near the spring, another sequence (Section 1) evidences in its lower part coarse limestone gravels containing blocks also of phytohermal origin (max diameter 30-40 cm). The gravels are sometimes embricated and with parallel bedding (Gm). The clastic sedimentation is interrupted by sandy lenses with crossbedding (Ss) corresponding laterally with thin-layered stromatolithic travertine deposition (Ts). Further, 20-30 cm thick phytoclastic calcarenites (Sh), without chronological reference, are found. The abundant travertine blocks on top of the sequence

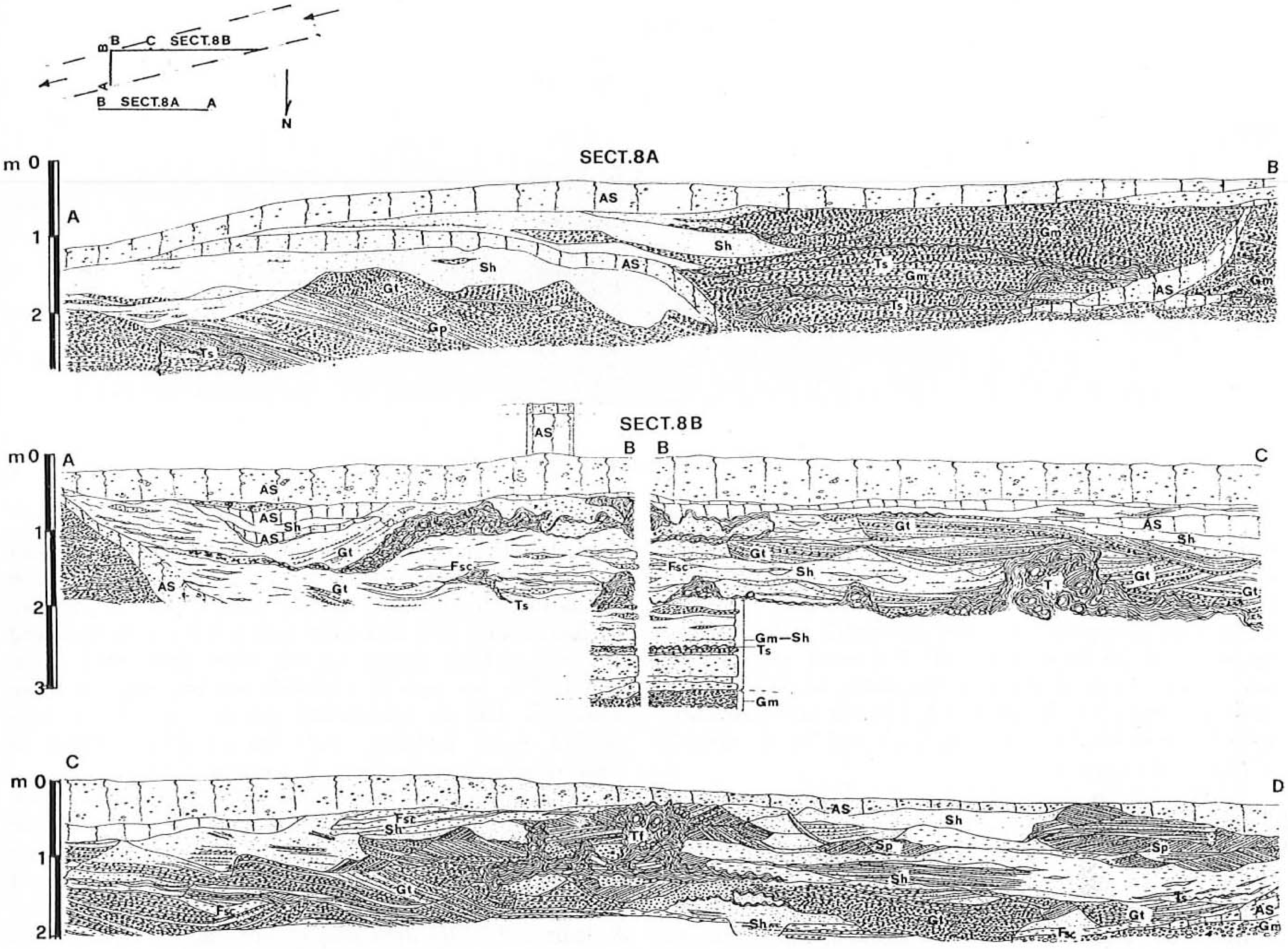

FIG. 5 - Sections 8A and B (Casa Fornaro): for description, cf text.

suggest an erosion of phytohermal deposits located upslope which can be correlated with the events following the phytohermal phase of the previous section.

Downstream from Conceria Ottolina (fig. 1), numerous sections have been observed that have allowed a more detailed description of the valley evolution. This locality is near the apex of an alluvial deposit about 25 m thick, 500 m long and 200 m wide, mainly formed of alternations of phytoclastic calcarenites and phytohermal travertine (fig. 3; Sections 3-6). Further paleogeographic considerations have been based on observations made on outcrops located a few dozen of meters downstream (Sections 7-11).

In Sections 6 (fig. 4A) and 7 (fig. 4B), illustrative of the characteristics of the basal part of the deposit, the prevalently phytoclastic travertine sediments rest on Gm gravels or shallow channels with limited lateral extension (Gt). The stratigraphy of Section 6, near which the bedrock crops out, is more complex; coarse channel bed gravels, sandy and sandy silt fill (Sh and Fm) are intercalated with the gravelly facies. These sediments have been altered by an alluvial soil (AS; sandy loam; wet, 10YR 4/1 dark gray) on the top of which gravelly lenses (Gm) and sandy layers (Sh) have been deposited, again altered by an alluvial soil (AS; sandy loam; wet, 10YR 4/1 dark gray). Also in Section 7, at the top of the gravelly deposits, two superposed alluvial soils have developed, probably corresponding to those observed in Section 6. Here phytoclastic sands (Sh), 1.5 m thick, with local intercalations of gravelly lenses (Gm) overlie the alluvial soils. In addition, there is the presence of a gravelly bar (Gp) connected with the lateral migration of an approx. 1-m-deep channel. At the base of this channel and at the top of the gravelly lenses, thin stromatolithic crusts (Ts) can be observed, locally extending to create small phytoherms, thereby indicating the continuous lateral transition to environments characterized by gentle slopes (lithofacies 3 of GOLUBIC & *alii*, 1993). The occurrence of parallel bedded phytoclastic sands and silts (Sh and St) with local silty-clay intercalations (Fm) in the upper part of these sections, suggests the formation of narrow pools over a long period of time.

The middle-upper part of the Esanatoglia alluvial deposits (Sections 3, 4 and 5) is made up of phytoclastic sediments alternating with 3-4 phytohermal travertine bodies several meters thick (up to 8 m). The emplacing of these bodies, whose formation can be associated with the presence of small

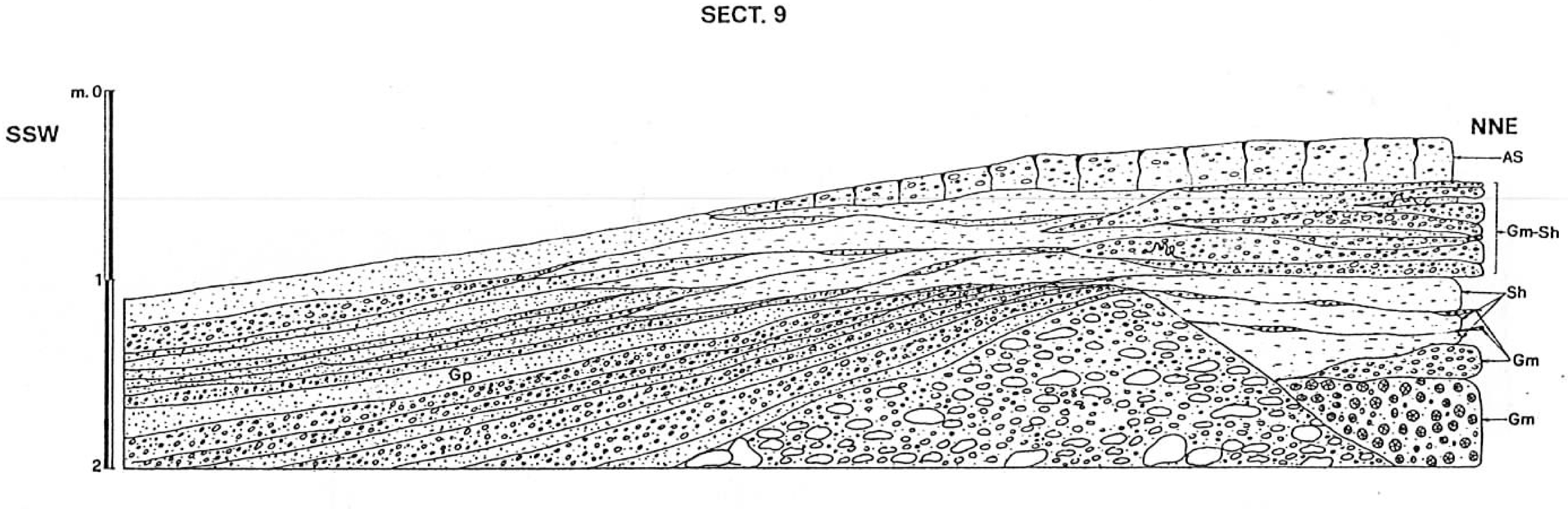

FIG. 6 - Section 9 (Autorimessa Binni): for description, cf text.

waterfalls (De Zutter, 1981; Nicod, 1986; Golubic & *alii*, 1993), evidences a prevalently horizontal growth with a fair-sized vertical component connected with the progressive concretioning of the thresholds which marked the edges of the pools upstream. The sandy and silty facies, inside which centimetric fragments of phytohermal travertine can often be observed, have in fact frequently been noted inside the depressions created by the growth of the phytohermal facies.

Sections 3 (fig. 3B) and 4 (fig. 3D) show the sedimentological characteristics of the intermediate part of the deposit, formed exclusively of phytoclastic and phytohermal sediments. In Section 3 inside a phytoclastic sandy layer (layer A) a large piece of polished black ceramic, apparently not reworked, was found; this fragment can be attributed to the end of Neolithic (ca 5.500. B.P.). In the upper part of the deposit (Section 5, fig. 3C), formed prevalently of phytoclastic sediments with a limited percentage of phytohermal ones, two other archaeological levels were found (layers B and C). The upper one, containing some ceramic fragments of the Apenninic culture (ca 3.300-3.500 yrs. B.P.) is situated at the top of the travertine alluvial deposits all over the area, and is buried by colluvial sediments more than 1 m thick which were emplaced in historical times, given the presence of glazed ceramic material. In the lower layer, there is the presence of lithic and ceramic artefacts with «barbottin» decoration that shows remarkable analogies with that described in the upper levels (layer 4) of the Aquatina di Fabriano site (Lollini, 1965); it may thus be referred to the Eneolithic (ca 4.500-5.000 y. B.P.). A time span of 1.000 years occurred to have the deposition of 2 meters of phytoclastic travertine.

Downstream, the travertine sediments decrease considerably in thickness and are often found within the channels. The Casa Fornaro section, approximately 12 m above the present-day stream (Section 8A; fig. 5), evidences concave (Gt) and planar (Gp) crossbedded gravels due to the superposition of longitudinal and lateral bars deposited inside channels which are a few meters deep and locally exceed 10 m in width. The fill is represented also by massive phytoclastic sands (Sh) with pebbly lenses and thin lenses of stromatolithic deposits (Ts) emplaced during pauses in the clastic sedimentation. Locally there is also the presence of alluvial soils (AS) that alter both the bar sediments and the channel beds during periods when these were abandoned. The present-day channels cut the base of these sediments that are prevalently gravelly, massive or with parallel planar bedding, with characteristics similar to those observed at the base of Sections 6 and 7.

A nearby section (Section 8B; fig. 5) evidences a channel about 4 m in depth and 10 m wide partly cutting the deposits of Section 8A; on the left flank of this, planar crossbedded gravels (Gp) are found. After a long period of abandon, during which an alluvial soil developed (AS, sandy loam, 10 R 3/2 dark greyish brown), the channel was filled by crossbedded fine gravels and sands (Gt, St, Sp) which point to a considerable extent of minor channeling. Also present are sandy (Sh), silt and clayey (Fsc) layers, and locally phytohermal bodies of modest thickness. The concretioning also occurs at the expense of branches and leaves. Some clasts are formed of rounded ceramic fragments, transported a considerable distance by flood. Sometimes around the gravelly and sandy clasts present in scant layers in the matrix, reddish and brownish bands displaying macroscopic characteristics have been observed, suggesting the existence of environments similar to those described by Kaemmerer & Revel (1989).

In Section 9 (fig. 6) at the summit of the Upper Pleistocene alluvial deposit, channels can be observed filled with gravelly layers and planar crossbedded phytoclastic sands (Gp). Among the sediments, ceramic fragments, apparently not reworked, have been found as well as elements of vitreous paste necklaces datable to around 3.000 y. B.P. Laterally, interbedding has been observed with alluvial soils containing abundant archaeological remains from the Sub-Apenninic culture (3.000 y. B.P.). Still further downstream, for various kilometers inside clearly identifiable channels, phytoclastic sands are observed (fig. 1). The summit of these channels is sited at the same height as the Upper Pleistocene alluvial plain, 10-12 m above the bed. The Upper Pleistocene sediments are usually weathered by

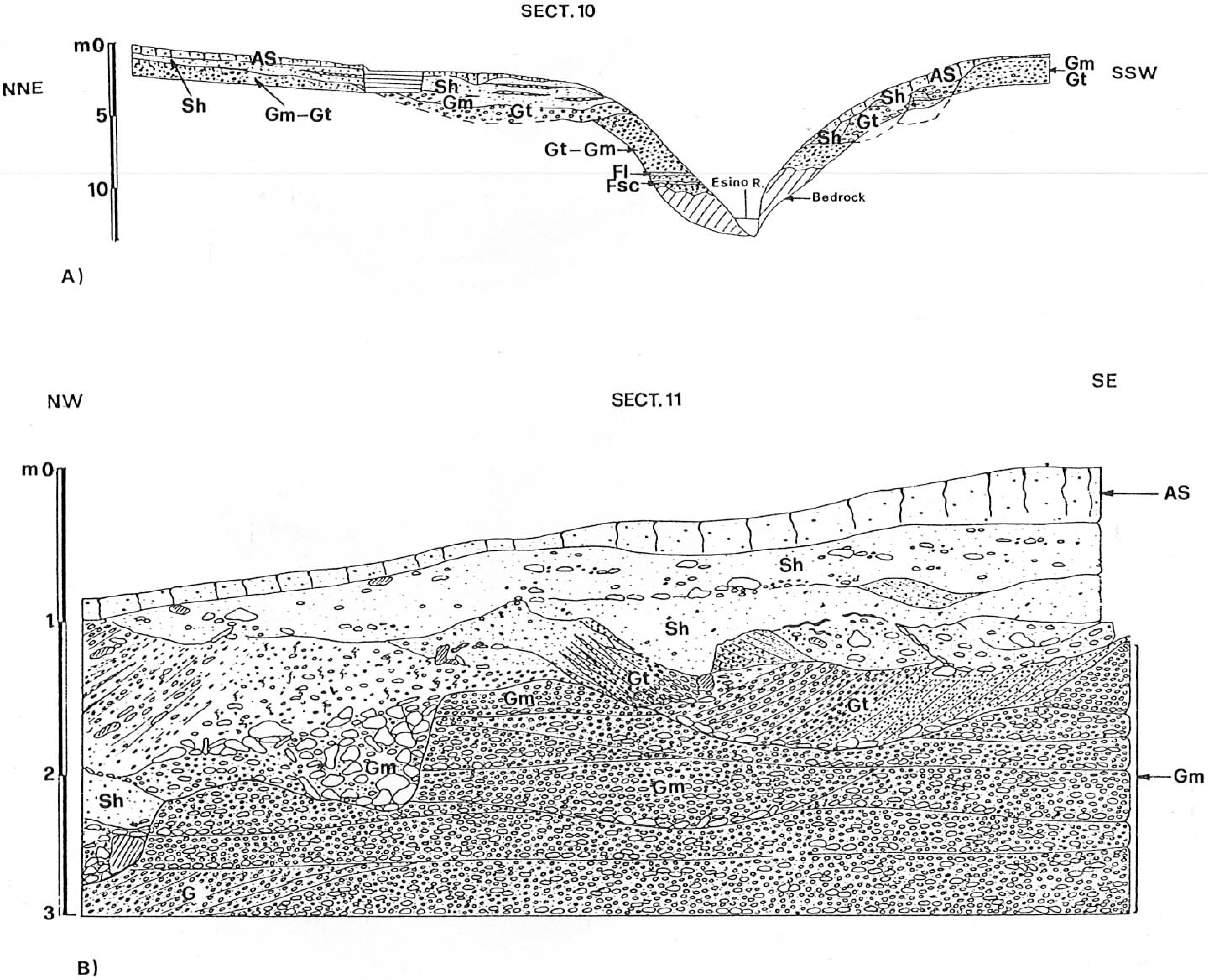

FIG. 7 - A: Section 10 (Conceria Zampini): cross section made after construction of a methane pipeline; B: Section 11 (Casa Sammarco): for description, cf text.

brown and brown-vertic soils, deeply leached, missing in CaC03 and with exclusive flint skeleton. In different places they contain lithic and ceramic remains ofthe Sasso Fiorano culture (ca. 7.000 y. B.P.).

Towards the central part of the Upper Pleistocene plain, brown soils (BS) are observed, progressively cut off and locally covered by phytoclastic sands from floods (Sh) (Section 10; fig. 7A). Moreover, in Sections 10 and 11 (fig. 7B), sited on the flanks of the present-day valley, other paleochannels were observed at altitudes closer to that of the present-day thalweg. The fill consists in concave (Gt) and parallel planar crossbedded gravelly sediments (Gtn), interbedded with lenses and layers of phytoclastic sands (Sh). There is also the presence of numerous ceramic fragments apparently not reworked.

CHRONOLOGY OF THE EVENTS

In the upper reaches of the River Esino valley, the Upper Pleistocene fluvial sedimentation is testified to by the presence of extensive large-sized alluvial nappes. This terminated with the Late-Glacial deposition of gravelly lithofacies (Gm and Gt) intercalated with silty-sandy facies (Sh, Fm and Fcf) (CALDERONI & *alii*, 1991) (fig. 8A). These sediments show that a slow aggradation fluvial regime was set up which was associated with flood phenomena, but characterized by channels that were deeper and more sinuous than those responsible for the fluvial sedimentation during the Upper Pleniglacial.

It is probable that in the Late-Glacial, upstream of Esanatoglia, even if the physical degradation processes were

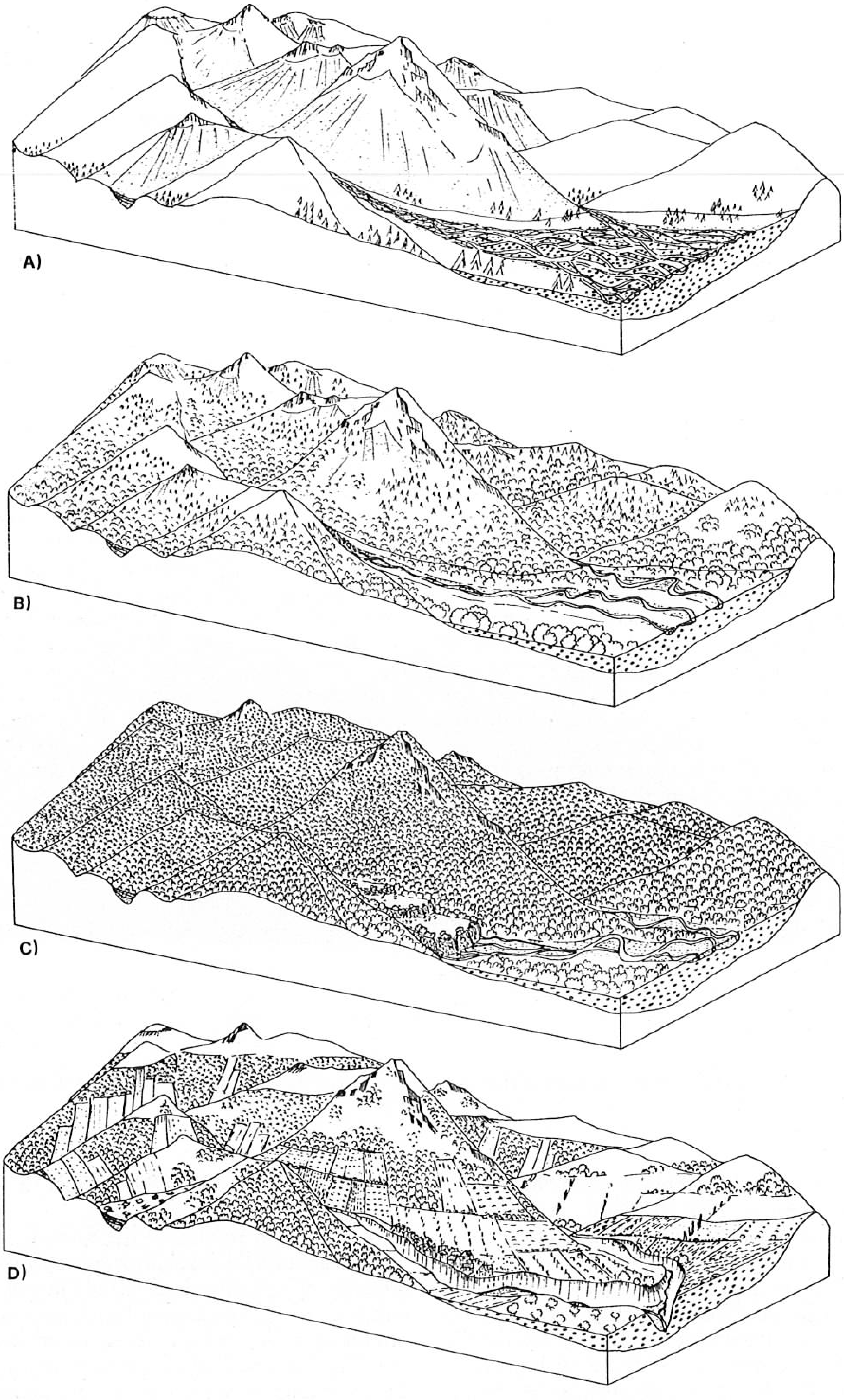

FIG. 8 - Main morphological and sedimentary events in the Esanatoglia valley: A) at the foot of the slopes laid bare and undergoing cryonival processes, a braided channel plain developed (Upper Pleistocene); B) progressive recolonization of the slopes by vegetation, leading to entrenchment of the debris deposits inside the ridge, and of the alluvial fans outside the ridge; locally, the bedrock crops out due to selective erosion (Late Glacial); C) maximum forestal development and deposition of phytohemal and phytoclastic travertine at the previously formed steps (Early Holocene); D) progressive degradation and elimination by human activity of the forestal cover, with a consequent halt to travertine deposition and its subsequent entrenchment (Bronze Age to present).

considerably slowed down, a vast alluvial fan was still being formed. This was fed by debris sediments, both from the slopes and the valley floor. The basal sediments of Sections 6 and 7 can be ascribed to this phase.

At the end of the Late-Glacial, the alluvial fan deposits were no longer fed by debris material from the ridge and must have been been cut into by numerous channels which locally, as in the neighborhood of Esanatoglia, were so deep as to lay bare the bedrock (fig. 8B).

During the Holocene, the vegetation cover reached its highest altitude and led to the evolution of brown soils on the plain, of which very often only the (B) horizon can be observed. These soils are well preserved in the Late-Glacial alluvial plain and contain lithic and ceramic material dating back to 7.000 y. B.P. The fact that this has been buried by thin layers of travertine sands, which slightly upstream (Section 9) contain Bronze Age finds, shows that in between these periods the Late-Glacial alluvial fan had not yet been affected by downcutting. Therefore, its entrenchment must have occurred after 3.000 y. B.P., a considerably later date than that for the middle-lower reaches of the marchean valleys where this phenomenon had already taken place (COLTORTI, 1991). Alluvial soils developed even inside the channels which cut into the Late-Glacial alluvial plain and remained sometimes abandoned for long periods of time (Sections 8A and 8B) after the lateral shifting of the active ones. The presence of phytoclastic sands and crusts in sediments overlying the Late Glacial ones (Section 6) and in the channel which slightly downvalley cut the alluvial fan deposits (Sections 8A and 8B), reveals how in the spring area travertine deposition started very early.

Chronologically, the Esanatoglia travertine sediments seem to include a large part of Early Holocene, since in the middle-upper part (Sections 3 and 4) archaeological findings, dated to 5.500 y. B.P., have been found, and remains of Middle-Late Bronze Age settlements (3.500-3.000 y. B.P.) mark the end of the deposition. The formation of phytohermal travertine began in the areas close to the source and then progressively extended downstream, at times covering the gravelly deposits of alluvial fans laid down during the last Glacial. In the neighborhood of Esanatoglia (fig. 8C), the formation of the small waterfalls that are the site of biohermal deposition was probably favored by the marked dislevel and irregularity ofthe longitudinal profile, and as well by the greater width of the valley. This irregularity is connected with the presence downstream of rocks which are more subject to erosion (the contact between Scaglia Cinerea and Rosata). Upstream, the growth of the waterfall thresholds created depressions in which phytoclastic sedimentation was prevalent.

The genesis of the Esanatoglia travertine, was connected, as still happens today, with the circulation of subsurface and deep waters, and was not conditioned by the presence of those of hydrothermal origin. Its formation seems to have begun during Early Holocene when the vegetation cover started to increase, and can thus apparently be correlated with the greater amount of CO_2 of biological origin dissolved in the waters (NICOD, 1986). As is shown by the Bronze Age artefacts of Section 4 (3.500 y. B.P.) found in the upper part of the deposit, its decline occurred more or less between the Atlantic and Subboreal zones.

The absence of debris sediments and limestone gravels intercalated in the travertine sediments points to a lack of any important erosive dynamics during Holocene, either on the slopes or on the valley floor. Travertine deposits occurred at Triponzo in the nearby Nera basin between 6.290 ± 175 and 1.135 ± 75 B.C., and thus their formation ceased almost contemporaneously with the deposits in question (VINKEN, 1968). Analogous observations have been made at numerous Central European and North African sites (WEISROK, 1968; VANDUR, 1982).

It can in any case be noted that this event corresponds to the increase in Central Italy of populations with an economy based on agriculture and farming. In a large part of the Mediterranean basin, the first important deforestation works, with which the soil erosion phenomena are connected, date back to this period (VITA-FINZI, 1979; COLTORTI & DAL RI, 1985). Moreover, it should be emphasized that in the Gubbio basin travertine sediments had already ceased to be formed in Upper Neolithic (7.000 y. B.P.) (COLTORTI, 1994), and it is therefore most probable that the end ofthe travertine deposition varied from one place to another according to the severity of the anthropic impact. Similar observations have recently been put forward for numerous travertine deposits in Europe (VANDUR, 1986; VILÉS & *alii*, 1993). Anyhow, the soil erosion processes in mountainous areas did not control the fluvial dynamics very strongly, since no clastic sediments are to be found intercalating or overlying the travertine sediments. Furthermore, after 3.500 y. B.C., only processes of progressive downcutting have been recorded. Many of the internal valleys of the Umbro-Marchean area have undergone a similar evolution, as for example the Giano and Potenza Rivers.

During the Middle Ages, strong regressive erosion and considerable deepening of the hydrographic network affected both the Upper Pleistocene gravelly sediments and the Holocene travertine deposits at Esanatoglia (fig. 8D). To prevent the effects of this erosion, which threatened the southern side of the town, some check dams were built up.

CONCLUSIONS

The Holocene sedimentation in the source area of the River Esino seems to be conditioned first of all by variations in climate due to the general post-Glacial improvement, and then increasingly, from protohistorical times onwards, by the landscape modifications determined by the anthropic impact.

During Late-Glacial there was a reorganization of the hydrographic network and a reworking of the debris and alluvial material that still filled the valley floor. The alluvial fan deposits were apparently reworked by more stable and sinuous channels having a greater competence than the previous ones.

One result of the rapid expansion of forests during Early Holocene was the formation of phytohermal and phytoclastic travertine, correlated with a greater amount of CO_2 of biological origin in the waters. Beginning from 3.500 y. B.P., the travertine deposition ceased. This important change in fluvial deposition seems to be connected with an increase in the human occupation and degradation of slopes, which reached an acme during the Middle and Upper Bronze Age.

During historical times down to the present day, the hydrographic network has undergone constant deepening, and outside the ridge, into the alluvial deposits the bedrock has locally been reached.

BIBLIOGRAPHY

Ambrosetti P., Carraro F., Deiana G. & Dramis F. (1982) - *Il sollevamento dell'Italia centrale tra il Pleistocene Inferiore e il Pleistocene Medio*. CNR, P.F. «Geodinamica» Contributi Conclusivi per la Realizzazione della Carta Neotettonica d'Italia, p. 2, 219-223.

Bally A.W., Burbi L., Cooper C. & Ghelardoni R. (1986) - *Balanced sections and seismic reflection profiles across the Central Apennines*. Mem. Soc. Geol. It. 35, p. I, 257-310.

Biondi E. & Coltorti M. (1982) - *The Esino flood plain during the Holocene*. Abstracts XI INQUA Congress, Moscow, 111, 45.

Bisci C., Dramis F. & Gentili B. (1992) - *Recent and present geomorphological evolution of river beds and mouths in central-southern Marche (Italy)*. Geoöko Plus, 3, 83-96.

Boccaletti M., Calamita F., Centamore E., Chiocchini U., Deiana G., Moratti G., Micarelli A., Potetti M. (1986) - *Evoluzione dell'Appennino Tosco-Umbro-Marchigiano durante il Neogene*. Giorn. Geol., ser. 2, 48, 227-233.

Calamita F., Cello G., Centamore E., Deiana G., Micarelli A., Paltrinieri W. & Ridolfi M. (1991) - *Stile deformativo e cronologia della deformazione lungo tre sezioni bilanciate dall'Appennino Umbro-Marchigiano alla costa Adriatica*. Studi Geol. Camerti, vol. spec. 1991, 295-314.

Calamita F. & Deiana G. (1986) - *Evoluzione strutturale Neogenico-Quaternaria dell'Appennino Umbro-Marchigiano*. Studi Geol. Camerti, vo. spec. «La Geologia delle Marche», 91-98.

Calderoni G., Coltorti M., Consoli M., Dramis F., Farabollini P., Pambianchi G. & Percossi E. (1989) - *Degradazione dei versanti e sedimentazione nei pressi di Borgiano (Appennino Marchigiano) nell'Olocene*. Mem. Soc. Geol., 42, 301-310.

Calderoni G., Coltorti M., Dramis F., Magnatti M., & Cilla G. (1991) - *Sedimentazione fluviale e variazioni climatiche nell'alto bacino dell'Esino durante il Pleistocene Superiore*. In: Fenomeni di Erosione e Alluvionamento degli alvei fluviali, Università degli Studi di Ancona, Dipartimento di Scienze dei Materiali e della Terra, Ancona, 171-190.

Cantalamessa G., Centamore E., Chiocchini U., Colalongo M.L., Micarelli A., Nanni T., Pasini G., Potetti M., Ricci Lucchi F., Cristallini C. & Di Lorito L. (1986a) - *Il Plio- Pleistocene delle Marche*. Studi Geol. Camerti, vol spec. «La Geologia delle Marche», 61-81.

Cantalamessa G., Centamore E., Chiocchini U., Micarelli A. & Potetti M. (1986b) - *Il Miocene delle Marche*. Studi Geol. Camerti, vol. spec. «La Geologia delle Marche», 35-55.

Canuti P.., Cencetti C., Conversini P., Rinaldi M. & Tacconi P. (1991) - *Dinamica fluviale recente di alcuni tratti dei fiumi Arno e Tevere*. In: Fenomeni di erosione e alluvionamento degli alvei fluviali, Università degli Studi di Ançona, Dipartimento di Scienze dei Materiali e della Terra, Ancona, 21-35.

Castiglioni G.B., Girardi A., Sauro U. & Tessari F. (1979) - *Grèzes litées e falde detritiche stratificate di origine crionivale*. Geogr. Fis. Dinam. Quat., 2, 64-82.

Centamore E., Deiana G., Micarelli A. & Potetti M. (1986) - *Il Trias-Paleogene delle Marche*. Studi Geol. Camerti, vol. spec. «La Geologia delle Marche», 9-27.

Chiesa S., Coltorti M., Cremaschi M., Ferraris M., Floris B. & Prosperi C. (1990) - *Loess and Quaternary deposits in the Marche province*. In M. Cremaschi (ed.) - The loess in northern and central Italy: a loess basin between the Alps and the Mediterranean region. Quaderni Geodin. Alpina Quat., 103-130.

Ciccacci S., D'Alessandro L., Dramis F., Fredi P. & Pambianchi G. (1985) - *Geomorphological evolution of the Umbria-Marche Ridge Northern Sector*. Studi Geol. Camerti, 10, 7-15.

Cilla G. (unpuhlished) - *Forme e depositi alluvionali quaternari nell'alto bacino dell'Esino (tra Albacina e la sorgente)*. Università di Camerino, Dipartimento di Scienze della Terra, Tesi di Laurea, 1989-90.

Coltorti M. (1981) - *Lo stato attuale delle conoscenze sul Pleistocene superiore e il Paleolitico inferiore. e medio della regione marchigiana*. Atti del I° Convegno sui Beni Culturali e Ambientali delle Marche, Numana, 63-122.

Coltorti M. (1991) - *Modificazioni morfologiche oloceniche nelle piane alluvionali marchigiane: alcuni esempi nei fiumi Misa, Cesano e Musone*. Geogr. Fis. Dinam. Quat., 14, 73-86.

Coltorti M. (1994) - *The Pleistocene basin of Gubbio (Central Italy): Geomorphology, genesis and evolution*. In: C. Malone & Stoddart S., *Territory, time and state. The archeological development of the Gubbio basin*, Cambridge University Press, Cambridge, 17-25.

Coltorti M., Consoli M., Dramis., Gentili B. & Pambianchi G. (1991) - *Evoluzione geomorfologica delle piane alluvionali delle Marche centro meridionali*. Geogr. Fis. Dinam. Quat., 14, 87-100.

Coltorti M., Cremaschi M., Peretto C. & Sala B. (1980) - *Cronostratigrafia dei depositi pleistocenici con industrie del Paleolitico inferiore* (Lombardia orientale, Veneto, Emilia-Romagna, Marche). Atti della XXIII Riun. Sc. Ist. It. Preistoria e Protostoria, 123-145.

Coltorti M. & Dal Ri L. (1985) - *The human inpact on the landscape: some examples from the Adige Valley*. Papers in italian archeology. In: Malone C. & Stoddart S. (eds.) - The human landscape, British Archeological Review, Internal Series, 243, vol. IV, p. I, 105-134.

Coltorti M. & Dramis. F. (1987) - *Sedimentological characteristics of stratified slope waste deposits in the Umbria Marche Apennines (Central Italy) an their genetic implications*. In: Godard A. & Rapp A. (eds.) - Processus et mesure de l'erosion, Ed CNRS, Paris, 145-152.

Coltorti M. & Dramis. F. (1988) - *The significance of stratified slope-waste deposits in the Quaternary of Umbria-Marche Apennines, Central Italy*. Zeit. Geomorph., N. F., Suppl. Band 71, 59-79.

Coltorti M., Dramis F. & Pambianchi G. (1983) - *Stratified slope-waste deposits in the Esino river basin (Umbria-Marche Apennines, Central Italy)*. Polarforschung, 53 (2), 59-66.

De Zutter Ph. (1981) - *Apercú bryosociologique des tufs calcaires actifs de moyenne et de haute Belgique*. Colloques Phytologiques sur les Vegetations Aquatiques, Lille, 279-293.

Dramis F. (1992) - *Il ruolo dei sollevamenti tettonici a ampio raggio nella genesi del rilievo appenninico*. Studi Geol. Camerti, vol. spec. 1992/1, 9-16.

Dramis F., Pambianchi G., Nesci O. & Consoli M. (1991) - *Il ruolo degli elementi strutturali trasversali nell'evoluzione tettonico-sedimentaria e geomorfologica della regione marchigiana*. Studi Geol. Camerti, vol. spec. 1991/2, 287-293.

Dufaure J.J., Bossuyt D. & Rasse M. (1989) - *Critères géomorphologiques de néotectonique verticale dans l'Apennin Central adriatique*. Bull. Ass. Fr. Etude Quat., 40(3), 151-160.

Gentili B. & Pambianchi G. (1987) - *Morfogenesi fluviale e attività antropica nelle Marche centro meridionali*. Geogr. Fis. Dinam. Quat., 10, 204-217.

Gentili B. & Pambianchi G. (1988) - *Segnalazione di alcuni episodi fluvio-lacustri nelle Marche meridionali*. Geogr. Fis. Dinam. Quat., 10, 59-60.

Golubic S., Violante C., Ferreri V. & D'Argenio B. (1993) - *Algal control and early diagenesis in Quaternary travertine formation (Rocchetta a Volturno, Central Apennines)*. Boll. Soc. Paleont. It., vol. spec. I, 231-247.

Kaemmer M. & Revel J.C. (1989) - *Signification des précipitations d'origine biologique de fer et de manganése dan le alluvions Quaternaires du Sébou (Maroc)*. Bull. Ass. Fr. Etude Quat., 40 (4), 213-218.

Lollini D.G. (1965) - *Il Neolitico nelle Marche alla luce delle nuove scoperte*. Atti del VI Congresso Internazionale di Scienze Preistoriche e Protostoriche.

Miall A.D. (1977) - *A review of the braided river depositional environment*. Earth Sc. Rev., 13, 1-62.

Miall A.D. (1985) - *Architectural element analysis: a new method of facies analysis applied to fluvial deposits*. Earth Sc. Rev., 22, 261-308.

Nicod J. (1986) - *Facteurs phisico-chimique de l'accumulation des formations travertineuses*. Méditerranée, 1-2, 161-164.

Roveri E. (1964) - *Sul ciclo di erosione rinnovatosi lungo i corsi d'acqua dell'Appennino emiliano*. Boll. Soc. Geol. It., 84, 289-309.

Servizio Geologico D'Italia (1979) - *Carta Geologica d'Italia Foglio 301*. Poligrafico dello Stato, Roma.

Silvestrini M. & Pignocchi G. (1987) - *Il giacimento del Paleolitico superiore di Fosso Mergaoni presso Serra San Quirico (Ancona)*. In Marche: Archeologia, Storia e Territorio, Atti del I Convegno Pre-Protostoria delle Marche, Istituto Regionale per la Pre-Protostoria nelle Marche, Arcevia-Sassoferrato, 7-27.

Vandur J. (1982) - *Les travertins de piemonts: contribution a l'etude des géosistèmes karstiques méditerranee*. Acte du colloque «Montagnes et Piemonts». CNRS, XIV, 1-12.

Vandur J. (1986) - *Travertines holocénes et pression antropique*. Méditerranée, 1-2, 168-173.

Vilés H.A., Burger D. & Goudie A.S. (1993) - *A reason for declining tufa deposition in Germany and Britain*. Abstracts of the 3rd International Conference on Geomorphology, Hamilton, 149.

Vinken R. (1968) - *Zur entstehung und altersstellung der travertine limnichen sedimente nud fluviatelen terrassen in gebiet der mittleren Nera und des Corno (Umbrien, Mittelitalien)*. Eiszeitalter Gegenwast, 19, 5-30.

Vita Finzi C. (1969) - *The Mediterranean valleys. Geological Changes in Historical times*. Cambridge University Press, Cambridge, 433 pp.

Vittorini S. (1991) - *La diminuzione del trasporto torbido nei fiumi italiani tra il periodo prebellico e quello attuale*. Geogr. Fis. Dinam. Quat., 14, 251-258.

Weisrok A. (1986) - *Variations climatiques et period de sedimentation carbonate a l'Holocéne. L'ages des dépots*. Méditerranée, 1-2, 165-167.