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THE SOUTHEASTERN TIBER BASIN (SPOLETO, CENTRAL ITALY): GEOLOGY AND STRATIGRAPHY OF PLIO-PLEISTOCENE SEDIMENTS

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RIASSUNTO - *Il Bacino Tiberino sud-orientale (Spoleto, Italia centrale): geologia e stratigrafia dei sedimenti plio-pleistocenici* - Il Quaternario *Italian Journal of Quaternary Sciences* , 9(2), 1997, 159-180- La stratigrafia e la sedimentologia del settore meridionale del bacino Tiberino orientale ha permesso di individuare una fase deposizionale prevalentemente pliocenica, un'importante fase erosiva e numerose fasi deposizionali pleistoceniche separate da fasi erosive minori. La sequenza inferiore giace al di sopra di una superficie di discordanza che taglia tutte le formazioni pre-plioceniche e che viene correlata con la superficie di planazione affiorante alla sommità dei rilievi appenninici umbro-marchigiani e dei M.ti Martani. La serie "pliocenica" è costituita da una alternanza di sedimenti di conoide alluvionale, fluviali e lacustri per oltre 400 metri di spessore. Nei pressi della base della sequenza, sono state rinvenute faune a mammiferi riferite all'Unità Triversa, correlabile con la parte finale del Pliocene inferiore-inizio Pliocene Medio ma non si hanno dati per la fine di questa fase deposizionale. Questi sedimenti sono stati deposti in un ampio bacino sinforme. La frazione clastica grossolana proveniva da ovest verosimilmente in seguito al coevo sollevamento dei M.ti Martani. Dato che tra dorsale e bacino è presente solamente un vistoso fronte di sovrascorrimento, è stata ipotizzata l'esistenza di una coevo regime "compressivo" e la probabile riattivazione del fronte di sovrascorrimento.I sedimenti della fase più recente sono riferibili al Pleistocene. Si tratta di sedimenti detritici, di conoide alluvionale, fluviali e lacustri che risultano suddivisi in varie unità terrazzate poste a quote progressive sui fondi vallivi. Questi sedimenti si depositano in un bacino delimitato da faglie dirette attivatesi parallelamente ad importanti movimenti di sollevamento generalizzato. La conformazione del bacino è guidata prevalentemente dalla faglia normale sintetica appenninica ubicata sul fianco orientale e da faglie antitetiche che tagliano il precedente bacino "pliocenico". Faglie appenniniche ed antiappenniniche condizionano l'incisione della valle del Tessino che costituisce una delle più importanti linee di drenaggio dell'area.

ABSTRACT - *The southeastern Tiber Basin (Spoleto, central Italy): geology and stratigraphy of the Plio-Pleistocene sediments* - Il Quaternario *Italian Journal of Quaternary Sciences* , 9(2), 1997, 159-180 - Stratigraphical and sedimentological studies on the southern part of the Eastern Tiber Basin indicated the presence of a depositional phase of mainly 'Pliocene' age, and of an important erosional period followed by a number of Pleistocene depositional phases separated by minor erosional events. The lower sequence overlies an unconformity cutting all the pre-Pliocene formations, which was correlated to the 'planation surface' that truncates the top of the Umbria-Marche mountain ridges and Monti Martani. The 'Pliocene' sequence is formed by an alternation of alluvial fan, fluvial and lacustrine sediments up to 400 m thick. Close to the base of the sequence, a mammal fauna attributable to the Triversa Unit (Lower Pliocene-beginning of the Middle Pliocene), was identified. The sedimentation took place in a wide synform basin. The western provenance of coarser sediments suggests their connection with the contemporaneous uplifting of Monti Martani. Because of the presence of a great overthrust front between the mountain ridge and the basin, a "compressional" regime and a reactivation of the Monti Martani overthrust have been hypothesised. The youngest sediments are of Pleistocene age and are composed of debris, alluvial fan, fluvial and lacustrine sediments. These are subdivided into terraced units at altitudes progressively higher over the present valley bottom. The deposition of these sediments took place in a basin bordered by extensional faults, which became active contemporaneously to general uplifting movements. The basin is controlled by the NW trending extensional synthetic fault located on the eastern flank and by antithetic faults which displaced the former "Pliocene" basin. NW- and NE-trending faults favoured the incision of the Tessino valley, which is one of the most important drainage lines of the area.

Parole chiave: Sedimentologia, evoluzione geomorfologica, neotettonica, Plio-Pleistocene, Bacino Tiberino orientale, Italia Centrale
Key words: Sedimentology, geomorphological evolution, neotectonics, Plio-Pleistocene, eastern Tiber Basin, Central Italy

1. INTRODUCTION

The structural setting of the Apennines chain is characterized by large tectonic depressions on the Tyrrhenian side of Italy and by smaller depressions within the Apenninic mountains. These small depressions, which are absent in the peri-Adriatic basin, are filled by sediments whose chronology, although uncertain, was used to explain the progressive eastwards migration of extensional processes which originated in the western side of the chain.

The tectogenesis of the chain is characterized by the emplacement of numerous overthrusts that are supposed to be active since the Burdigalian and which are still active in the Adriatic (Elter *et al.*, 1975; Boccaletti *et al.*, 1983; 1986; Calamita & Deiana, 1988; Lavecchia *et al.*, 1988; Calamita *et al.*, 1991; Decandia & Tavernelli, 1991a; Calamita & Pizzi, 1992). Normal faults became active to the west of the compressive fronts, during or soon after their emplacement. However, extensional faults were also present in the sequences inherited from the Jurassic (Centamore *et al.*, 1979; Tavernelli, 1995).

The chronological setting of the Plio-Quaternary deposits and their relationship in time and space with the different tectonic elements have not yet been completely understood. In fact, the recent improvement of the knowledge on Quaternary climatic events has not been followed by a systematic application of modern methodologies. Moreover, many data on the geology of Apenninic areas are based on surveys carried out dozens of years ago.

The Spoleto depression is located in the southern part of the eastern branch of the Tiber Basin (Fig. 1)

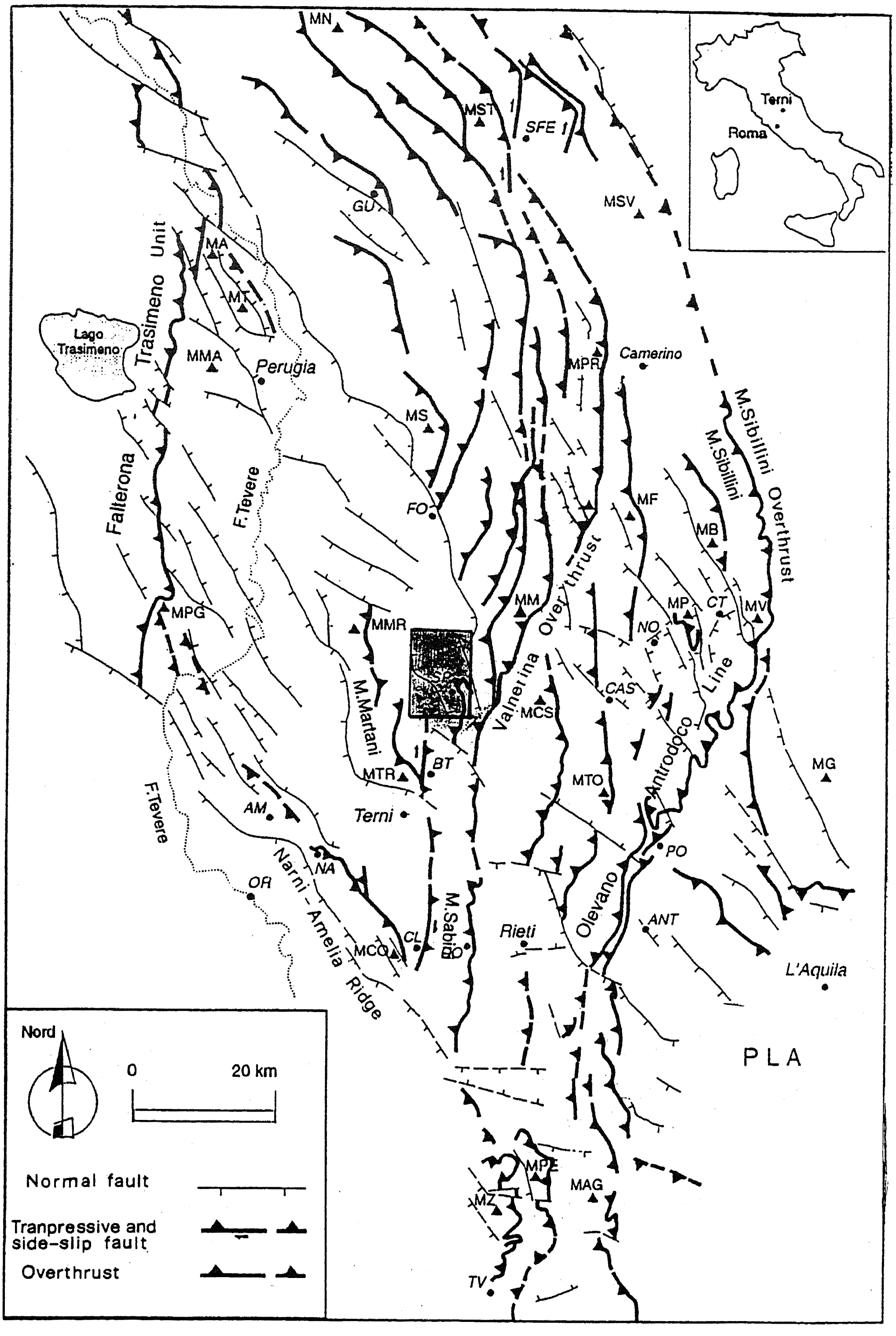

Fig. 1 - Structural setting of the North-central Apennines showing the principal relationships between the Tuscany Domain (*Unità Falterona-Trasimeno*) and the Latium-Abruzzi Platform (PLA) (from Calamita, 1990).

AM: Amelia; ANT: Antrodoco; BT: Battiferro; CAS: Cascia; CO: Contignano; CL: Cottanello; CT: Castelluccio; FO: Foligno; GU: Gubbio; MA: Monte Acuto; MAG: Monte Aguzzo; MB: Monte Bove; MCO: Monte Cosce; MCS: Monte Coscerno; MF: Monte Fema; MG: Monte Gorzano; MM: Monte Maggiore; MMA: Monte Malbe; MMR: Monte Martanpo; MN: Monte Nerone; MP: Monte Patino; MPE: Monte Pellecchia; MPG: Monte Peglia; MPR: Monte Primo; MS: Monte Subasio; MST: Monte della Strega; MSV: Monte S.Vicino; MT: Monte Tezio; MTO: Monte Tolentino; MTR: Monte Torricella; MV: Monte Vettore; MZ: Monte Zappi; NA: Narni; NO: Norcia; OR: Orte; PO: Posta; SFE: Sassoferrato; SP: Spoleto; TV: Tivoli.

Assetto strutturale dell'Appennino centro settentrionale con le principali relazioni tra il Dominio toscano (Unità Falterona-Trasimeno) e la Piattaforma laziale abruzzese (PLA) (da Calamita, 1990). Per i simboli, vedi sopra.

which, since Pliocene (chronologically subdivided according to Rio *et al.*, 1995), has undergone several phases of fluvio-lacustrine sedimentation. Recent researches are focussed to other sectors of the Tiber Basin, in particular many stratigraphic and sedimentological studies were devoted to the Basin western branch (Ambrosetti *et al.*, 1978; 1987; 1995; Conti & Girotti, 1977; Barberi *et al.*, 1994; Basilici, 1995). As to the part taken into consideration in this paper, geological and structural studies were carried out along the margin of the basin and, in particular, on the Spoleto mountains (Decandia & Giannini, 1977a-c; Decandia, 1982a; Decandia & Tavernelli, 1991a-b) and Monti Martani (Calamita & Pierantoni, 1992; Barchi *et al.*, 1991). The Spoleto continental sediments were studied at the beginning of the Century in order to exploit lignite deposits (De Marchi *et al.*, 1879-1963; Lippi-Boncampi, 1959; Sabella, 1959; Jacobacci, 1959). Many discussions were made on the evolution of the hydrographic network of the North-central Apennines, which displays a different pattern in the Adriatic side with respect to the

Tyrrhenian side (Marinelli, 1926; Giannini & Pedreschi, 1949; Sestini, 1950; Mazzanti & Trevisan, 1978; Cattuto *et al.*, 1992).

A new geological and geomorphological study (scale 1:10,000), based on lithological and sedimentological criteria, was carried out on the Plio-Quaternary formations. Whenever possible, due to the prevailing fluvial and lacustrine nature of the sediments, the facies analysis method of Miall (1985) was applied. Particular attention was paid to the relationships of these deposits with pre-Pliocene formations.

For the first time, two major depositional phases, separated by an important tecto-sedimentary unconformity, were recognized in the Spoleto Basin. The older phase covers part of the Pliocene, whereas the younger one is Pleistocene in age. The sediments of the Pleistocene phase are inside a tectonic depression bordered by normal faults, whereas the older sediments fill a downwarped area delimitated by "compressional" structures. An evolution model for which the variations in the tectonic style and their interference with climatic changes constrain clastic deposition, is proposed in this paper .

2. GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The Tiber Basin stretches out from Terni (to the S) to Borgo S. Sepolcro (to the N) (Lotti, 1917; Albani, 1962; Ge.Mi.Na., 1963) (Fig.1).To the W, it is delimited by the Amelia and Peglia mountains and, to the E, by the Umbro-Marchean Ridge (Lotti, 1926; Conti & Girotti, 1977; Ambrosetti *et al.*, 1978; Cattuto *et al.*, 1979; Boccaletti *et al.*, 1986). To the South of Perugia, the Monti Martani ridge subdivides the Basin into two portions. The southern borders of the Spoleto Basin are determined by the convergence of the Umbro-Marchean and Monti Martani ridges in the Umbro-Marchean-Sabine Arc. The Spoleto Mountains portion of the Umbro-Marchean Ridge is characterized by the presence of numerous overthrusts (Decandia, 1982a; Damiani *et al.*, 1991; Calamita *et al.*, 1991; 1994) (Fig.1). The front of these overthrusts, which is approximately oriented NS in the northwestern part, gradually turns to the SW in the southeastern part, becoming transversal to the Apennines chain axis.

Along the ridges, the Umbro-Marchean sedimentary sequence crops out. It is represented by a more than 1000 m thick multilayer, from the *Anidriti di Burano* Formation (Upper Trias) to the *Marnoso-Arenacea* Formation (Upper Miocene). The tectogenesis of the chain in the Umbrian pre-Apennines spanned from the Upper Serravallian to the Messinian, whereas, in the Umbro-Marchean Ridge, it was active from the Upper Messinian to the Lower Pliocene *p.p.* In the literature, the emersion of this portion of the Apennines is dated to the Messinian (Damiani *et al.*, 1991; Calamita *et al.*, 1991). Transcurrent or extensional faults became active after the compressive elements. However, in some areas, it was seen that many normal faults are genetically associated with overthrusts (Decandia & Tavernelli, 1991b).

The uplifting of the Monti Martani ridge probably occurred during the Upper Pliocene and is supposed to be delimited on both sides of the ridge by extensional faults (Cattuto *et al.*, 1979; 1992). These authors suggest that complex structural models (Kingma, 1958; Crowell, 1974) might locally be responsible for the subdivision of depositional environments and related sedimentation.

Ge.Mi.Na. (1963), on the basis of borehole cores, proposed for the entire Basin a sequence formed (from bottom to top) by a "lower sandy-conglomeratic complex" (*Complesso sabbioso-conglomeratico inferiore*), a "clayey complex", a "clayey-sandy complex" (*Complesso argilloso* and *Complesso sabbioso-argilloso*) and an "upper sandy-conglomeratic complex" (*Complesso sabbioso-conglomeratico superiore*). Detailed stratigraphic investigations were subsequently carried out only in the basin western branch (Conti & Girotti, 1977; Ambrosetti *et al.*, 1987; Barberi *et al.*, 1994). The lower first term of the sequence is a "grey clay" (*Argille grigie inferiori*), which represents a phase of fine deposition in a wide lacustrine basin during the Upper Pliocene. Lenticular conglomeratic bodies are present at the top of this unit. Upwards, there is an unconformity related to the *'Acquatraversa'* phase of the Tyrrhenian side (Bigazzi *et al.*, 1973). The sedimentation in the basin started again in the Lower Pleistocene (Follieri, 1977; Conti & Girotti, 1977) with the deposition of a "clayey-sandy complex" (*Complesso argilloso-sabbioso*). This complex laterally overlies the Cretaceous-Oligocene bedrock. There are also lateral transitions to the "Chiani-Tevere sandy clays" (*Argille sabbiose del Chiani-Tevere*) and to calcareous silts and travertines. Another unconformity follows, which is covered by the so-called "upper detrital complex" (*Complesso detritico superiore*). It is made up mainly of sands and conglomerates which laterally interfinger with travertines, peat seams and silts.

In the same area, Ambrosetti *et al.* (1995) indicated the presence of 4 lithostratigraphic units: *'Fosso Bianco'* (mostly lacustrine clays; Lower-Middler Pliocene), *'Ponte Naia'* (humid climate alluvial fan deposits; Upper Pliocene), *'Santa Maria di Ciciliano'* (lacustrine clays, Lower Pleistocene) and *'Aquasparta'* (travertine and alluvial terraces; Pleistocene). In the southern part of the basin, between Fosso Bianco and Santa Maria di Ciciliano, an angular unconformity is present.

On the basis of paleontological and palynological analyses, the sediments of the Eastern Tiber Basin had in the past been attributed to the Upper Pliocene (Ricci, 1882; Pantanelli, 1884; Follieri, 1977). The mentioned faunal assemblage is formed by *Castor fiber, Mastodon borsoni, Mastodon arvernensis* and *Tapirus arvernensis.* On the basis of a recent revision of the Villafranchian mammal faunas in Italy (Ficcarelli, pers. comm.), this association can be referred to the Triversa Mammal Unit (Azzaroli *et al.*, 1988; Torre *et al.*, 1992), which chronologically is attributed to the end of the Lower Pliocene-beginning of the Middle Pliocene.

A 'planation surface' is preserved at the top of the limestone ridges of the area. 'Planation surface' remnants were described by Desplanques (1969) in other parts of the Umbrian region, by Demangeot (1965) for Abruzzi, by Coltorti (1981), Calamita *et al.* (1982), Ciccacci *et al.* (1985), Dramis *et al.*, (1991), Dramis (1992) for the Marche area and the Umbrian-Marchean

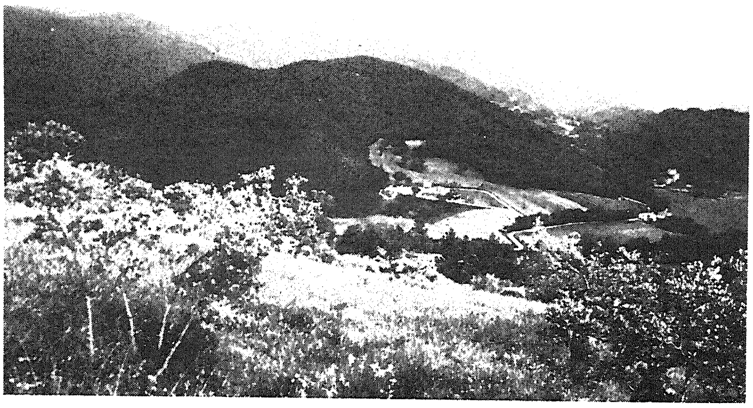

Fig. 2 - The 'planation surface' at the top of the Umbro-Marchean Apennines to the south of Spoleto and east of the Tessino Valley. The formations outcropping on hills top are flattened independently of their resistance to erosion.

La 'superficie di planazione' alla sommità dell'Appennino umbro-marchigiano a sud di Spoleto e ad est della valle del Tessino. Tutte le varie formazioni affioranti alla sommità dei rilievi sono interessate dai processi di spianamento a prescindere dalla loro resistenza all'erosione.

Ridge and by Bartolini (1980) for Tuscany. This morphological element is the remnant of the older continental modelling of the chain, which dates back to the Lower Pliocene. In fact, in the nearby Colfiorito area, a thick fluvio-lacustrine sequence, which fills large paleovalleys cutting the 'planation surface', was dated to the Lower Pleistocene on the basis of paleontological findings and paleomagnetic investigations indicating the Jaramillo Event in the middle part of the fluvio-lacustrine deposits (Coltorti *et al.*, in press). Similar sediments are present also in large paleovalleys on the present southern watershed, around Montebibico (Coltorti *et al.*, 1995). These deposits allow to recognize an important erosional phase before the Lower Pleistocene and the presence of a drainage system with a not well-defined watershed. In the aforementioned areas, this drainage pattern follows Jurassic tectonic lineaments (NS and EW). In correspondence of a new tectonic phase, at the end of the Lower Pleistocene, newly activated NW- and NE-stretching faults led to the deepening of the hydrographic network.

A few short notes on river captures around Spoleto were used by Decandia (1982b) and Cattuto & Gregori (1986) as evidence of local fault activation during the Quaternary.

3. THE SOUTHEASTERN TIBER BASIN

3.1 The pre-Pliocene bedrock

The geology of the Spoleto Mountains is described by Lotti (1926), Decandia & Giannini (1977a-c), and Decandia (1982a). Decandia & Tavernelli (1991) and Barchi & Brozzetti (1991) fitted the structural style of the area to the recent models on the evolution of the Apennines.

The bedrock geological mapping in the areas close to the outcrops of the Plio-Pleistocene sequence, has confirmed, with a few exceptions, the work done by previous authors. The eastern side of the basin is bordered by a system of NW-trending W-dipping normal faults, with thousands of meters of downthrow (Fig. 1). This system displays a remarkable lateral continuity for more than 30 km, from Assisi to Campello sul Clitunno. The abovementioned fault system delimits, to the west, the reliefs of the Umbro-Marchean Ridge where the homonymous sedimentary sequence crops out (Centamore *et al.*, 1979).

On the western side of the basin, there are the terrains of the *'Marnoso-Arenacea'* Formation, which are Miocene in age (Ricci-Lucchi & Pialli, 1973; Centamore & Chiocchini, 1989) and characterized by pelitic-arenaceous facies. This Formation is affected by many small folds and faults with prevalent NS direction. Westward, the Formation is overlain by the Monti Martani chain (Damiani *et al.*, 1991; Calamita & Pierantoni, 1992), where the Umbro-Marchean sequence crops out down to the Upper Trias units (Ac-cordi & Moretti, 1967).

The situation is more complicated at the southern border of the basin where the eastern master fault is subdivided into various segments by NW- and NE-oriented minor faults. The contact between the Plio-Pleistocene sequences and the bedrock is extremely irregular. Portions of the Umbro-Marchean sequence are present up to the middle part of the basin in areas that, northwards, are usually characterized by terrains of the *'Marnoso-Arenacea'* Formation. Particular importance is given to an escarpment at Collicelli, where a highly fractured outcrop of the *'Corniola'* Formation can be observed. The outcrop is about 20 m in thickness and more than 200 m long. Towards the W, the in-depth presence of a N-trending fault bringing into contact *'Corniola'* with the *'Marnoso-Arenacea'* Formation is to be assumed. This structural unit may be the northward continuation of the Battiferro Fault, which Calamita & Pierantoni (1992) considered a high-angle Miocene back-thrust. Along the eastern border of the studied basin, this fault that can be recognized in outcrop from Spoleto to the Terni Basin, is buried under Pliocene sediments. There are no evidence for its reactivation even during Pleistocene.

3.2 The Plio-Pleistocene deposits

In correspondence of the Maroggia Stream, an important unconformity cuts the Plio-Pleistocene sequence, which was considered as a single depositional phase in the literature (Plate 1). To the west of the Maroggia Stream, older sediments containing lignite[1] (Ge.Mi.Na., 1963) and mammal fauna (Ricci, 1882; Pantanelli, 1884),

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(1) Reddish clays associated with the lignites oxidation were observed in correspondence of these layers also in depth (De Marchi *et al.*, 1879-1944; Sabella 1959). Similar phenomena are present in recently exploited lignite open-pit mines near Ponte di Ferro, in the vicinity of the Bastardo Basin. In many parts of the area, these clays cover the slopes as waste material from old mines and furnaces fueled with clays interlayered with lignites.

display truncated layers dipping up to 30°-40° (Fig. 3). To the east of the stream, a clastic sequence, which follows the present drainage network, crops out; its well preserved upper depositional surface is subhorizontal such as the layering.

Another unconformity was identified, as aforementioned, along the western branch of the basin, in the Upper Valdarno (Bossio *et al.,* 1992; 1993) and in the Gubbio Basins (Coltorti, 1994). The alluvial sediments of the Middle and Upper Pleistocene form hanging terraces in paleovalleys which are also cut trough the lower sequence.

3.3 The lower unconformity and its relationships with the surrounding reliefs

The Pliocene sequence unconformably overlies all the terrains of the Umbro-Marchean sequence. West- and southwestwards, it covers different portions of the *'Marnoso-Arenacea'* Formation (Plate 1). Southwards, at Colle Ferretto (Fig. 3, sect. A-A'), Pliocene sediments overlie the *'Scaglia Rosata'* limestone and marly limestone, whereas at Collicelli (Fig. 3, sect. D-D') they overlie the previously mentioned *'Corniola'* outcrop. In all these cases, the contact is a flat surface. Along the limestone eastern escarpment, located out of the study-area, this sequence does not crop out. The eastern boundary of the Pliocene basin was subsequently involved in the activity of the normal faults bordering the 'graben' where the present-day valley bottom is located (Fig. 3, sect. D-D'). Depositional/erosive processes within the 'graben', led to the emplacement of Pleistocene deposits.

The drainage network deep downcutting between the Pliocene sediments and Monti Martani caused a relief inversion process. In fact, Pliocene gravel units are located on the watershed, at an altitude higher than the valley bottom, which cuts the terrains of the *'Marnoso-Arenacea'* Formation (Fig. 3 A-A', C-C'). A great portion of the sequence was consequently eroded. It is, however, to point out that, at the top of Monti Martani, remnants of the 'planation surface' are present. From Mt. Forrano (1084 m), this geomorphological unit progressively lowers, both north- and southwards, down to altitudes close to 500 m.

The 'planation surface' was recognized in many tracts of the Umbro-Marchean Ridge at altitudes even higher than 1800 m (Calamita *et al.,* 1994). Along this ridge, 'planation surface' remnants are found at progressively lower elevations towards the west and southwestern borders of the basin down to altitudes close to 800 m (Mt. Luco, 804 m) (Fig. 2) and even lower to the south of Spoleto (Torricella, 605 m). However, at the southern limit of the basin, in the Montebibico area, this surface is again located at altitudes close to 900-1000 m (Coltorti *et al.,* 1995).

The 'planation surface' is a morphological element with very flat parts. Demangeot (1965) distinguished two erosional surfaces: the 'summit erosional surface', which is similar to the one just described, and a 'Villafranchian surface', the modelling of which, in the peri-Adriatic basin, was supposed to reach the end of Lower Pleistocene.

Geomorphological stability was a very important condition for the creation of the 'planation surface'. However, in the Peri-Adriatic Basin coarse clastic sediments coming from the erosion of the Apennines ridges, are younger than the Lower-Middle Pliocene (Cantalamessa *et al.,* 1986a). This suggests that the 'planation surface' was modelled during the Lower Pliocene. The surface that outcrops at the western borders of the basin beneath the 'Pliocene' sequence, is very flat and at elevations slightly lower than the remnants of the planation surface. It can be assumed that such surface corresponds to the planation surface.

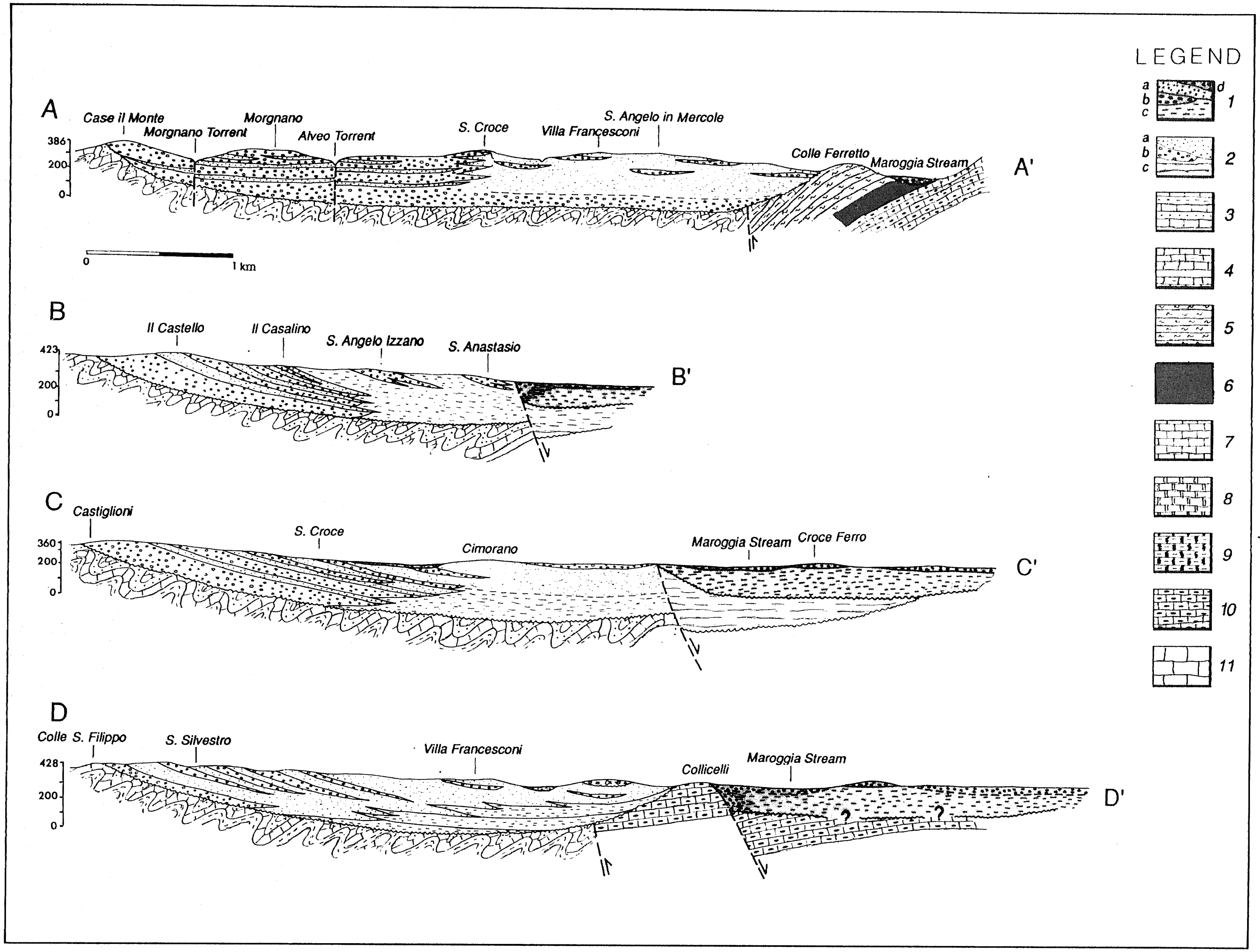
The lower unconformity surface appears downfolded with parts dipping up to 45°. The maximum thickness of the basin infilling, which corresponds to the axis of this NS fold, is located close to Morro di Busano-Villa Francesconi (Plate 1; Fig. 3, sect. DD'). A following phase of areal modelling, which might correspond to the Demangeot's Villafranchian Surface, is testified by the flat surface cutting the Pliocene sediments at the top of the hills in the Morgnano-S.Croce area, NW of Spoleto. This surface, which is largely dismembered, was an erosional glacis toward Monti Martani, across the area where the *'Marnoso-Arenacea'* Formation crops out. An erosional glacis is also present on the southern part of the eastern border of the basin (Sustrico-S. Anna area) (Fig. 4) and may be attributed to the same modelling phase. In this area, close to the valley bottom, the glacis is a depositional feature, the sediments of which form the first infilling of the Tessino valley (Plate 1). This proves a long-lasting erosional phase between the folded and eroded sediments of the Pliocene and the Pleistocene deposits.

3.4 The fluvio-lacustrine deposits

The sediments cropping out in the basin were grouped according to lithological criteria. Frequent and rapid lateral variations, which are a common feature in this type of environment (Reineck & Singh, 1973; Reading, 1978), were observed. In Plate 1 attached, the units have been divided into 'Debris flow', 'Gravels', 'Gravels and sands', 'Gravel, sands and silts', 'Sands and gravels', 'Sands', 'Silt and clays' and 'Clays and silts'. A more complete Pliocene sequence was recognized in the central part of the basin. The single units have informally been named after the outcrop localities; in many cases, significant sections are described using the Miall's classification (1977; 1985).

3.4.1 The Pliocene sequence in the basin western area

The sediments cropping out between the localities of Il Castello (493 m) and S. Brizio (250 m) (Plate 1), dip 30-40°E (Fig. 3). Alluvial fan gravel deposits, thinning eastward and alternating with alluvial plain sediments including clayey facies, form the sequence. This sequence directly overlies the *'Marnoso-Arenacea'* Formation. A thick layer of gravel, cropping out at Colle Fabbri


LEGEND
a
b
c
d
1
a
b
c
2
3
4
5
6
7
8
9
10
11
A
Case il Monte
Morgnano Torrent
Morgnano
Alveo Torrent
S. Croce
Villa Francesconi
S. Angelo in Mercole
Colle Ferretto
Maroggia Stream
A'
386
200
0
0
1 km
B
Il Castello
Il Casalino
S. Angelo Izzano
S. Anastasio
B'
423
200
0
C
Castiglioni
S. Croce
Cimorano
Maroggia Stream
Croce Ferro
C'
360
200
0
D
Colle S. Filippo
S. Silvestro
Villa Francesconi
Collicelli
Maroggia Stream
D'
428
200
0

(387 m), Colle S. Filippo (424 m) and between Castiglioni and Case il Monte (386 m) (Fig. 3), indicates the development of coalescent alluvial fans. The western origin of these sediments is shown by paleocurrent indicators and by the composition of clasts. The resulting *bajada* (Bull, 1977; Hooke & Rhorer, 1979) was formed by fan lobes which prograded over different sectors of the basin in different times. Northward, alluvial fan deposits become thinner up to disappear close to Terraja. Southward, in the S. Silvestro-S.Angelo in Mercole area, they change laterally into alluvial plain sediments in which sandy facies prevail.

Fig. 3 - Spoleto basin: stratigraphic sections crossing mainly Pliocene sediments 1- Pleistocene sediments: **a**, sands; **b**, gravels; **c**, silts and clays; **d**, debris; 2 - Pliocene sediments: **a**, sands; **b**, gravels; **c**, silts and clays; 3 - *Marnoso-Arenacea* Formation (Miocene); 4 - Schlier (Oligocene); 5 - *Scaglia* (Eocene-Oligocene); 6 - *Marne a Fucoidi* (Cenomanian *p.p.* - Aptian *p.p.*); 7 - *Maiolica* (Aptian *p.p.*- upper Titonian *p.p.*); 8 - *Calcari diasprini umbro-marchigiani* (lower Titonian - Callovian); 9 - *Bosso* (Oxfordian- Pleinsbachian); 10 - *Corniola* (Pleinsbachian- Lotharingian); 11 - *Calcare Massiccio* (Sinemurian- Hettangian). Most of the basal limits of the "Pliocene" sediments were established according to information from *Ente Minerario dell'Umbria*. Most probably the basin formed after the downwarping of a 'planation surface'correlated with the Lower Pliocene 'planation surface' that is preserved at the top of the surrounding hills. This surface cuts all the formations as well as the faults deriving from the Miocene-Early Pliocene shortening of the chain. In Section D, located to the west of Collicelli, there is a fault, which can tentatively be correlated with the Battiferro fault, interpreted as a back-thrust by some autors. Coarse-grained sedimentation in Pliocene times came from the west. The apex of the main fan was located to the West of Sections B and C.

Sezioni stratigrafiche attraverso il bacino di Spoleto che interessano principalmente i sedimenti pliocenici: 1, Sedimenti pleistocenici: a, sabbie; b, ghiaie; c, limi e argille; d, detriti; 2, Sedimenti pliocenici: a, sabbie; b, ghiaie; c, limi e argille; 3, Formazione marnoso-arenacea (Miocene); 4, Schlier (Oligocene); 5, Scaglia (Eocene-Oligocene); 6, Marne a Fucoidi (Cenomaniano p.p.-Aptiano p.p.); 7, Maiolica (Aptiano p.p.-Titonico sup.); 8, Calcari diasprini umbro-marchigiani (Titonico inferiore-Calloviano); 9, Bosso (Oxfordiano-Pleinsbachiano); 10, Corniola (Pleinsbachiano-Lotharingiano); 11, Calcare massiccio (Sinemuriano-Hettangiano). La maggior parte dei limiti inferiori dei sedimenti Plio-Pleistocenici sono stati identificati in accordo con le ricerche dell'Ente Minerario dell'Umbria. Molto probabilmente il bacino è stato creato in seguito ai movimenti di piegamento che hanno interessato la 'superficie di planazione' la quale è ancora preservata alla sommità dei rilievi circostanti. Questa superficie ha eroso le differenti formazioni così come le faglie create durante il raccorciamento della catena verificatosi durante il Miocene-Pliocene inferiore. Nella Sezione D, ad ovest di Collicelli, è stata individuata una faglia correlata a quella di Battiferro che alcuni autori hanno interpretato come un back-thrust. La sedimentazione grossolana durante il Pliocene proveniva da ovest. L'apice della conoide principale era ubicato ad ovestdelle sezioni B e C.

The cropping out sequence is (from bottom to top)[2]:

a) *'Cascinano Gravels'.* A few sections of limited thickness were observed at the contact with the bedrock. In the type locality (Fig. 5A), the sedimentological characteristics of the upper part of this unit, which is about 100 m thick, are: coarse to fine rounded to subrounded gravels, with a scarce sandy matrix, displaying a planar cross stratification (Gp). The layers are about 1 m thick, and are characterized by an eastward dipping of about 20-25°. A northward flow direction can be observed. In the upper part of the outcropping sequence, an about 3 m thick massive heterometric gravel (Gm) with the same sedimentological characteristics and slightly unconformable over the underlying sediments, is present. Lithologically these gravels, such as all gravels cropping out in this part of the basin, are formed by rocks of the Umbro-Marchean sequence, from *Maiolica* to *Scaglia Rosata,* and by calcarenitic lithotypes of the *'Marnoso-Arenacea'* Formation.

b) *'Castello sands and clays'.* At the top of the previously mentioned unit, there is a series of small outcrops of coarse- to very coarse-grained sand and gravels. Sands are orange-reddish in colour and display a small-scale cross stratification. The limited extension of the outcrops did not allow a thorough sedimentological description of the unit. However, the definition of a single unit is possible because of their lateral continuity. Only a few clayey lenses were observed.

At the base of this unit, the Mining Authority (Ente Minerario; De Marchi *et al.,* 1879-1944; Sabella, 1958; Lippi-Boncampi, 1959; Jacobacci, 1959) found a lignite seam, 3 to 8 m thick, with a dip of 30-40°E to NE. The lignite cropped out from Morgnano to S. Angelo in Mercole for over 4 km along the strike and was exploited with wells and inclined shafts, down to 400 m below the ground surface and 86 m below sea level (Ministero dell'Industria e Commercio, 1963). During excavation, the presence of faults, which interrupted the lateral continuity of the lignite seam preventing a complete exploitation of the deposit in depth, was noticed. It is therefore difficult to recognize whether the structural highs and lows, as identified during the lignite exploitation (Lippi-Boncampi, 1959; De Marchi *et al.,* 1879-1944), are to be attributed to synsedimentary or to postdepositional tectonics.

At the top of the lignite layer, within the clayey sediments, a mammal fauna with *Castor fiber, Tapirus arvernensis, Mastodon arvernensis* and *Mastodon borsonii* (Ricci, 1882; Pantanelli, 1884) allows the attribution to the Triversa Villafranchian Faunal Unit. In the miners' reports this layer is mentioned to locally overlie conglomerates and lacustrine clays, as well as the bedrock that is formed by either the *'Marnoso-Arenacea'* Formation or the *'Eocene Marly Limestones'.* The total thickness of

(2) Informal names are used to distinguish the units.

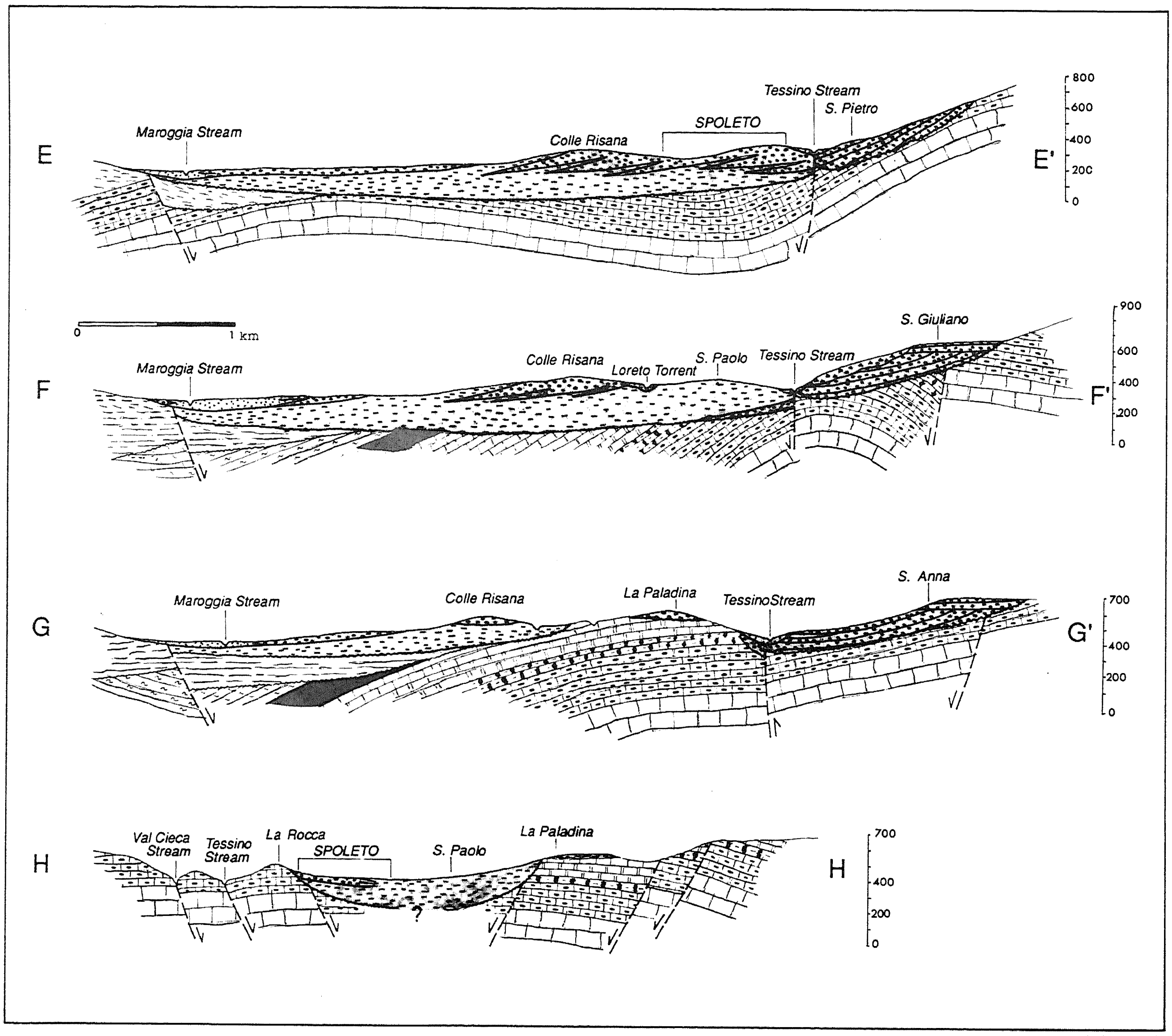


Fig. 4 - Spoleto basin: stratigraphic sections crossing mainly Pleistocene sediments. Legend as in Fig. 3. The lower limit of the sequences is unknown. Coarse-grained sedimentation came from the east, as a result of the activity of the extensional master fault, which at present delimit the basin (see also Plate 1). Toward the plain, there is a rapid change to finer sediments (alluvial plain deposits, swamp and lacustrine sediments).

Sezioni stratigrafiche attraverso il bacino di Spoleto che interessano principalmente i sedimenti Pleistocenici. La legenda è analoga a quella di Fig. 3. Il limite inferiore della sequenza è sconosciuto. La sedimentazione grossolana proveniva da est, come risultato dell'attività della master fault *distensiva che anche attualmente borda il bacino (vedere anche Tav. 1). Verso la pianura è stato evidenziata una rapida variazione di facies con ambienti deposizionali caratterizzati da sedimentazione più fine e facies di pianura alluvionale, sta-*

the *"Castello sands and clays"* is about 30-40 m.

c) *'Morgnano Gravels'.* An abrupt transition marks the passage to this unit, which is 70-100 m thick. The sedimentological characteristics, on the basis of few outcrops, are similar to those of the *'Cascinano gravels'.*

d) *'Case il Monte Sands'.* This unit is formed by medium- to coarse-grained sands, locally displaying a small-scale planar cross-bedding (Sp. These sands are interlayered with thin massive gravels (Gm) and greyish silts (Fcf). Within the greyish silts, paleobotanical remains (charcoal, leaves, etc.) and land snails were observed. The total thickness of the unit is about 20-30 m.

e) *'Casalino Gravels'.* This unit crops out almost continuously over the *'Case il Monte Sands'.* Close to the type locality (Fig. 5B), two out of the observed five thin channels (CH elements) can be described as follows. The lowest channel displays medium to fine massive gravels (Gm) with a scarce sandy matrix and local channel lags, whereas thin silt and mud lenses are present. The channel shows marked lateral thinning and interfingering with fine greyish clays with sandy and silty interlaminations and scattered carbonatic nodules (Fl). Only a few gastropod remains were observed. Well cemented medium to coarse-grained massive orange sands are present laterally and below a set of small gravelly channels. Thin trough cross-bedded gravels (Gt) passing laterally to planar cross bedded gravels (Gp) represent the filling of channels. An analogous sequence occurs in the uppermost part of the log. The total thickness of *'Casalino Gravels'* varies from 50 to 200 m.

f) *'Villa Francesconi Sands'* (Fig. 6A). To the south of Santa Croce, the whole sequence cropping out in the northwestern area of the basin, changes laterally: gravelly units (see above) become thinner and it is dubious how to link them with the ones outcropping northward. In fact, sedimentation becomes predominantly sandy. *Villa Francesconi Sands'* are characterized by well stratified coarse- to very coarse-grained sands showing parallel (Sh) and planar cross stratification (Sp) with small sets orthogonally oriented to each other. A deep channel (CH), filled with medium to coarse gravels was recognized. Minor faults trending N40°E were also identified.

Further to the south, two sections on the right side of Maraggiolo Stream show many intercalations of sands and gravels. The lowermost section is made up of coarse sediments (Fig. 5C). There are no CH elements, but layers of massive stratified (Gm) and locally planar (Gp) gravels are common. The fine to coarse gravels are rounded and rich in a sandy matrix. The low angle planar cross bedding is emphasized by the alignment of clasts. Sandy and silty-clayey layers alternate with gravelly layers. A deep weathering with many carbonate nodules and precipitate along root traces (K-horizon) is a common characteristic.

Higher up in the sequence, section 6B was logged. In the upper part, there are well stratified, from fine to medium sands showing horizontal bedding (Sh) and planar cross bedding (Sp). A few and very thin grey muddy levels with no lateral continuity are also present. To the right of 6B, the sands become coarser and layers have, at places, an erosional base. Layers of very coarse sands to fine gravels show trough cross-bedding (St). The scours often have a lag of fine gravels or mudballs (up to 5 cm in diameter). More continuous muddy levels are also present in this part of the section. A shallow channel (CH) with thin gravel bars (Gm) and mud balls was observed. The unit is up to 200 m thick.

g) *'S. Brizio Silts and Clays'.* These are very abundant in the upper part of the sequence. Northwards, the previously described units are absent and these layers lie directly over the bedrock. In the central-northern part of the basin, the *'S. Brizio Silts and clays'* are subdivided into three units by the outcrops of the *'S. Angelo Izzano Gravels and sands'.* These sediments were recognized in the plough zone, but no sections were localized. Within the upper clay unit, a few gravelly and sandy bodies were recognized at S. Anastasio. Gravel lenses crop out also within predominantly sandy deposits on the ridge between Morro and Collicelli. These are probably lateral facies of the previously mentioned finer sediments.

At Terraja, close to the basin present margins, at the upward transition to the overlying clayey sediments, a small section was logged (Fig. 6C). There are subrounded to subangular heterometric very coarse to fine gravels, often with a gravelly matrix. Yellowish massive sands (Sh), from very coarse- to fine-grained, are predominant. Thin layers with planar cross bedding were observed. A thin layer of matrix supported gravel (Gms) is also present. The finer sediments are represented by massive silts and clays. Upward, thin layers of weathered silts and clays (K-horizon) were observed. The total thickness is about 100 m.

h) *Debris flow deposits.* In the eastern part of the basin, at Collicelli and Case Paroli, a matrix supported angular and subangular heterometric debris deposit (locally with clasts more than 1 m in diameter) crops out. This deposit is more than 10 m thick; the clasts are composed only of *'Corniola'* and *'Calcari Diasprini'* fragments. The matrix is generally a whitish carbonate mud, although at places it is mostly gravelly. The deposit does not show internal grading and there is a non-erosional lower surface. Similar sediments crop out also at Petrognano, in the northernmost part of the basin, where they lie over the bedrock. Their characteristics and the lower unconformity limits allow us to attribute their emplacement to large debris flows with a high concentration of sediments coming from the Umbro-Marchean Apennines. Giant gravitative movements, rock block slides and rock slumps, were recently described by Gentili *et al.* (1992) and by Coltorti & Farabollini (1995) as occurring in other intra-Apenninic depressions.

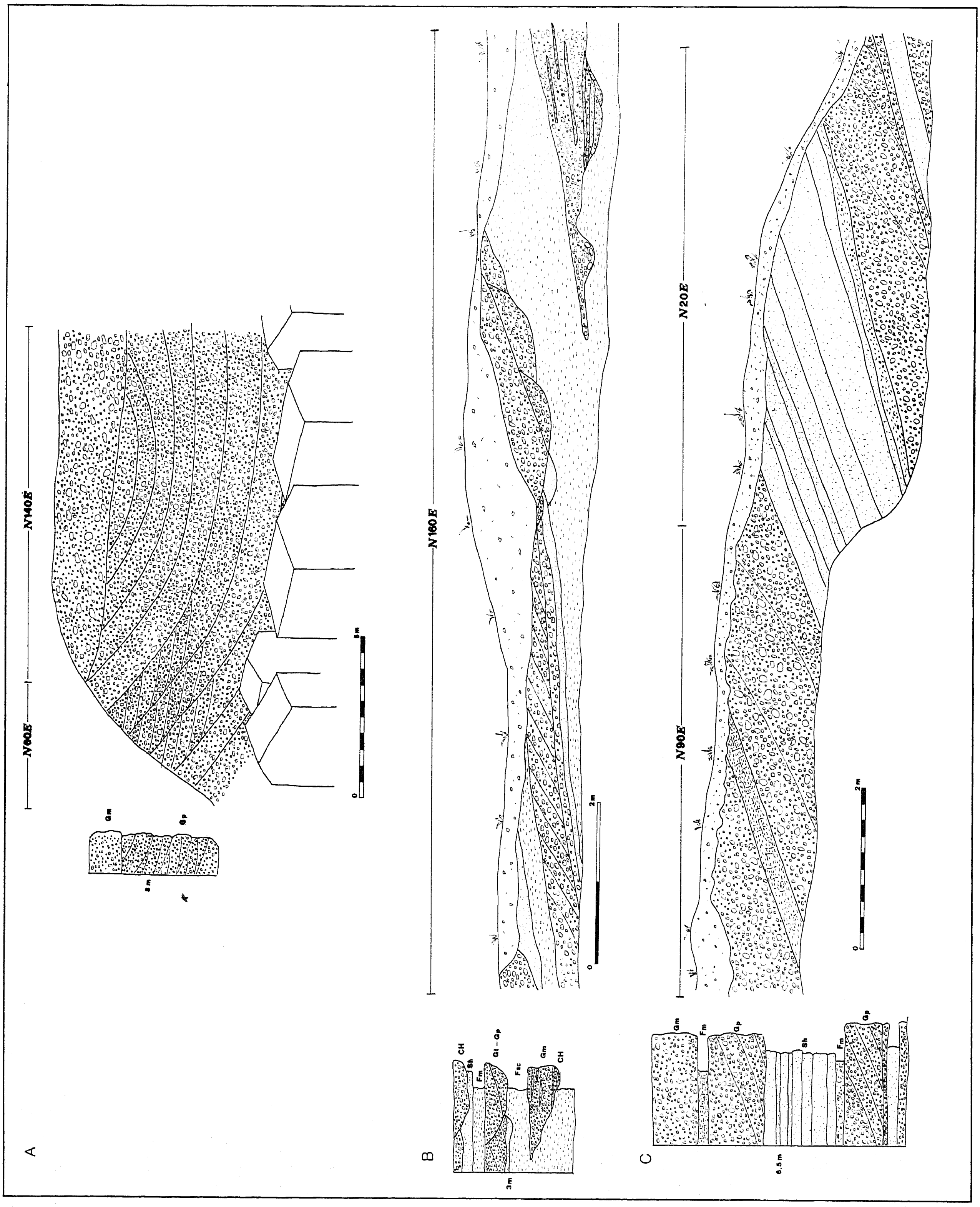
The eastern side of the basin is characterized by flat lying or gently westward dipping units. Moreover, it was not possible to identify the basin original borders, because these are buried underneath the present plain. To the southeast, sandy and silty facies, similar to the Villa Francesconi Unit, prevail. To the northeast, deposits with features similar to those of the 'S. Brizio Silt and Clays' are present.

3.4.2 Paleoenvironmental considerations

Sedimentary sequences and relative structures indicate that, during the 'Pliocene,' a large depression — a syncline-like structure — originated from the downwarping of the 'planation surface' in the Eastern Tiber Basin. It is therefore possible that part of the 'planation surface' is below sea level. Negative earth movements in the depression were balanced by positive movements in Monti Martani and the Umbro-Marchean Apennines. In the whole area, these movements occurred close to the base level. This is suggested by the fact that, despite uplifting movements which affected the whole peninsula after the end of Lower Pleistocene, Pliocene sediments are still below sea level.

The Spoleto depression, similarly to many other tectonic basins (Fraser & Decelles, 1992), was affected by a long period of vertical aggradation. In the basal part of the sequence (*Cascinano Gravels* and *Morgnano Gravels*), architectural elements influenced by gravel bar deposition (GB) are present, suggesting a braided pattern in the middle and distal part of the alluvial fan or in an upper braidplain (Model 2 of Miall, 1985).

Sandy layers with a remarkable continuity (*'Castello sands and clays'* and *'Case il Monte sands'*) indicate a stasis in coarse sedimentation and a transition either to more distal facies in the alluvial fan environment or to a


A
N90E
N140E
Gm
Gp
8m
0
5m
B
N160E
0
2m
CH
Sh
Fm
Gt-Gp
Fsc
Gm
CH
3m
C
N90E
N20E
0
2m
Gm
Fm
Gp
Sh
Fm
Gp
6.5m

sandy dominated alluvial plain.

The peat layers, which are described by various authors although can never be observed in the field probably because of their overexploitation for more than a century, have similar environmental significance. However, differently from what was suggested by Luettig (1959), peat and lignite not necessarily have to be associated with an Interglacial climate. For example, the peat of Gubbio was associated with an Interstadial climate (Ge.Mi.Na., 1963) and Calderoni *et al.* (1991) showed that peat in the upper Esino basin, on the eastern side of the Umbro-Marchean Apennines, formed during the Interstadial phases of the Last Glaciation.

The *Casalino sands and gravels* indicate depositional environments characterized by Gravel Bedforms and Overbank Fines architectural elements. Finer sediments are cut by shallow channels in the distal part of an alluvial fan, at the contact with the alluvial plain, inside swamps and small lacustrine basins. After the filling of the channels, gravel bars prograded into the plain. Afterwards, in the swamps, shallow channels with some lateral shifting (wandering ?) (Desloges & Church, 1987; Miall, 1992) deposited coarse sediments.

The *'Villa Francesconi sands'*, (Fig.6A, B) in which Sandy Bedforms elements with rare shallow channels predominate, suggest the onset of an alluvial plain characterized by sandy deposition and sand flat growth (Cant & Walker, 1978), even if the limited exposition of the outcrops does not allow the observation of the channel main facies. No sections of the *'S. Angelo Izzano Gravels and Sands'* and *'S. Brizio Silts and Clays'* showing paleoenvironmental details were found, although the Terraja section (Fig. 6C) is an evidence of the presence of swamps and small lakes at the toe of fans periodically reached by free flows (sandy and gravel bedforms) and debris flows. The Collicelli, Case Paroli and Petrognano deposits suggest that the eastern flanks of the basin, usually dominated by a fine sedimentation, were affected by large gravitative movements.

In the preserved sequence, the deposition of fine sediments, repeatedly interrupted by the emplacement of gravelly and sandy deposits, characterizes the final part of the filling. These sediments are well represented in the northwestern part of the basin; whereas, in the southwestern part, in the surroundings of S. Angelo in Mercole, less differentiated sequences sedimented for most of the time.

3.5 The Pleistocene sequences

After the end of the Pliocene depositional phase, a change in the structural style and general uplifting movements occurred (Ambrosetti *et al.*, 1982), and the following Pleistocene sedimentation is represented by alluvial terraces separated by periods of downcutting. The upper depositional surfaces are situated at progressively higher elevations above the valley floor.

3.5.1 The older Pleistocene sequence

In the southern sector, between S. Anna (665 m) (Tessino river) and Croceferro (291 m), to the north of Spoleto, gravelly sediments more than 100 m thick are present. They are horizontally stratified or slightly dipping NNW in the upper part of the sequence, whereas dip up to 20° in the lower and middle parts, which crop out along Sustrico Stream, a tributary of Tessino river (Fig. 4; Plate 1).

From bottom to top, the sequence is formed by:

a) *'Sustrico Gravels'.* They are strongly cemented conglomerates. Well-stratified massive gravels (Gm) predominate, at places associated with thin planar cross bedded gravels (Gp). The layers, which contain a scarce sandy matrix and subangular and subrounded clasts, are up to 20-30 cm thick. Clastic elements are mostly composed of *'Calcare Massiccio'* and *'Corniola'* Formations with subordinate elements from *'Calcari Diasprini'* and *'Maiolica'.* According to Cattuto & Gregori (1986), structures indicate the emplacement of alluvial fans into a narrow valley as indicated also by the up to 20° dipping strata. Locally, a pink cement is present, which gives to the rock an appearence similar to that of the so-called *'mortadella gravels'* described by Demangeot (1965) in Abruzzo and attributed to various Glacial periods. These deposits are the filling of a paleovalley, which deeply cuts through the Umbro-Marchean terrains. The maximum width of the paleovalley occurs between Ponte di Pompagnano and Vallecchia. Close to Ponte Antonelli, in the lower part of the outcropping sequence, a few meters of massive clay sediments (Fm) were identified.

b) *'La Cura-Colle Risana Gravels'.* At La Cura, these deposits are formed by subangular and subrounded gravels (Gm) in horizontal massive layers up to 2 m thick suggesting that, during the final aggradation phase, the valley was enlarged and filled by gravel bars deposited by a braided river. The upper depositional surface, which was dismembered by the downcutting of the valley and displaced by NE- and NW-trending faults, has a lateral

Fig. 5 - A) Stratigraphy of the Cascinano gravels at the type locality. There is a minor unconformity in between the lower and the upper gravels. These facies belong to a middle alluvial fan environment. B) Stratigraphy of the Casalino Gravels at the type locality. Alluvial plain facies alternate with shallow gravelly channels displaying planar cross bedding. C) Maraggiolo Stream Section located in the southern part of the basin where sequences in the central part of the area are not well differenciated. Gravelly planar cross bedded units alternate with massive sands in the distal part of an alluvial fan.

A) Stratigrafia delle Ghiaie di Cascinano alla località tipo. E' presente una discordanza minore tra le ghiaie inferiori e superiori. Queste facies rappresentano la parte intermedia della conoide; B) stratigrafia delle Ghiaie del Casalino alla località tipo. Si alternano facies di pianura alluvionale con sottili canali ghiaiosi a stratificazione incrociata planare; C) la sezione del Torrente Maraggiolo ubicata nella parte meridionale del bacino dove le sequenze osservate nella parte centrale non sono ben differenziate. Ghiaie a stratificazione incrociata planare si alternano con sabbie massive nella parte distale di una conoide alluvionale.

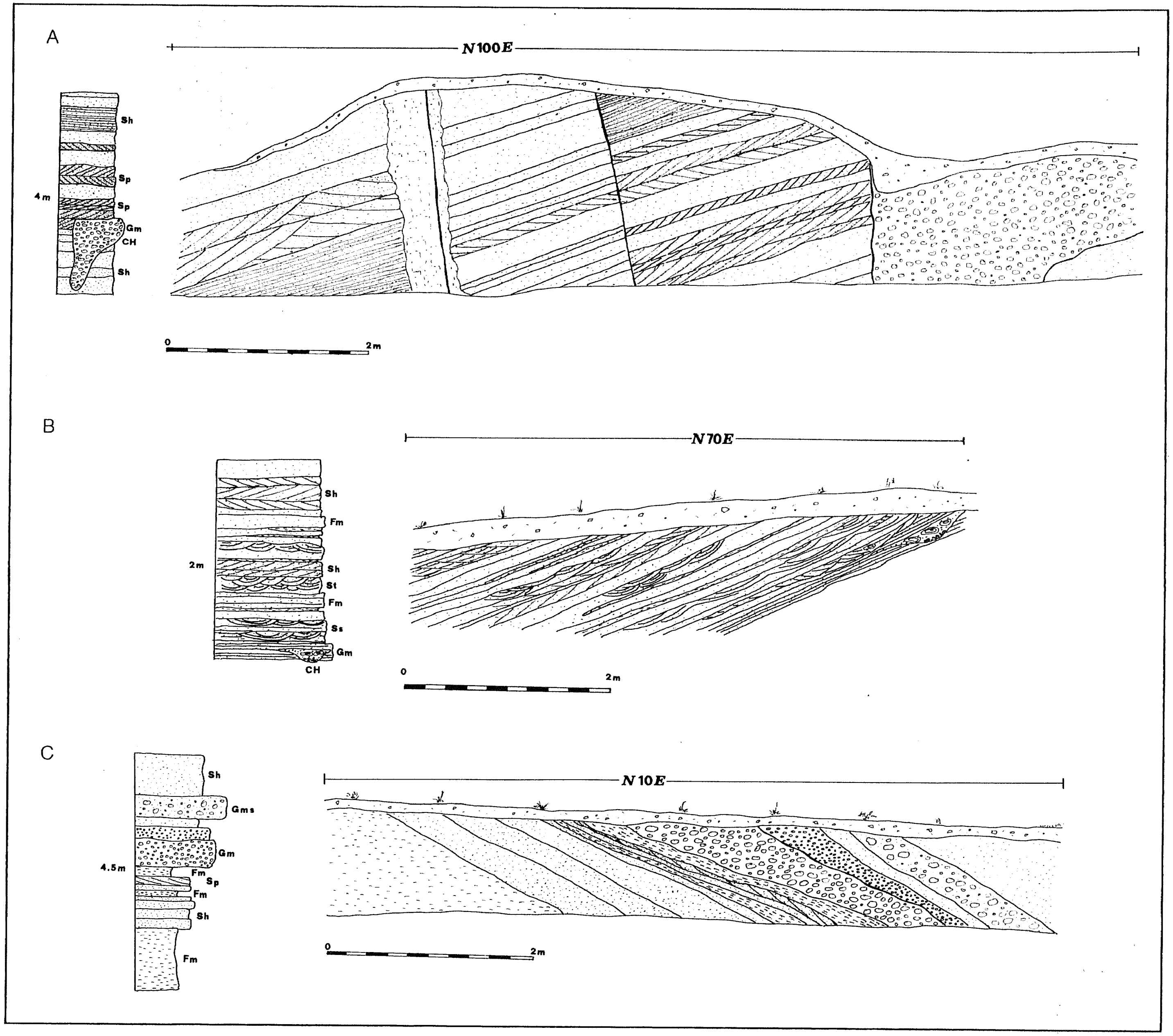


Fig. 6 - A) Villa Francesconi sands at the type locality. Small faults displace the sequence. The cross bedded sands show an abrupt change of flow direction. A small channel is present in this area, which is located in the distal part of the alluvial fan at the contact with the alluvial plain; B) Upper part of the Maroggiolo Stream sequence formed mainly by trough and planar cross bedded sandy sediments with thin alternances of fine sediments and small gravelly channels with mud balls; C) Terraja Section. Alluvial plain clays and silts alternate with sandy and gravelly bodies. A matrix supported gravel indicates that this area of the alluvial plain was reached by gravity flows.

A) sabbie di Villa Francesconi alla località tipo. Piccole faglie dislocano la sequenza. Le sabbie a stratificazione incrociata mostrano rapide variazioni della direzione di flusso. Un piccolo canale è presente in quest'area che era ubicata nella parte distale di una conoide alluvionale al passaggio con la pianura; B) parte superiore della sequenza del Torrente Maroggiolo costituito prevalentemente da sabbie a stratificazione incrociata concava e planare con sottili alternanze di sedimenti fini e piccoli canali ghiaiosi con mud balls *all'interno della pianura alluvionale; C) sezione di Terraja. Sedimenti limosi ed argillosi si alternano con corpi ghiaiosi e sabbiosi all'interno della pianura alluvionale. Un livello di ghiaie a supporto di matrice indica che questa parte della pianura alluvionale era raggiunta da flussi gravitativi.*

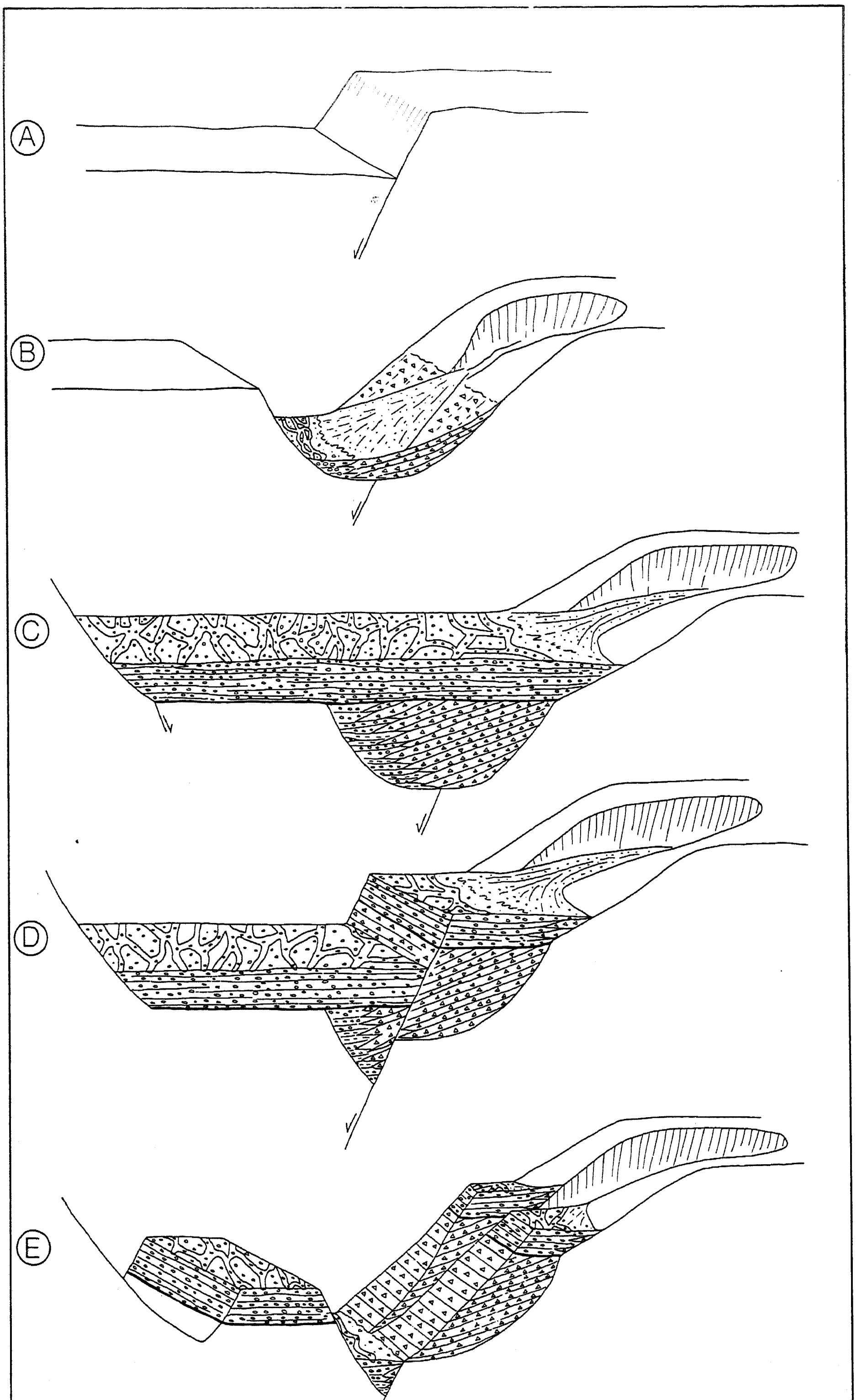


Fig. 7 - Evolutionary scheme of the Tessino fault affecting the Pleistocene sequence. A) the fault displaced the 'planation surface' before or during the valley deepening; B) beginning of an aggradational phase in the Tessino valley mainly fed by local talus and debris fan deposits. On the valley bottom, clay layers were locally deposited; C) filling of the valley by braided river sediments and aggradation also over the lowered parts of the 'planation surface' at La Paladina; D) continuation of the activity of the Tessino fault and displacement of La Cura-Colle Risana unit, which represents the upper depositional part of the aforementioned aggradation; E) downcutting of the Tessino valley that has continued until the present. It is possible that the displacement shown in Scheme D and the downcutting processes were contemporaneous.

Schema evolutivo della faglia del Tessino che disloca la sequenza pleistocenica; A) la faglia disloca la 'superficie di planazione' prima e durante l'approfondimento vallivo; B) inizio di una fase aggradazionale nella valle del Tessino alimentata prevalentemente da talus e coni detritici; localmente sul fondo valle si depongono delle argille; C) riempimento della valle da parte di corsi a canali intrecciati ed aggradazione anche al di sopra delle parte abbassate della 'superficie di planazione' alla Paladina; D) prosecuzione dell'attività della faglia del T. Tessino e dislocazione dell'unità di La Cura-Colle Risana che rappresenta la parte sommitale della fase deposizionale precedente; E) incisione della valle del T.Tessino sino ai nostri giorni. E' possibile che la dislocazione illustrata nello schema D ed i processi di incisione siano stati contemporanei.

transition to the slope by means of an erosional glacis. This surface is well preserved at La Cura (550 m), Petricola (562 m) e S. Anna (663 m) localities.

c) *'La Paladina Sands and Gravels'.* The narrow valley at the entrance of the Spoleto plain, in locality Villa Milani (380 m), was completely buried by alluvial sediments during the final aggradational phase. The alluvial sediments buried also the horizontally-eroded bedrock (Fig. 7). In locality La Paladina (532 m), the sediments are rounded gravels interlayered with thick sandy layers (50 m in thickness).

The remarkable thickness of this sequence along a few kilometers in the valley, was interpreted by Cattuto & Gregori (1986) as the result of the activity of a NE-trending fault, located along the valley itself. Because the bedrock outcrops on both sides of the valley, in correspondence

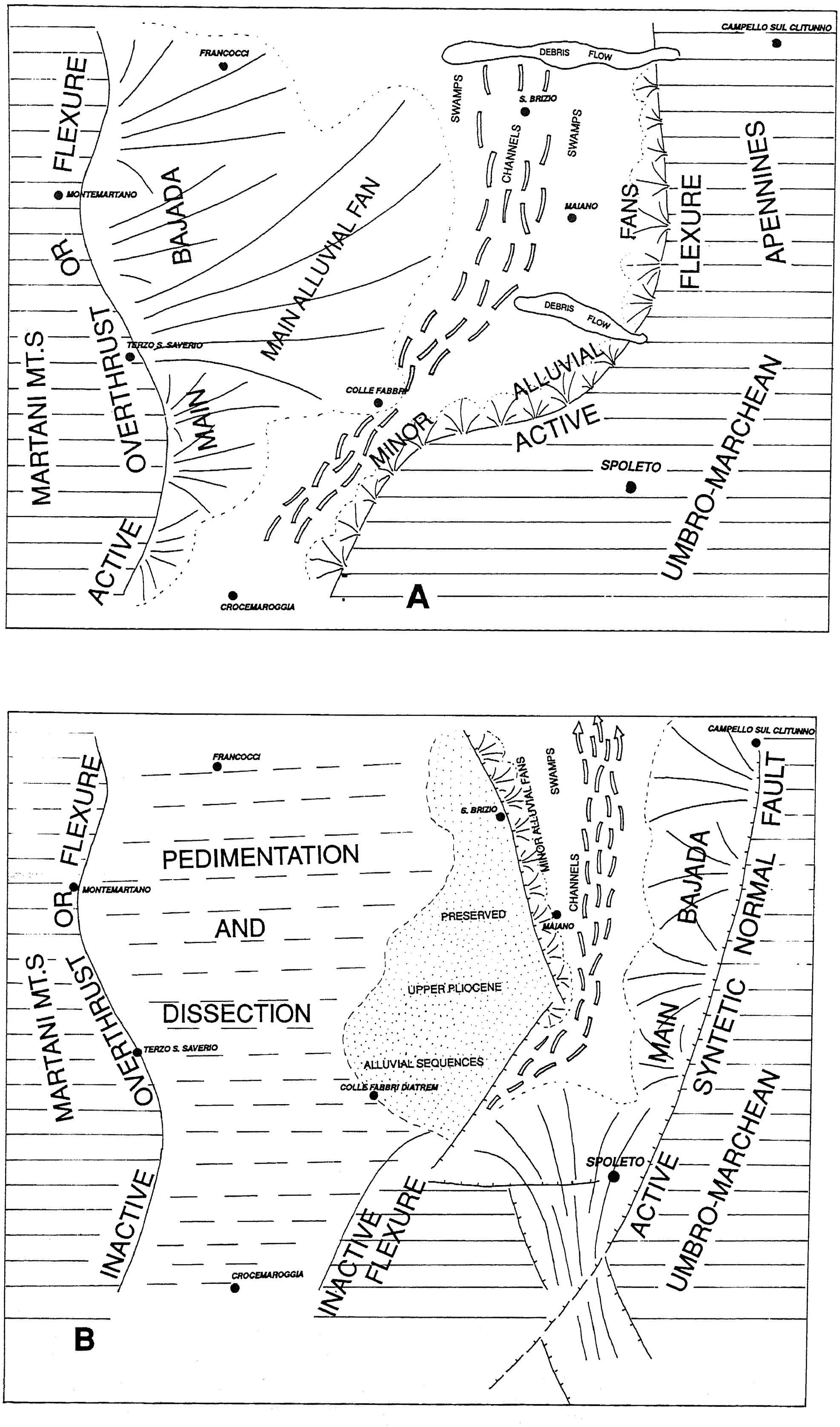


Fig. 8 - A) A downwarping process gave rise to the Spoleto basin at the end of the Lower Pliocene. It is possible that the western side of the basin was an effect of the reactivation of the Monti Martani overthrust. The main *bajada* was in fact located on this side of the basin. Minor alluvial fans and debris flows came from the eastern side. Alluvial plain and lacustrine sediments characterized the central part of the basin in the Upper Pliocene. B) The downwarping movements as well as the Monti Martani overthrust ceased their activity, and pedimentation and dissection affected a great part of the deposits. The emplacement of large alluvial fans was controlled by the activity of an extensional master fault running from Spoleto to Campello sul Clitunno. The western side of the new basin was bordered by a set of extensional antithetic faults which displaced the "Pliocene" sequence. In the southern part of the basin a large valley, generated by NNW-trending normal faults, was covered by the deposits of the Sustrico and La Cura-La Paladina-Colle Risana sequence.

A) Il bacino di Spoleto si è originato alla fine del Pliocene inferiore in seguito a movimenti di abbassamento. E' possibile che il lato occidentale del bacino venne generato dalla riattivazione del sovrascorrimento dei M.Martani. Una serie di coni alluvionali coalescenti erano infatti ubicati su questo lato mentre dal lato opposto giungevano debris flow. Sedimenti di pianura alluvionale e lacustri caratterizzavano la parte dentrale del bacino nel Pliocene; B) i movimenti di piegamento così come il sovrascorrimento dei M.Martani divengono inattivi e larga parte dei sedimenti depostisi in precedenza vengono dissecati ed interessati da pedimentazione. La deposizione di ampi coni alluvionali era condizionata dall'attività della master fault *distensiva che corre tra Spoleto e Campello sul Clitunno. Il lato occidentale del nuovo bacino era bordata da faglie antitetiche distensive che dislocano la sequenza del Pliocene superiore. Nel settore meridionale del bacino un'ampia valle venne generata da faglie normali NNO-SSE lungo la quale si depositarono le sequenze di Sustrico e di La Cura-La Paladina-Colle Risana.*

of the Villa Milani narrowing, these authors hypothese that the scissors movement of the fault probably generated a depositional trap. However, opposite to Villa Milani, the body of a large landslide locally covered by debris was observed. This shows that the paleovalley existed for the entire depositional history, with some parts being affected by gravitative movements and others by stream deposition. Similarly, well-cemented landslide scree tongues, interlayered with debris flow and alluvial sediments dipping up to 30°NW, can be seen along the eastern side of the valley up to San Pietro locality.

The Tessino fault displaced the 'planation surface' towards NW (Fig. 7A) before or during the valley deepening (Fig. 7B) and following infilling (Fig. 7C). The fault activity continued after the end of the clastic deposition. In fact, the upper depositional surface is located at different altitudes on the valley sides (Fig. 7D, E), as it can be observed at S. Giuliano (628 m). The displacement of a vertical fault with recurrent activity can explain this fact.

Northwestward, the same sediments crop out in the localities Colle di Spoleto (403 m) and Colle Risana (446 m). In the latter locality, the deposits are formed by heterometric rounded and subrounded gravels (Gm and Gt), slightly inclined to the NW, with an abundant sandy matrix. These deposits represent the medium and distal part of a large alluvial fan at the opening of the Spoleto basin.

d) *'Loreto Clays and Silts'.* These sediments can be recognized in the plough zone and in a few outcrops underneath the afore-described sediments on Colle Risana slopes. They are massive clays with few lenses of peat evidencing lacustrine conditions in the plain. Gravelly bodies of small thickness are interlayered. The scarce amount of these gravels indicates that the Tessino river was an important source of materials for the basin only after the deposition of this unit. If the *'Loreto clays and silts'* correspond to the afore-mentioned clays cropping out along the Tessino river near Ponte Antonelli, there would be further evidence for a very long downcutting period after the "Pliocene" cycle.

3.5.2 Final Middle Pleistocene, Upper Pleistocene and Holocene

Erosional phases in Central Italy are considered to be associated with long-lasting Interglacial conditions. On the other hand, the deposition of alluvial fan sediments and braidplains characterise the colder periods of the Final Middle and Upper Pleistocene (Coltorti, 1981; Calamita *et al.,* 1982; Chiesa *et al.,* 1990; Calderoni *et al.,* 1991).

In the Spoleto area, a long erosional phase followed the deposition of the older Pleistocene sediments and affected also the "Pliocene" sediments and the western side of the Umbro-Marchean Apennines. During this phase, the Tessino river valley was re-exhumed (Fig. 7D). This river entered the Spoleto basin to the west of the town, across the wide S. Paolo saddle. It continued eastward of Colle S. Tommaso, where a large alluvial fan, extending for more than 3 km from Tre Madonne (330 m) to Case Campo Franconi (240 m), was deposited.

During the following erosional phase, the Tessino river was captured to the west of La Rocca, where it cuts a deep gorge across the *Corniola* Formation, and continued to the west of Colle S. Tommaso. A second alluvial fan, which extends up to the confluence with Maroggia Stream, was deposited in the area allowing for the progressive shifting of Maroggia Stream against the western slope of the valley. The capture was preceded by a period of downcutting probably during the Last Interglacial. In fact, the Tre Madonne-Case Campo Francioni alluvial fan is weathered into a relic soil with an argic reddish Bt horizon with scattered carbonate concretions (palexeralf), similar to the Last Interglacial soils described by Chiesa *et al.* (1990) in the nearby Marche region. The upper part of the younger alluvial fan includes brown soils only, which developed during the Holocene. The capture seems therefore to be connected with a headward erosion.

The deposits of the Colle Risana unit may be correlated with the ones which formed the older terraced alluvia in the Umbro-Marchean area (1st order terraces). The unit has also the same position as the terraced alluvia from a morpho-stratigraphic point of view.

A further downcutting of the valleys, particularly in mountain and hilly areas, occurred during the Holocene. At present, however, the Tessino Stream almost entirely infiltrates into the upper part of the younger alluvial fan. The larger Maroggia river has paleochannels which are preserved at the opening of the Spoleto basin. Any-how, it is to point out that, during historical times, all watercourses have been rectified and protected by artificial levees in order to utilize the plain for agricultural purposes. Without such a type of works a swampy and lacus-trine environment would probably still exist.

4. TECTONIC EVIDENCE

Faults and fractures, which were identified in the area, belong to five main structural systems: E-W, N-S, NE-SW, NW-SE and NNW-SSE. There are scarce evidence of the first two systems, which displace the Pliocene sediments and, on the western side of the basin, also the pre-Pliocene terrains. An E-trending fault, to the east of Uncinano, along Cascinano Stream, dislocates the gravel layers cropping out on both sides of the valley. Other faults, with a minor displacement, are supposed to run along the nearby Alveo and Morgnano streams. Between Villa Francesconi and S. Silvestro, a N-trending normal fault displaces the "Pliocene" sequence toward the east for some tens of meters.

N40°E-trending faults with a limited downthrow were identified at Villa Francesconi and Morro di Busano. These are parallel to a more important fault along the Maroggia Stream, which has a SE downthrow and delimits the Pleistocene deposits to the west. To the north, between Ponte Bari and Castel Ritaldi, it is interrupted by a NNW fault, although the fault escarpment developing on the S. Brizio clay sediments, is greatly eroded.

The presence of a similarly oriented fault affecting the *'Marnoso-Arenacea'* Formation, is suggested by a triangular slope at 'Poggio del Vescovo', to which the 50-60 m displacement of the ridge surface can be attributed. Another fault is located along Sustrico Stream, to the south of Spoleto. The downthrow is about 50 m to SW and, again, suggested by the displacement of the depositional surface of the La Cura Gravels.

A NNW fault was observed at Villa Mari. In this locality, a rectilinear escarpment delimits to the south a higher area, where La Cura-Colle Risana gravels were deposited. These gravels come from the Tessino palaeovalley, where more than 100 m of sediments are present. However, a displacement in the opposite direction was observed on the southeastward extension of this fault along Vallecchia Stream, at the S. Giuliano locality.

The literature (Stoppa, 1988; Stoppa & Lavecchia, 1992) gives account of an intrusive melilitic diatreme with carbonatitic affinity on the northwestern extension of the Villa Mari fault; however, owing to chemical characteristics and a very low magma density, the location of the neck at shallow depth would not necessarily be connected with a fault. Along the Tessino river tributaries and on the southeast-ern slope of the basin, NE-trending faults are present. Also in this area, the faults displace the La Cura-Colle Risana gravels upper surface for about 70-100 m to the NW.

No evidence of any activity of the faults in Upper Pleistocene-Holocene times were found on the sides of the Pleistocene basin, whereas there are traces of their activation in the Lower-Middle Pleistocene. Moreover, the fact that there are no faults displacing the late Middle and Upper Pleistocene alluvial fans and terraces, indicates that their activity was concentrated before 0.2 ka.

5. SEDIMENTARY EVOLUTION AND TECTONICS

Two major depositional phases characterise the evolution of the Spoleto basin (Fig. 8A and B). The first one (Fig. 8A) is represented by sediments cropping out from Colle Ferretto to Petrognano on the basin western slope. These are alluvial fan sediments, which show vertical and lateral transition to sediments of fluvial and lacustrine environments. The most complete sequence (Fig. 9) outcrops to the east of Uncinano; it is formed, from bottom to top, by the units of Cascinano Gravels, Castello Sands and Clays, Morgnano Gravels, Case il Monte Sands, Il Casalino Gravels and Sands, and S. Brizio Silts and Clays separated by the deposition of the S. Izzano Gravels and Sands. To the south, many gravel units disappear and the heteropic Villa Francesconi Sands crop out. Debris flow deposits reached the basin from the east. The depositional phase began at the end of the Lower Pliocene, as the presence of a mammal fauna attributed to the Triversa Unit at the top of the Cascinano gravels indicates, whereas there is no chronological evidence for its end. It is remarkable that most of the "Pliocene" coarse sedimentation came from the West; whereas, in the Middle Pleistocene, the alluvial fan sedimentation is concentrated along the eastern side (Fig. 8A and B). In the absence of normal faults on the western side of the basin, it is to conclude that the origin of the Monti Martani ridge is linked to the reactivation of the main overthrust.

The Pliocene deposits sedimented into a synform basin characterised by a syndepositional sinking; contemporaneously, the Monti Martani ridge to the west, and the Umbro-Marchean Ridge to the east, were uplifting. This suggests that, during the Middle-Upper Pliocene, compressive movements were still active in Central Italy. If this is generally accepted for the Adriatic side of the Apennines, it is less evident for the Tyrrhenian side. A polyphasic tectonics in Umbria was first hypothesised by Decandia & Giannini (1977a). Although the ages were not precisely indicated, these authors assume that compressional regimes continued up to the Serravallian (the supposed age of the Belvedere conglomerates to the east of the Spoleto area). Nevertheless, indications of compressive movements alternating with general extensional tectonic conditions were reported by several authors (see, *e.g.* Boccaletti *et al.,* 1991). The results obtained seem to indicate that the "compressional" tectonic regime lasted for the entire Pliocene. After this compressive phase, an extensional one followed, which was characterised by fragile tectonics which affected mostly the western flank of the Umbro-Marchean Ridge and subordinately the western flank of the basin. The emplacement of a carbonatitic diatreme that cuts the Pliocene sequence at Colle Fabbri, is connected with this extensional phase (Stoppa, 1988; Stoppa & Lavecchia, 1992). $^{39}Ar/^{40}Ar$ datings on whole rock samples gave an age of about 0.55 Ma.

The various phases of progradation and retreat of the coarse clastic sedimentation may indicate a shifting in the depositional dynamics. However, more probably, the remarkable lateral continuity of many sedimentary facies and their sudden variations in grain size and facies may be indicative of climatic changes (Alexander & Leeder, 1987), such as recognized also in sea-bottom sequences (Berger, 1978; Shackelton, 1986; Rio *et al.,* 1994; Suc *et al.,* 1995) and in continental deposits of Northern Europe (Gibbard *et al.,* 1991; Zagwijn, 1992).

At a certain time of the Upper Pliocene-Lower Pleistocene, sediments were uplifted and dissected. An erosional phase occurred and a large part of the basin borders was eroded. Large valleys were cut through the Umbro-Marchean Ridge as well as through the Monti Martani ridge. At the end of the Lower Pleistocene, general uplifting movements occurred, as the presence of hanging younger alluvial terraces indicates.

The master fault, which at present delimits the Eastern Tiber Basin, became active originating a real graben. From this moment, the evolution of the area is similar to that of other tectonic depressions in the North-central Apennines (Calamita *et al.,* 1982; Martini & Sagri, 1993; Coltorti, 1994), which is largely connected with the activity of the faults which delimit the Umbro-Marchean Ridge to the east and the Pliocene sediments to the west.

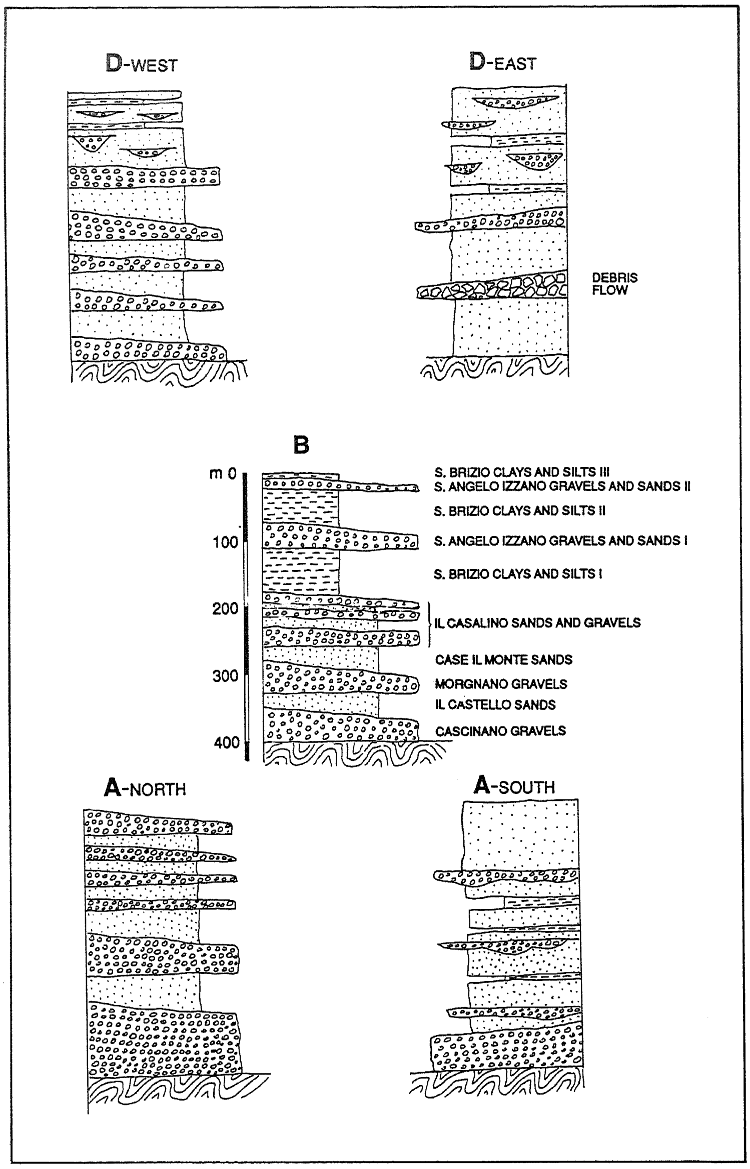


Fig. 9 - Schematic representation of the Pliocene sedimentary sequences in the different parts of the basin. The main section is located in the eastern side of the basin close to Sect. B (see Plate 1). Sections A and D show lateral variations of depositional environment.

Sequenza schematica dei sedimenti del Pliocene superiore nelle varie parti del bacino. La sezione principale è ubicata sul lato orientale del bacino nei pressi della sezione B di Tavola 1. Le altre sezioni (A e D) mostrano le variazioni laterali degli ambienti deposizionali.

According to Martini & Sagri (1993), this evolution may well be adapted to a model considering the emplacement of large coarse-grained alluvial fans developing on the fault hanging wall side and prograding into an alluvial plain with local shallow lakes (Leeder & Gawthorpe, 1987).

During the Middle Pleistocene, in the area close to Spoleto, after an important erosional phase which gave rise to narrow valleys, the thick sequence of La Cura-Colle Risana Gravels was emplaced. The narrow valleys were completely filled by debris and alluvial fan sediments which, in the final period, were deposited even on very flat surfaces at the top of the valley sides. In the Spoleto plain, a large and thick alluvial fan sequence was deposited; this overlies lacustrine clays probably deposited also in the inner part of the basin. The rapid progradation of gravel bodies into the clays suggests that cold climatic fluctuations occurred ensuring availability of sediments.

Two erosional phases during the Last Interglacial and the Holocene alternated with cold depositional phases (alluvial fan and alluvial plain deposits) during the Late Middle and Upper Pleistocene, the thickness of which does not equal that of the older alluvial deposits. Traces of capture of the Tessino river in this period indicate the reactivation of NW- and NE-trending faults, which seems to be the last evidence of neotectonics in the area.

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