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Morphotectonics of the Pescara River basin (Central Italy)

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ABSTRACT

This work presents a morphotectonic map of the Pescara River basin (1:40,000 scale), located in the piedmont-hilly area of the central-eastern Apennines (Abruzzo Region, Italy), and stretching from the eastern slope of the chain (Maiella Massif, Morrone Mt. and Gran Sasso Range) to the Adriatic coast. It is the outcome of an extensive drainage basin-scale geomorphological analysis and incorporates four main sections: orography and hydrography; morphotectonics; azimuthal analysis of the morphotectonic elements; Quaternary fluvial deposits and morphotectonic profiles. The morphotectonic map provides a basis for the study of morphotectonic features at basin-scale, the reconstruction of paleo-landscapes with special regard to drainage network evolution, and the recognition of tectonic control and selective erosion on the landscape. It also contributes to an outline of the main phases of the post-orogenic landscape evolution of the piedmont-hilly area of the Apennines, resulting from the link of alternating morphotectonic and surface processes.

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Geomorphological mapping; fluvial terraces; longitudinal profiles; drainage evolution; Pleistocene; Adriatic piedmont

1. Introduction

Determining the relative influence of tectonics, climate, base-level, and local factors on the evolution of the fluvial system is key to understanding landscape dynamics (Bull, 2007; Schumm, 1977). In this context, an integrated geomorphological analysis of fluvial terraces in uplifting areas represents one of the most widely used methods to investigate the role of tectonic and climate forcing in controlling landscape evolution (e.g. Bridgland & Westaway, 2008; Pazzaglia & Brandon, 2001).

In the Adriatic piedmont of the Italian Apennines, major valleys are characterized by a staircase of alluvial terraces that have developed since the Middle Pleistocene, and whose evolution is correlated with climatic oscillation and uplift processes (Coltorti, Consoli, Dramis, Gentili, & Pambianchi, 1991; Demangeot, 1965; Dramis, 1992; Farabollini & Nisio, 1997; Nesci, Savelli, Calderoni, Elmi, & Veneri, 1995). The particular arrangement of Quaternary fluvial terraces in the Pescara River basin (Central Adriatic Piedmont) has attracted the attention of many researchers for a long time (Alberti, Lipparini, & Stamponi, 1962; Bonarelli, 1931; Carrara, 1998; Demangeot, 1965; Principi, 1930). More recently, studies of these features have been carried out in the framework of the Geological Map of Italy (APAT, 2006; ISPRA, 2010a, 2010b). Most of these studies were undertaken at a local scale, missing a geomorphological characterization at a basin-scale. Furthermore, soft bedrocks of this region rarely preserve evidence of tectonic deformation,

making the analysis of geomorphic features a valuable tool in reconstructing the tectonic setting (Centamore, Ciccacci, Del Monte, Fredi, & Lupia Palmieri, 1996; Currado & Fredi, 2000).

In this work, we present the morphotectonic map of the Pescara River basin, at a 1:40,000 scale, implemented with integrated geomorphological analyses focused on hydrographic, fluvial/alluvial and morphotectonic features. As part of an extensive geomorphological analysis in the central-eastern Apennines (Miccadei, Orrù, Piacentini, Mascioli, & Puliga, 2012b; Miccadei, Piacentini, Dal Pozzo, La Corte, & Sciarra, 2013; Miccadei, Piacentini, Gerbasì, & Daverio, 2012a; Piacentini, Sciarra, Miccadei, & Urbano, 2015; Piacentini, Urbano, Sciarra, Schipani, & Miccadei, 2016; Santo et al., 2014; Sciarra, Coco, & Urbano, 2016), this map provides a basis for the study of morphotectonic features at basin-scale and the reconstruction of paleo-landscapes with special regard to drainage network evolution.

2. Study area

The Pescara River is located in the piedmont-hilly area of Abruzzo Region (Central Apennines), stretching from the eastern slope of the chain (Maiella Massif, Morrone Mt., and Gran Sasso Range) to the Adriatic coast for about 45 km (see physiographic map on the Main Map upper-left slice). This river is fed by two main tributaries draining mountain basins (Aterno and Sagittario rivers) and by the Pescara springs, all

located in the eastern chain sector. The overall hydrographic basin covers a surface area of some 3170 km², of which about 800 km² are in the piedmont-hilly area (Pescara River basin *stricto sensu*).

The chain area shows a high-relief landscape dominated by resistant Mesozoic-early Tertiary (pre-orogenic) carbonate ridges and erodible Tertiary (syn-orogenic) siliciclastics valleys, and by Quaternary continental (post-orogenic) deposit-filled intermountain basins (D'Alessandro, Miccadei, & Piacentini, 2003). The Adriatic piedmont fringes the easternmost ridges of the chain and is characterized by a low-relief hilly landscape (i.e. hogback, cuesta, mesa reliefs) carved on Mio-Plio-Quaternary terrigenous deposits, related to syn-, late-orogenic phases of the Apennines, and by Quaternary marine regressive deposits and continental deposits of post-orogenic phase. Here, the marine environment persisted until the Early Pleistocene, when the regional north-eastward tilting of the area followed the main thrusting (Centamore & Nisio, 2003) led to a sub-parallel (SW-NE) arrangement of the main valley across the emerged coastal plain (D'Alessandro, Miccadei, & Piacentini, 2008; Mayer, Menichetti, Nesci, & Savelli, 2003). Generalized tectonic uplift started in the Middle Pleistocene (D'Agostino, Jackson, Dramis, & Funicello, 2001; Pizzi, 2003), along with a series of glacial-interglacial cycles linked with the Mid-Pleistocene climate transition (e.g. Piasias & Moore, 1981), that forced alternating phases of fluvial incision (at both warming and cooling transitions) and deposition (at cold stages), as recorded by a staircase of fill terraces recognizable along the major valleys (e.g. Coltorti et al., 1991; Nesci et al., 1995). According to a general classification, these terraces are arranged in no less than four different orders, commonly named T1 to T4, starting from the highest. These features are well exposed along the Pescara River basin that connects the drainage system of the eastern chain with the consequent one of the Adriatic piedmont, playing an important role in the Quaternary evolution of the Central Apennines (Piacentini & Miccadei, 2014).

3. Methods

In order to define the role of morphotectonics in the evolution of the study area, an integrated drainage basin-scale study was carried out. Vector topographic data (1:25,000–1:5000 scale) were provided by Abruzzo Region (2007a, 2007b). A 5 m cell Digital Terrain Model (DTM) was processed from the 1:5000 scale vector map.

Orography (slope analysis and hypsometry) and hydrography analyses were based on the 5 m DTM and 1:5000 scale topographic maps (Ciccacci, D'Alessandro, Fredi, & Lupia Palmieri, 1992; Strahler, 1952). The drainage network and sub-basins were digitized

from the 5 m DTM, controlled by means of 1:5000 scale orthophoto color images (Abruzzo Region, 2009) and then analyzed focusing on stream profiles and pattern types (Hack, 1973; Howard, 1967; Twidale, 2004). The photogeology analysis was performed on 1:5000 scale orthophoto color images (Abruzzo Region, 2009) for preliminary mapping of the main landforms (structural, fluvial and slope landforms, etc.), and on 1:33,000 scale air-photos (IGMI, 1954) for the mapping of the anthropized areas.

Field survey (scale 1:10,000) was carried out in the years 2013–2016, investigating bedrock, Quaternary continental (post-orogenic) deposits, and the main morphotectonic elements (Centamore et al., 1996; Chelli, Segadelli, Vescovi, & Tellini, 2015; Ciccacci, Fredi, Lupia Palmieri, & Salvini, 1986; Griffiths, Smith, & Paron, 2011; Miccadei et al., 2013; Panizza & Castaldini, 1987; Picotti, Ponza, & Pazzaglia, 2009). Morphotectonic elements were classified according to their location in the landscape (ridges, slopes, valleys, hydrography forms, and fluvial terraces) and morphogenetics. The mapping was focused on the analysis of alluvial (terrace tread and strath, scarps, erosional surfaces) and hydrographic (hanging and beheaded valleys, counterflow confluences, and straight valleys) features, and their correlation to specific evidence of morphotectonics.

After a genetic characterization of terraced deposits during field mapping, the correlation of these deposits with the relative terrace level (order) was inferred by means of morpho-lithostratigraphic transverse profiles. In this way, terrace levels within individual sub-basins, from the youngest to the oldest, were defined based on the heights of terrace surfaces (tread and strath when visible) above the bottom valley and on their morphological continuity. Then, the reconstruction and comparison of the trend of terrace along different drainage sub-basins were computed via morphotectonic transverse profiles, in which morphotectonic elements are portrayed, summarizing collected data. To better understand the longitudinal distribution of any single terrace level these data were plotted on a longitudinal profile, with the *x*-axis representing the distance from the mouths of the basins. Local correlation, geochronological constraints (dating, paleosols, and lithic industries) and correlation with the neighboring valleys allowed us to outline Pleistocene–Holocene UBSUs (Unconformity-Bounded Stratigraphic Units, International Subcommittee on Stratigraphic Classification, ISCC, Salvador, 1994). Finally, a statistical azimuthal analysis of the mapped morphotectonic elements considered more significant in the study of the fluvial landscape was performed. This analysis allowed us to define the connection and alignment of the elements along a specific orientation, giving evidence of morphotectonic processes (Ciccacci et al., 1986). The relationship between geomorphic evidence of tectonics and fluvial deposits is likely to

provide evidence of morphotectonics and contribute to determining its control on valley development, thus attempting relative geomorphological constraints in the timing of landscape development.

4. Results

The main features of the Pescara River basin are presented on the morphotectonic map, which incorporates four main sections, described in the following paragraphs.

4.1. Orography and hydrography section

From the east of the mapped area, the Pescara River cuts the easternmost relief of the chain at the ‘gorge of Popoli’. Downstream of the ~7.5 km long gorge, it flows from 205 m a.s.l. down to the Adriatic Sea, collecting several minor tributary basins. The longitudinal profile has a concave shape, with a length of some 40 km and an average gradient of 5.12 m/km. The overall drainage basin covers a surface of some 800 km² in which three main sectors can be recognized:

- (1) *The chain front sector*, including the eastern slopes of the southern Gran Sasso arc (e.g. Mt. Cappuccciata, 1801 m a.s.l.; Mt. La Queglia, 995 m a.s.l.) and of the northern Morrone Mountain (2061 m a.s.l.). To the southwest of the mapped area, the chain–piedmont boundary is more articulated due to the northernmost slope of the Majella massif (2793 m a.s.l.);
- (2) *The piedmont sector*, with elevations ranging from 700–800 m to 200–300 m, slopes from ~50% to more than 100%, and local vertical scarps. This sector fingers the eastern chain front with a rugged to gentle (concave) morphology locally interrupted by deep and narrow incisions of the main water-courses; and
- (3) *The eastern hilly-coastal sector*, mostly with tabular relief, at an elevation of <350 m a.s.l., slope value ≤50% but with some local high slopes to vertical scarps along the edges of the tabular relief. The orographic setting shows a main (Pescara) valley shifted to the far southern side of its basin, with limited steep slopes on the right side and large gentle slopes on the left side.

The whole Pescara River basin is divided into 22 sub-basins of which the main orographic parameters are defined in Table 1.

4.2. The main morphotectonic map section

On the morphotectonic map, lithology and morphotectonic elements are represented. Outcropping lithologies have been classified by their general geodynamic

Table 1. Orographic features (area, max, mean, and min elevation, hypsometric integral) for each drainage sub-basin of the Pescara River basin (number 1–22).

No.	Basin name	Area (km ²)	Max elev. (m a.s.l.)	Mean elev. (m a.s.l.)	Min lev. (m a.s.l.)	Hypsometric integral
1	Telegrafo	4.4	184	56	0	0.312
2	Grande	9.5	211	87	1	0.413
3	Seminario	5.2	195	64	2	0.376
4	Santa Teresa	6.4	156	49	3	0.333
5	Fontecchio	54.3	340	130	4	0.383
6	Madonna	11.1	163	81	6	0.468
7	Ciafalino	14.5	198	111	17	0.52
8	Nora	138.1	1791	492	31	0.268
9	Cigno	61.8	1427	369	60	0.231
10	Valle Cupa	21.6	578	259	82	0.366
11	Valle Baroni	7.1	568	298	126	0.394
12	Fossato	41.6	1400	575	133	0.352
13	Arolle	22.6	1716	548	154	0.259
14	Orta	162.5	2726	1,063	127	0.367
15	Lavino	72.7	2136	786	90	0.354
16	Alba	21.6	1261	368	74	0.255
17	S.M. Arabona	22.5	345	167	53	0.402
18	Calabrese	5	299	142	60	0.359
19	Taverna	4.9	260	129	47	0.396
20	Minors right-side	33.8	352	89	0	–
21	Minors left-side	10.8	283	130	38	–
22	Pescara Basin	820.3	2726	497	0	0.184

context of formation (APAT, 2006; ISPRA, 2010a, 2010b). The description and numbers refer to the map legend.

4.2.1. Bedrock lithology

4.2.1.1. Pre-orogenic bedrock (1). The pre-orogenic marine bedrock is mapped as a single unit (limestone, marly-limestone, and calcarenite sequence) which includes different kinds of carbonate rocks belonging to the platform-to-basin depositional systems of Triassic to Miocene age (APAT, 2006; ISPRA, 2010a), and constitutes the relief of the chain sector (western mapped area). Along the western slope of the La Queglia relief, a 3–4 m thick lamprophyre dike (1a) of Eocene age is intruded between two layers of limestone.

4.2.1.2. Early/syn-orogenic bedrock. The early/syn-orogenic marine bedrock comprises three main sequences (APAT, 2006; Centamore et al., 1992; ISPRA, 2010a):

- The marly-limestone, perlite and chalk sequence (2) includes rocks of basinal (Upper Messinian–Lower Pliocene) and continental shelf (Lower Pliocene) environments, and it is mapped along the mountain front sector.
- The pelitic–arenaceous sequence (3) includes turbidite rocks of Upper Messinian–Lower Pliocene age, that extensively outcrops in the central-western mapped area.

- The conglomerate sequence (4) represents the infill of lower Pliocene piggy back basins and is now recognizable in limited outcrops on the summit of the Fiore, Picca and Morrone mountains.

4.2.1.3. Late-orogenic bedrock. The Late-orogenic bedrock comprises two main units which record a gradual transition from a marine depositional environment to a continental one (APAT, 2006; ISPRA, 2010a; 2010b):

- The clay, sandstone, and conglomerate sequence (5) consists of three main associations (pelitic-sandy, sandy-pelitic, and sandy-conglomeratic) showing a deepening-upward trend during the Late Pliocene p.p. and a shallowing-upward trend during the Early Pleistocene. This sequence crops out in the entire eastern hilly-coastal sector as a wide homocline gently dipping north-east in which pelitic-sandy and sandy-pelitic associations are widespread along the valley bottoms and flanks respectively, whereas a sandy-conglomeratic association lies on the top of the mesa relief. Deltaic conglomerates and calcirudites (1a) are present at the base of this sequence, mapped between the Turrivalignani and Cepagatti villages.
- The conglomerate sequence (6) highlights a transition to a subaerial environment during the Middle Pleistocene p.p. (Di Celma, Ragaini, & Caffau, 2016), and is mapped in outcrops of very small extent within the Fontecchio basin.

4.2.2. Quaternary continental deposits

Quaternary (post-orogenic) continental deposits are listed below (units 7 to 20) and have been classified on the basis of their predominant morphogenetic process (fluvial and alluvial fan, fluvio-lacustrine, slope/weathering, beach/deltaic and anthropogenic). A specific focus was devoted to terraced deposits (Figure 1).

Mapped fluvial and alluvial fan deposits are as follows: terraced gravel and conglomerate (7), terraced gravel, gravelly-sand and conglomerate (8), terraced gravel and gravelly-sand (9), terraced gravel, sand and silty-sand (12), terraced sand, silt, and gravel (14), active and bankfull channel (19). The deposits of units 7, 8, 9, 12 and 14 are allostratigraphic units arranged in a staircase of fill terraces, often associated with minor suites of strath terraces (*sensu* Bull, 1991). These units show a basal unconformity (strath) typically carved across the bedrock (Figure 1(a)), with the exception of the youngest units (12 and 14) in the mid- and lower-Pescara valley, where they partly cut alluvium. The deposits of unit 7 are portrayed in few remnants of the piedmont sector. They usually constitute the top of the highest relief within sub-basins, but typically lie below the main basin divide. The deposits of unit 8 are widespread within the

Nora (Figure 1(b–c)), Cigno, Alba and Fontecchio basins, and along scattered outcrops on the left side of the mid-lower Pescara River valley. The deposits of units 9 and 12 are mapped with great continuity throughout the Nora and Alba basins, and all along the left side of the upper and mid-lower Pescara River valley. The deposits of unit 14 are commonly referred to as the ‘Holocene floodplain’ and outcrop all along the valley floors of the Pescara River and of the lowest reaches of its main tributaries. Watercourses are now deeply entrenched within these deposits (Figure 1(d)), allowing us to define them as terraced units. From a general stratigraphic point of view, the upstream deposits of units 7, 8, 9, and 12 in the chain front areas show coarse alluvial fan facies (debris-flow-dominated), whereas moving downstream they appear more fluvial-dominated. Along the Nora and Alba basins, great exposures of these units highlight a continuous lateral variation of facies from proximal, through mid-fan, to distal fan. In the central-eastern Pescara River valley, terraced deposits mainly consist of gravelly braided-stream alluvium (Figure 1(e)), even though units 9, 12, and 14 show a general fining-upward trend characterized by coarse-grained and finer sediments at the lower and upper portions, respectively. This dichotomy is particularly evident on units 9 and 12, lying at the junction of tributary catchments with the main valley. The deposit of unit 19 has been divided into two sub-units: (a) active and (b) bankfull channel. The sub-unit 19a lies at the base of the narrow channels in major torrents and rivers with low gradient (Figure 1(d)), reflecting the influence of the present flood regime. Sub-unit 19b is portrayed exclusively along the Pescara River and along the lowest reaches of its tributaries. Bankfull deposits outline the recent (after the mid-1900s) valley floors adjustment along the main watercourse, as well evidenced in similar rivers of the Region (Piacentini et al., 2016). Local correlation, geochronological data constraints (Agostini, 2003; Agostini, Di Canzio, & Rossi, 2001; Carrara, 1998; Marcolini et al., 2003) and the correlation with neighboring valleys (i.e. D’Alessandro et al., 2008; Della Seta et al., 2008) have allowed us to outline at least five Pleistocene–Holocene UBSU and infer their ages (see Table 2).

Mapped fluvio-lacustrine deposits are terraced travertine (11) and travertine (13). Terraced travertines (11) are discordant with the syn-orogenic bedrock and constitute the plate of the Tocco village on the right valley side (Figure 1(f)) and the nearby low relief of Vicenne on the left side. The travertine deposits of unit 13 are entrenched within the Terraced Travertines ones and constitute the flat bottom valley of the Castiglione-Piano D’Orta area. These deposits have sedimented in basins closed by natural dams mainly composed of autochthonous lithotypes (Carrara, 1998), organized in fan-shaped step-like terraces,

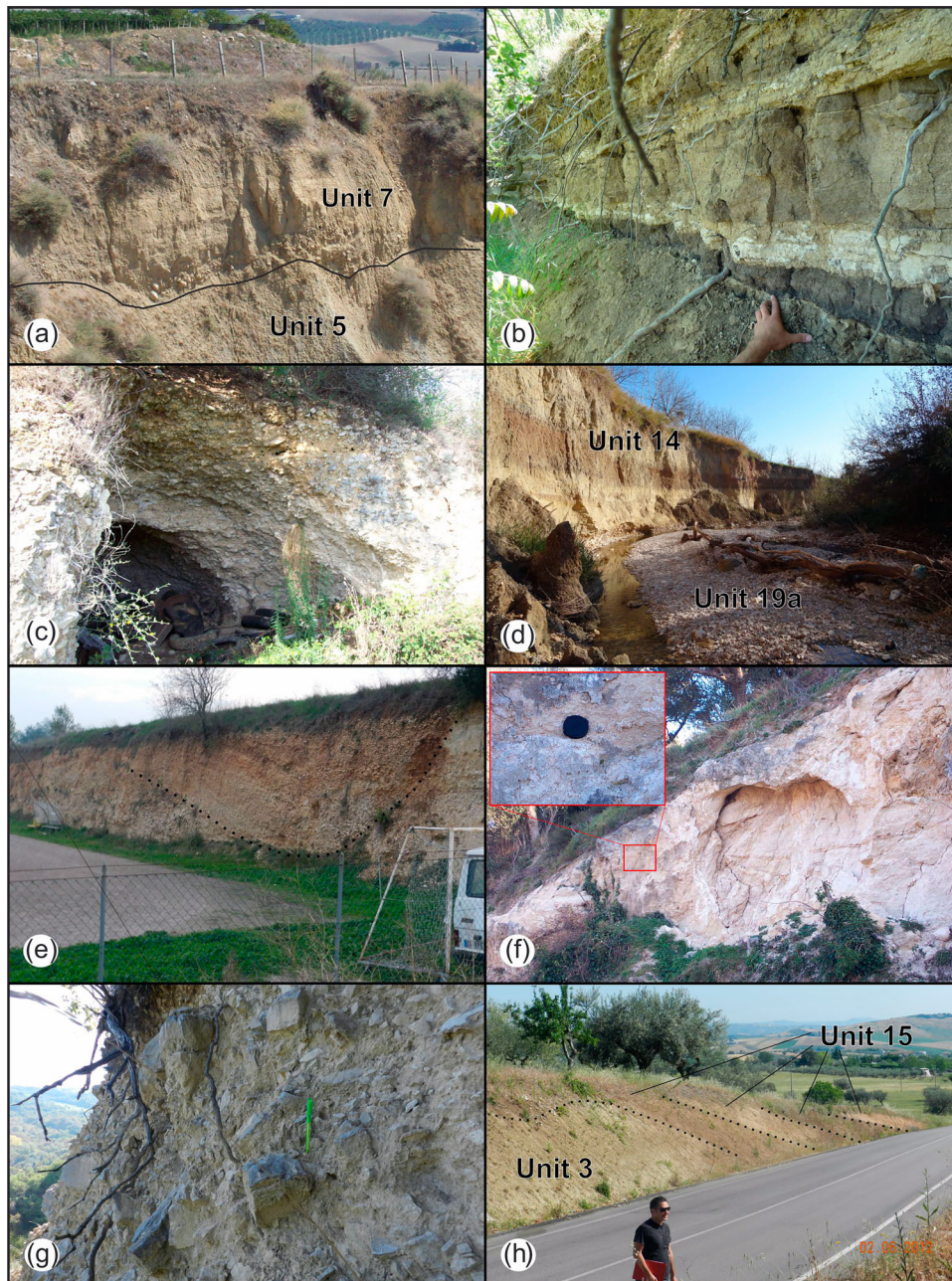







Figure 1. Lithology of the study area (the units numbers and ages refer to the legend of the map): (a) strath contact between the clay bedrock (5) and fluvial (overbank) deposits belonging to unit 7 (at S. Caterina); (b) dark tephra level within the terraced deposits of unit 8 (at Colle Picconetto), interlayered with silty-clay palaeosols (lowest level indicated by the hand) and sheet-like silty-sand and arenaceous layers (upper layers); (c) fluvial conglomerate deposits (8) at Piano Scarpara; (d) channel incision of the Cigno Torrent highlighting the fine sediments of unit 14 with brownish topsoil; (e) fluvial channel deposits within the gravel of unit 9 and reddish topsoil; (f) travertine deposits of unit 11 (near Tocco village); (g) ancient slope deposits (10) of the upper Nora valley; and (h) colluvial deposits (15) characterized by four main wedges.

progressing downstream. Unit 11 dates back to the Late Pleistocene whereas unit 13 is of Holocene age.

Mapped Slope/weathering deposits are: ancient slope (10), eluvial-colluvial (15), landslide (16), scree slope (17). Ancient slope deposits (11) are portrayed exclusively in the mountain front areas. Occasionally, they outcrop as small and isolated lobes hanging on mountain slopes, in which sedimentary features suggest a proximal alluvial fan environment (Figure 1(g)). Colluvial deposits (15) are widespread throughout the basin, particularly at

toeslopes, on convex valley flanks, and within concave bottom valleys (areas with slope angle $<20^\circ$). Frequently, these deposits are related to different sedimentation events (wedges), of which the oldest were recognized along road cuts (Figure 1(h)). Eluvial deposits (5) lie on the flat and gentle sloping tops of hills. Landslide deposits (16) and slope deposits (17) are related to several slope gravity processes and they outcrop with higher spatial density and size in the piedmont sectors. Deposits of beach/deltaic environment (18) and of anthropogenic origin (20)

Table 2. Correlation of fluvial and alluvial fan terraced deposits (colors refer to the lithological units of the map), terrace orders, and Pleistocene–Holocene UBSU.

Deposits		Terrace order	Age
Terraced gravel and conglomerate (8)		T1	Middle Pleistocene
Terraced gravel, gravelly-sand and conglomerate (9)		T2	Upper Middle Pleistocene
Terraced gravel and gravelly (10)		T3	Late Middle Pleistocene
Terraced gravel, sand, and silty-sand (13)		T4	Late Pleistocene
Terraced sand, silt, and gravel (15)		T5	Holocene

were grouped as ‘Other deposits’. Ancient scree slope deposits date back to the late Middle Pleistocene. Other units (15, 16, 17, 18, and 20) date back to the Holocene, even though some older unmappable deposits have been observed.

4.3. Morphotectonic elements

The study area is characterized by diverse landforms, heterogeneously distributed in relation to the morphological, hydrographic and lithological setting (Figure 2) of the three main orographic sectors. A statistical azimuthal analysis of morphotectonic elements highlights such connection and preferential alignment of these features.

4.3.1. Sector 1 (chain front)

The morphotectonic elements are mainly carved on pre-orogenic bedrock and their distribution is strictly influenced by lithostructural control and high slope angles. In the western chain front, N–S to NE–SW oriented structural scarps, hogback relief and straight (subsequent) valleys following the regional N–S trend of the thrust system overlapping pre-orogenic bedrock on syn-orogenic rocks. Along the mid-lower slopes, subsequent valleys bend in a general E orientation into main consequent valleys (e.g. upper Nora and Cigno streams). Vertical erosional deepening has helped the development of several and large mass movements with related landforms (landslide scarps and trenches). The northern culmination of the Maiella anticline is characterized by a wide N-dipping (10–15°) structural surface. This surface appears deeply weathered and displaced by NW–SE faults, and has therefore been mapped as several minor ‘structural surfaces’. NW–SE local tectonics and dip-slope strata also influenced the straight and parallel drainage of this area.

4.3.2. Sector 2 (piedmont)

The morphotectonic arrangement of this sector is strictly influenced by the lithostructural setting of the thrust system, which here only involves the early/syn-orogenic bedrock. The main features are a narrow hogback in the western relief and cuesta relief in the eastern-most areas, both oriented in a N–S to NE–SW direction, and associated subsequent valleys that join the main

consequent valleys with 90° or counterflow confluences. Main straight ridges, entrenched erosional surfaces and terrace scarps are mainly elongated in a NE–SW to NNW–SSE direction, evidencing linear incision processes along the straight subsequent valleys. The valley slopes are characterized by sharp vertical scarps and step-like slopes due to selective erosion of alternating sandstone and pelitic beds. In the lower Nora and Cigno basins, the main valleys bend from SW–NE to NW–SE; these deep valleys cut a SW–NE parallel drainage with associated hanging and beheaded valleys, triangular facets and counterflow confluences.

4.3.3. Sector 3 (hilly-coast)

The main drainage divide area is characterized by a structural surface on late-orogenic sandstone and conglomerate sequence (top of the mesa relief). These surfaces are often bounded by structural scarps and locally by landslide and/or degradational scarps. Beheaded valleys and saddles are mapped on the main drainage divide, and locally at the heads of small straight valleys, with a systematic orientation. Significant river bends and counterflow confluences are widespread in areas with an angular drainage pattern, mostly with the same orientations as the straight fluvial segments. Fluvial erosion scarps are mapped along the valley bottoms, where they affect floodplain (unit 14) and channel (unit 19) deposits, but also landslide and colluvial deposits. Terrace scarps are steeper where the streams have most recently swung against their base. Badlands were formed on clayey bedrock (unit 5) along the left side of the Pescara River basin and in the lower Nora valley. Most of these landforms are isolated and developed on S to SE facing slopes, except in the upper Arabona basin, where they are randomly grouped together, thus forming the typical *calanchi* landscape.

4.4. Morphotectonic profiles

Morphotectonic profiles consist of valley transverse and longitudinal profiles that have different horizontal and vertical scales for reasons to graphic and visual balance. In the transverse profiles, morphotectonic elements are correlated to continental deposits, outlining the distribution of the processes affecting the area (mainly fluvial and slope processes). The terraced deposits are drawn below the topography and the



Figure 2. Geomorphological features of the study area (symbols of morphotectonic elements are portrayed as in the main map): (a) panoramic view of the entrenched fluvial/alluvial fan terraces in the Nora valley (T1 = Middle Pleistocene; T2 = upper Middle Pleistocene; T3 = late Middle Pleistocene; T4 = Late Pleistocene); (b) structural scarps highlight the bedrock on which T2 and T3 terraces lie; (c) a hanging and beheaded valley with W–E orientation highlights a paleolandscape developed in the late Pleistocene (post T3 terraces) and subsequently dissected by N–S and SW–NE fluvial incision; (d) small hanging valleys, triangular facets, and counterflow confluences along the straight valley of the Poggio stream (Nora basin), possibly connected to lithostructural control (along WNE–ESE fractures and joints, also surveyed in the lowest Nora valley); and (e) badland areas in the uppermost reaches of the Arabona basin.

height above the present valley is defined for each terrace level (see tables in the profile section).

In the longitudinal profiles of the main valleys (Pescara, Alba, Nora, Cigno, and Fontecchio), terrace treads show a general downstream convergence geometry, even though the Pescara profiles appear more articulated at the confluences with the main tributaries. The Alba, Nora, and Cigno profiles are characterized by a physical continuity of tread levels, in which the knickpoint of modern streams have a lithostructural control or correspond with changes in the cross-section morphology of the valleys.

5. Conclusion

The morphostructural setting of the Pescara River basin and the arrangement of the fluvial terraces were

analyzed through the morphotectonic map and sections. Fluvial and alluvial deposits are arranged in five main orders of entrenched terraces (from the Middle Pleistocene to the Holocene), recording drainage evolution of the piedmont since its emersion. The transverse profiles show the relative incision of the fluvial terraces on the alluvial fan terraces and of the different terrace levels one into the other. The longitudinal convergent geometry of the terrace treads suggests the role of uplift in drainage development (Merritts, Vincent, & Wohl, 1994).

The remnants of the oldest alluvial fan surfaces (T1 and T2), on the top of the hilly reliefs and divides of the chain front areas, outline a landscape completely different from the present one – a Middle Pleistocene wide piedmont plain on which large alluvial fans formed, as already observed in the northern Adriatic piedmont

(Nesci & Savelli, 2003). These fans filled incipient valleys that are now ridges bounded by newly formed valleys on each side, evidencing inversion of relief processes (Pain & Oilier, 1995).

Between the Lower Cigno and Fontecchio streams, the spatial distribution of the T2, T3 and T4 terraces, elongated in the SW–NE direction and entrenched into the ancient fan surfaces and along both margins of the present valleys, indicates the development of a SW–NE consequent drainage starting in the upper Middle Pleistocene. This is confirmed by the SW–NE parallel pattern of the straight valleys and crests. In the lower portion of these valleys, the main streams make an abrupt bend (>60–90°), and then flow downstream into the Pescara River with straight WNW–ESE and NW–SE orientations (parallel to the minor valleys), cutting late Middle-Late Pleistocene terraces (T3 and T4). The resulting angular pattern of this sector, along SW–NE, WNW–ESE and NW–SE orientations (with associated hanging and beheaded valleys, and counterflow confluences), indicates the control of local tectonics on drainage development along WNW–ESE and NW–SE faults and fractures and suggests that the age of these elements can be ascribed to the late Middle-Late Pleistocene.

In this context, the last phase of drainage incision related to Late Pleistocene–Holocene climatic changes resulted in the gradual organization of the drainage network to its present configuration, and indicates a main lithostructural control in the development of the current fluvial landscape.

Software

The vector/raster data and [main map](#) were managed using Esri ArcGIS 10.1[®], with final editing performed using Corel Draw[®].

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