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LIVELY DRAINAGE OF THE NORTHERN APENNINE *

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ABSTRACT: In the Northern Apennine NW to SW oriented structures influence not only main water courses, largely hosted in the Plio-Quaternary basins (Mazzanti & Trevisan, 1978), but also minor streams located close to the present Apennine watershed.
Because of their location close the drainage divide, where the exhumation rate is at present faster, these minor river segments have developed in recent time (late Middle and mostly Upper Pleistocene), when the litho-structural discontinuities on which presently they are set, became exhumed. River piracies affecting these streams are even more recent events and were triggered by the on-going regional uplift.
In the high Reggio Emilia – Modena Apennines, the alignment of Ozola, Dolo, Dragone and Perticara upper river segments, oriented NW-SE, is controlled by weak-impermeable lithologies outcropping on a thrust front.
In the Frignano area, the evolution of the drainage network was deeply conditioned by the presence of lithologies featuring different erodibilities.
The Ombrone Pistoiese upper basin drainage is presently featuring a series of river piracies driven by the marked asymmetry of the watershed in that area.
Lithologic discontinuities on the one side and Middle-Upper Pleistocene widespread uplift on the other controlled the drainage evolution in the whole area.

Key words - Stream patterns, Middle and Upper Pleistocene, Northern Apennine.

1. INTRODUCTION

Stream patterns are basically controlled by two conflicting constraints: the gradient of the slope where they formerly originated and, if any, a lithostructural control of their path (Twidale, 2004). The geologic control is frequently not obvious because the river segment emplacement took place at higher crust levels (eventually wiped away by the erosion) featuring a different geologic frame.

The aim of the present paper is to show that water courses flowing in the proximity of the present Northern Apennine watershed were recently captured, due to the ongoing uplift, by transverse streams, deeply controlled, in their evolution, by lithologic discontinuities.

Captures occurring close to the watershed, both on the Adriatic and on the Tyrrhenian side mime, at a larger scale, the events which took place in the Middle Pleistocene chain uplift (Bartolini, 2003) which induced a low relief area, scattered with swamps and ephemeral lacustrine basins to be uplifted and dissected. The intervening increase in the uplift/denudation rates is supported by the onset of a fast prograding sedimentation pattern since 1.0-0.8 Ma B.P. on both the Padan and the Tyrrhenian side of the Apennines (Argnani et al., 1997; Carminati et al., 1999). The uplift resulted in the shift from an internally drained fluvio-lacustrine system to an open, through going (i.e. exorheic) river system (Bartolini & Pranzini, 1981; D'Agostino et al., 2001; Bartolini et al., 2003). The along trend rivers, draining the newly formed intermountain depressions, were captured, originating the present, peculiar drainage pattern formerly described by Mazzanti & Trevisan (1978). Namely the Arno River upper reaches, the Sieve, the Lima and others rivers assumed, by capture, their present hook shaped geometry (Fig.1).

2. THE ROLE OF DIFFERENTIAL UPLIFT

The detailed appraisal of drainage rearrangement by capture carried out by Bishop (1995) appears to correctly fit the features evidenced in the Northern Apennine.

The Middle and Upper Pleistocene uplift of the Northern Apennine although ubiquitous, was highly differentiated following the structural setting. The hook shaped Lima River course (Fig. 2) was since long (Camerini, 1942) interpreted as the output of a

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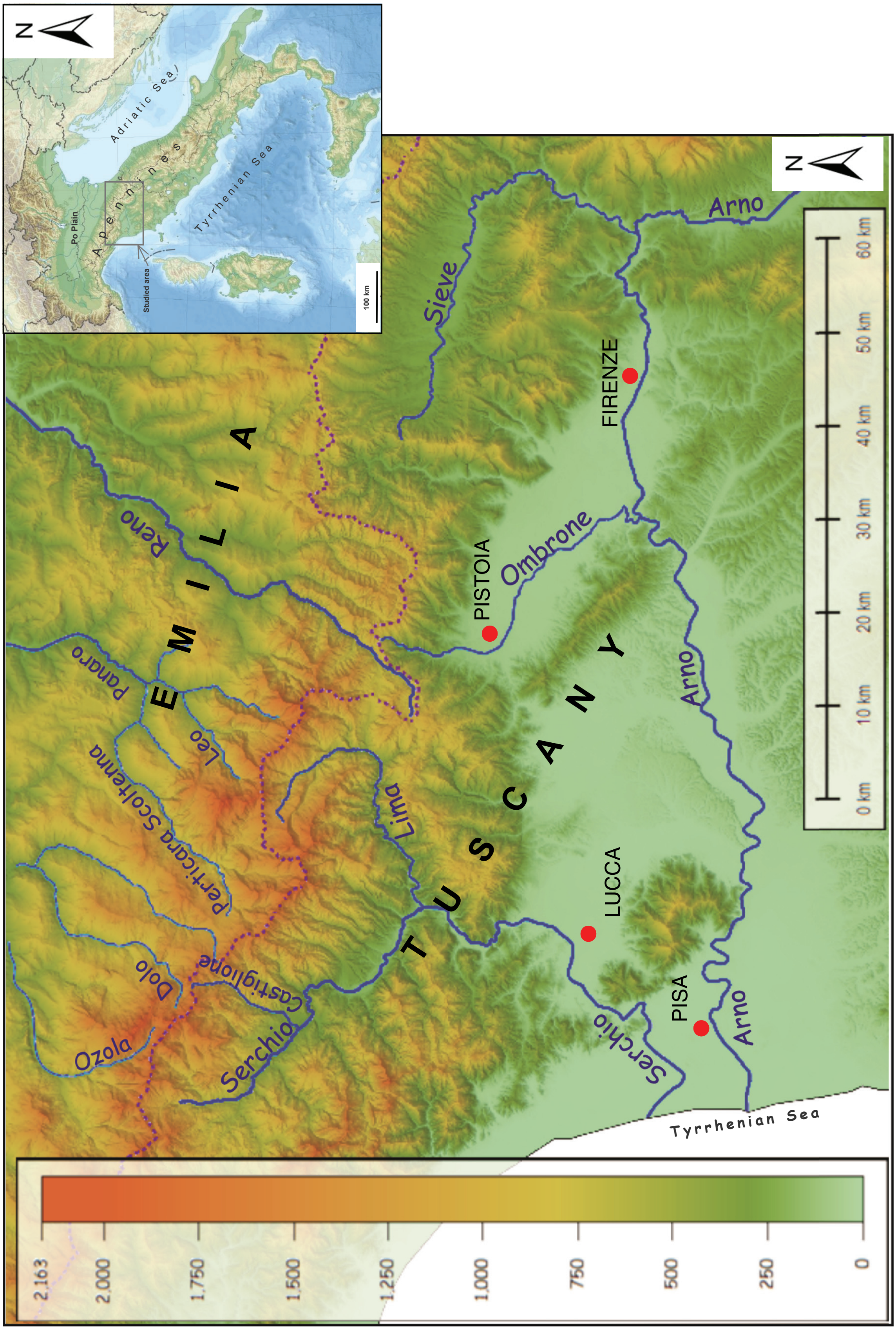

Fig. 1 Investigated areas. River elbows are a common feature of the Tuscan drainage. DTM 10x10 m. http://www.regione.toscana.it/web/geoblog/-/open-geodata.

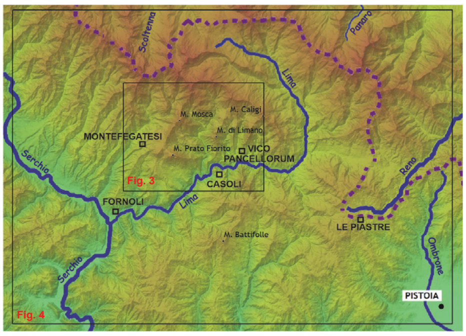

Fig. 2 - The hook shaped and geographic setting of Lima River. Figs. 3 and 4 ubcation is also shown.

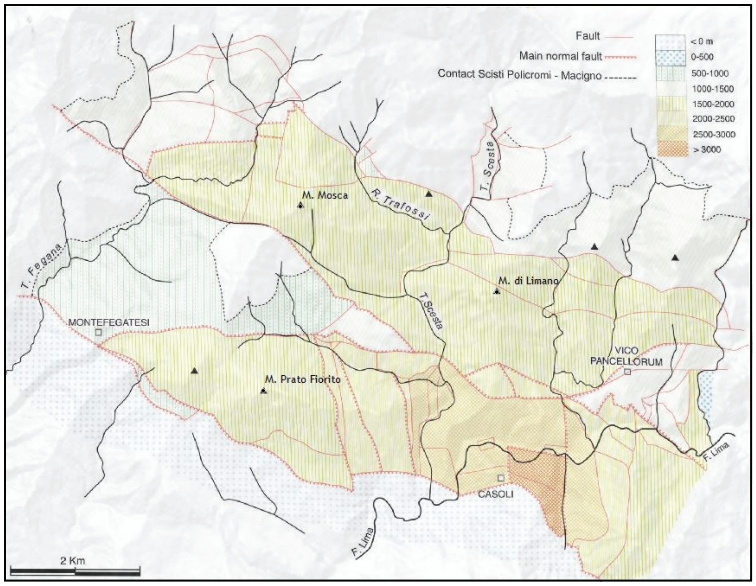

Fig. 3 - Middle-Upper Pleistocene uplift in the Lima River basin area. From Bartolini & Fazzuoli, 1998.

capture. The capture kinematics were, however, only recently investigated (Bartolini & Fazzuoli, 1998): the detailed appraisal of the Quaternary kinematics of the Val di Lima structural high showed that the Lima River, as well as several of his tributaries, are now located within the most uplifted fault blocks (Fig. 3). Due to the uplift, a former along trend drainage (Fig. 4) has been partially redirected at right angles.

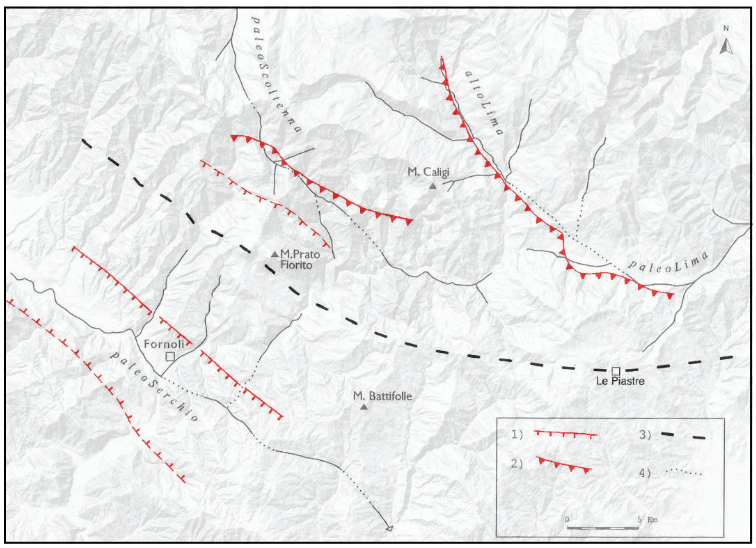

Fig. 4 - The supposed former along strike streams of the Lima and Serchio region, strongly controlled by the structural setting. From Bartolini & Fazzuoli, 1998.
1: normal fault; 2: thrust; 3: former Tyrrhenian - Adriatic divide; 4: former fluvial branches, presently wiped out.

3. HYDROGRAPHIC EVOLUTION OF THREE AREAS IN THE NORTHERN APENNINE DRIVEN BY THE GEOLOGICAL FRAME

3.1. Reggio Emilia – Modena Apennine

3.1.1. 1 Passo delle Radici

The drainage of this area, fringing the Apennine watershed, is characterized by the alignment of four river segments belonging to Ozola, Dolo, Dragone and Perticara (Figs. 5, 6 and 7).

These segments, which make up river heads, are NW-SE oriented. After flowing a few kilometres in this direction, the four streams become deflected towards the NE (i.e. to Pianura Padana and the Adriatic Sea).

Southwest of the alignment made up by the four mentioned streams, the main water courses flow to SE towards the Serchio Basin. The headwaters of one of these, the Castiglione River, created a bulge in the watershed, due to its valley extension, which divides the Ozola and Dolo area from the Dragone and Perticara one (Fig. 5). The valley extension of the Castiglione upper river basin was favoured by the ongoing subsidence of the Serchio structural basin as well as to the shaly Monte Modino Unit widely outcropping in the upstream Castiglione river basin. The regressive erosion prompted by the sinking Serchio basin is evidenced by the asymmetry of the Apenninic divide in this sector (Fig. 7).

These four segments are located on shale-marly formations outcropping in front of a thrust (Fig. 6a, b) made up of olistosthromes, ramp muds, draping muds, chaotic substratum of fore-trench flysch. As a matter of fact, during a late compressive phase of the Apennine chain build up (late Miocene-Pliocene) they acted as a decollement horizon in the thrust of Macigno sandstones over Monte Modino sandstones. Due to the regional

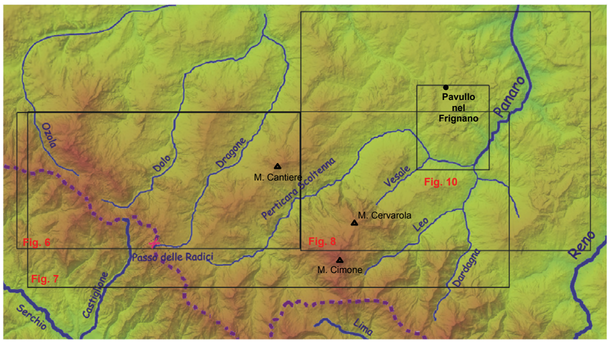

Fig. 5 - Reggio Emilia-Modena and Northern Tuscany Apennine: Ozola, Dolo, Dragone, Perticara rivers then Scoltenna and Castiglione rivers upper courses in the Passo delle Radici area; headward enlargment of the Castiglione River resulting in a wateshed bulge; Scoltenna, Leo and Panaro rivers drainage pattern in the Frignano area. Figs. 6, 7, 8 and 10 ubcation is also shown.

uplift, these formations became stripped and are presently undergoing rapid erosion.

The evolution of the hydrography in this area is here outlined.

Macigno and Mt. Modino Formations as well as the shale-marly weakness belt (Fig. 6 b) became exhumed during Middle Pleistocene. Since the four river segments flow over such lithologies, their onset is coeval with their exhumation. The Perticara headwaters stretched out until reaching the shale-marly weakness belt (Figs. 6 a,b), there disrupting an along-strike river system approximately located along the present Apenninic divide (Fig. 5). The upheaval of the chain triggered also the captures by the Dolo and the Dragone streams (Fig. 7).

3.1.2. Frignano

The south-west side of the area is characterized by thrusts (Monte Modino and Cervarola Units) while the middle and the northern sectors were fragmented into blocks by fault systems in a late orogenic phase. The geometric vertical location of lithologies featuring different erodibilities in the uplifted or in lowered blocks conditioned the evolution of the drainage network.

In general, the hydrography of the area features an anti-Apenninic orientation, as a consequence of the ongoing uplift. A particular feature of the middle Modena Apennine is however the striking deflection of the Scoltenna River (Fig. 5). Its upper course flows towards NE, therefore perpendicular to the Apenninic divide, pushing his river head far beyond the alignement of the former Apenninic divide, presently marked by Mt. Cimone, the highest peak in this sector of the chain (Fig. 5). The remarkable erosive energy of this river derives from the largely impermeable lithology of the valley bottom in its lower course (see ahead). Upslope from the confluence into the Panaro River, the Scoltenna River is instead oriented NW-SE and aligned with the Dardagnola River course. They both lay over a large outcrop of clay and shale dominated Ligurids (Unità Leo), which foster surface runoff (Figs. 8, 9).

The 1:100.000 Geological Map of Italy (Fig. 10) shows that a thin, elongated lacustrine and alluvial body overlies the Bismantova Group (Formazione di Pantano and Formazione di Cigarello, Bettelli et al., 2002) slab in the Frignano area. The wide valley lying today on top of the Epiligurian slab (Fig. 11) is a late relict of a former valley bottom of the Scoltenna River, subsequently captured by the very active Leo – Panaro system, mostly located

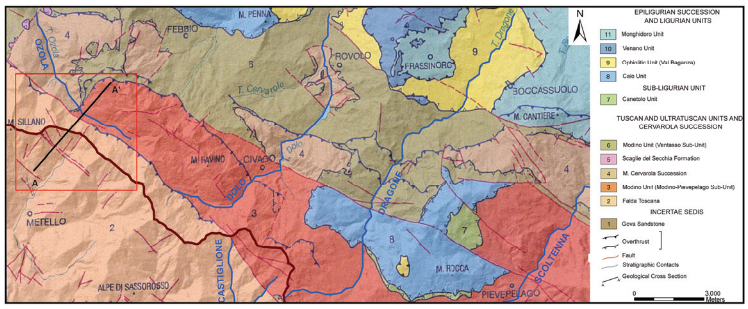

Fig. 6a - Ozola, Dolo, Dragone and Perticara rivers and their geological setting. From Carta strutturale 1:200.000 Sheet 236 "Pavullo nel Frignano".

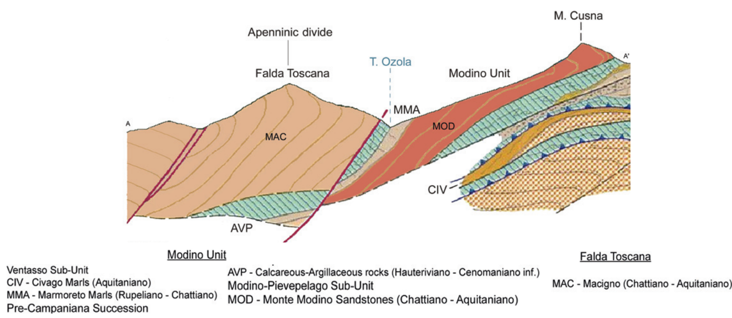

Fig. 6b - Geological section across Ozola River (location in Fig. 6a). From Carta geologica 1:50.000 Sheet 236 "Pavullo nel Frignano".

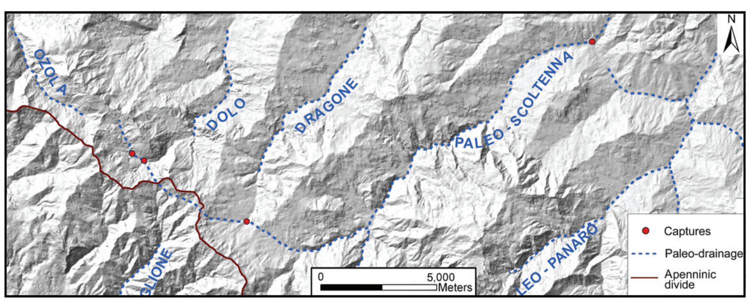

Fig. 7 - Western sector: captures by the Dolo and the Dragone rivers. In the eastern sector of the DTM, a left tributary of the Leo - Panaro rivers, flowing over the shaly "Argille a Palombini" Auctt. stretched out its headwaters to NW and eventually captured the paleo-Scoltenna River.

on the shaly dominated “Argille a Palombini” Auctt. belonging to the Ligurian Units. The latter appear separated form the Epiligurian slab in section A – A’ (Fig. 9) by a subvertical tectonic contact. The Epiligurian units are instead plainly overlying the Ligurian Units on the southeastern margin of the Frignano area (Fig. 12).

During early Middle Pleistocene times the Epiligurids widely outcropped in this area with their uppermost relatively impermeable units (Formazione di Cigarello) supporting a mostly NE trending drainage. As soon as the Epligurids became stripped by erosion, the exposure of the impermeable and incompetent Ligurids Units, and namely of the shaly “Argille a Palombini”, promoted a deep rearrangement of the drainage pattern (Fig. 13). In the mean time, the Frignano area became an upland where karstic processes (Fig. 14) slowly obliterated the former fluvial features. Panizza (1968) and Panizza & Mantovani (1974) correctly read the Frignano central smooth depression as a polje, and realized that the peculiar lithological setting of the Frignano slab had a deep impact on the hydrographic pattern evolution. As a matter of fact, the Scoltenna R. after fringing to the east the Frignano upland (which is presently disrupted by the regressive erosion of Lerna Stream, a left hand tributary of Panaro River, see Figs. 12, 13), farther ahead in its course bends again to the west thus bypassing the Epiligurid Zocca upland (Fig. 9a).

The present day altitude drop between the Scoltenna River at the piracy elbow (Figs. 5, 8, 9, 10, 11, 13) and the southwestern edge of the Frignano plate overlooking the Scoltenna River valley is 300 m. The river capture - sensibly favoured by lithology - took place most likely in late Middle Pleistocene times within a rapidly uplifting mountain chain.

The rocks which mostly favoured the entrenching of the rivers are the sedimentary melanges of the Ligurids, the weakest and most impermeable of lithologies making up the Northern Apennine.

These events point out the relevant role of the lithological control presently exerted on the chain morphology.

The role of lithology in driving the morphological features of the Apenninic chain has been recently regarded as marginal or irrelevant by Salustri Galli et al., (2002) who state that “the lithologies

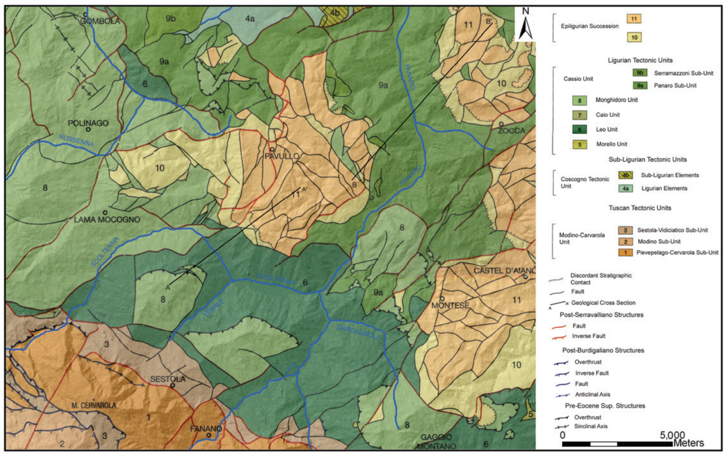

Fig. 8 - Geological setting of Panaro and Scoltenna rivers. From Schema Tettonico, Sheet 236 ”Pavullo nel Frignano”, modified.

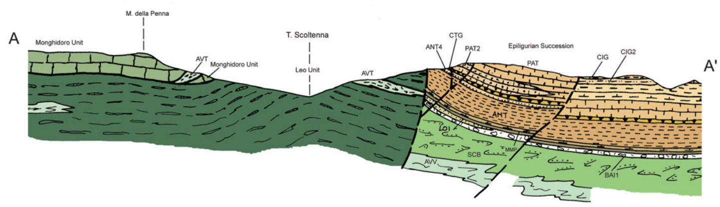

Fig. 9 - Cross section of the Scoltenna River (location in Fig. 8). From Schema Tettonico, Sheet 236 ”Pavullo nel Frignano”, modified.

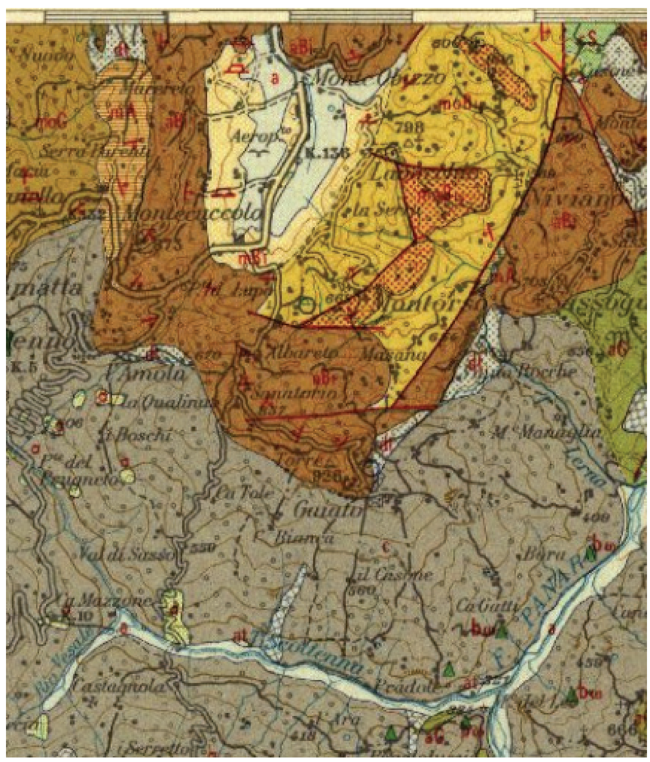

Fig. 10 - Geology of the upland Frignano area and setting of Scoltenna River. From Geological Map of Italy 1:100.000, Sheet 82, Modena.

Fig. 11 - Air view of the Frignano axial depression hosting Pavullo airport.

Fig. 12 - Air view of the geologic contact (red line) between the Arenarie di Bismantova and the underlying shaly Ligurian Units. The Lerna Stream headward erosion (see text) is evidenced.

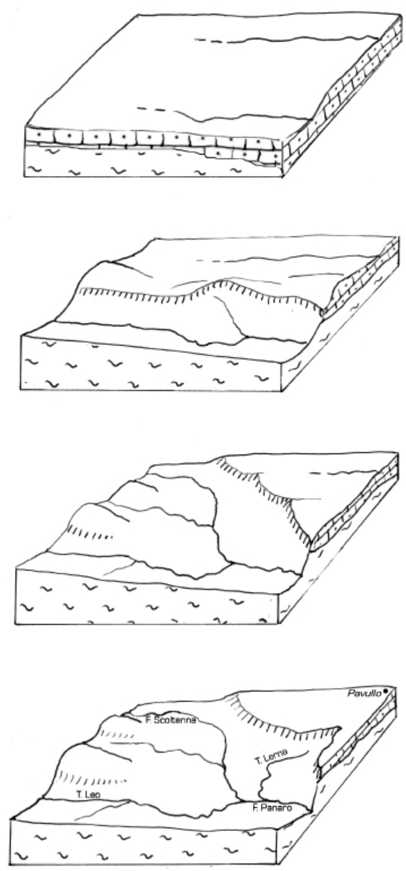

Fig. 13 - Morphologic evolution of the Frignano area in Middle to Late Pleistocene times (courtesy by Cristina Andreani). During the Middle-Late Pleistocene regional upheaval, the rivers draining towards NE, which were located in the areas where the Ligurian Units lay closer to the topographic surface, were the first ones who could reach, in their downward erosive path, the melanges horizons; they therefore outweighed, since then, the adjacent water courses located over less actively uplifting areas. The Panaro-Leo drainage was more favoured, by this configuration, than the paleo-Scoltenna one. While the paleo-Scoltenna River lower course was still flowing on the competent and permeable Epiligurids (calcarenites and sandstones) the Panaro River down-cutting reached the Ligurids melanges, which gave a further impulse to its down-cutting. Somewhere south of Pavullo a left tributary of Panaro River stretched out its headwater to NW and eventually captured the paleo-Scoltenna River (see Fig. 7). The morphology around the new course of the Scoltenna River, which became entirely set on the sedimentary melanges, rejuvenated.

Fig. 14 - Karstic processes at Ponte del Diavolo, 6 km WSW from Pavullo.

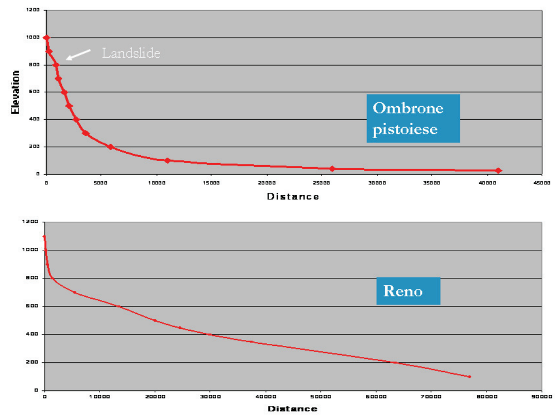

Fig. 16 - Along profile of the Reno and the Ombrone pistoiese Rivers.

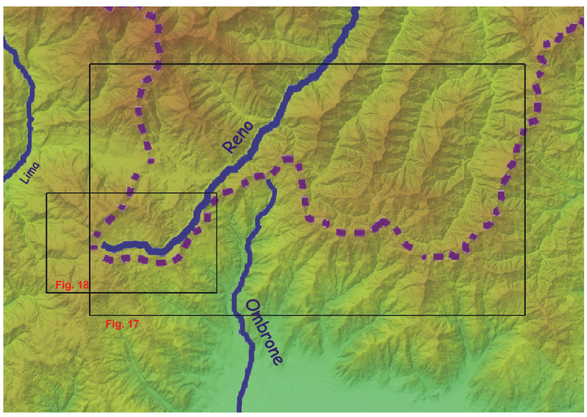

Fig. 15 - Ombrone Pistoiese and Reno rivers upper reaches. Figs. 16 and 17 ubcation is also shown.

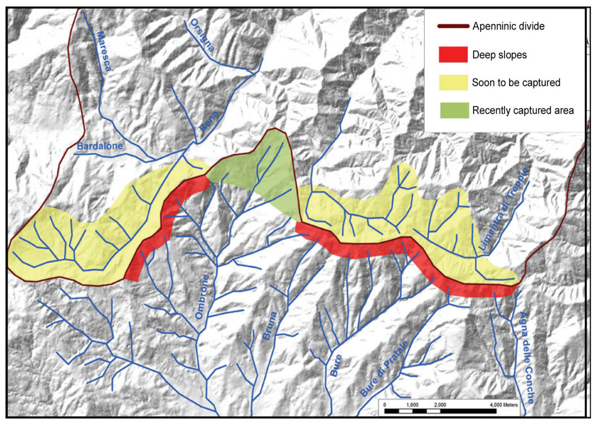

Fig. 17 - Drainage pattern of the Ombrone River upper reach area.

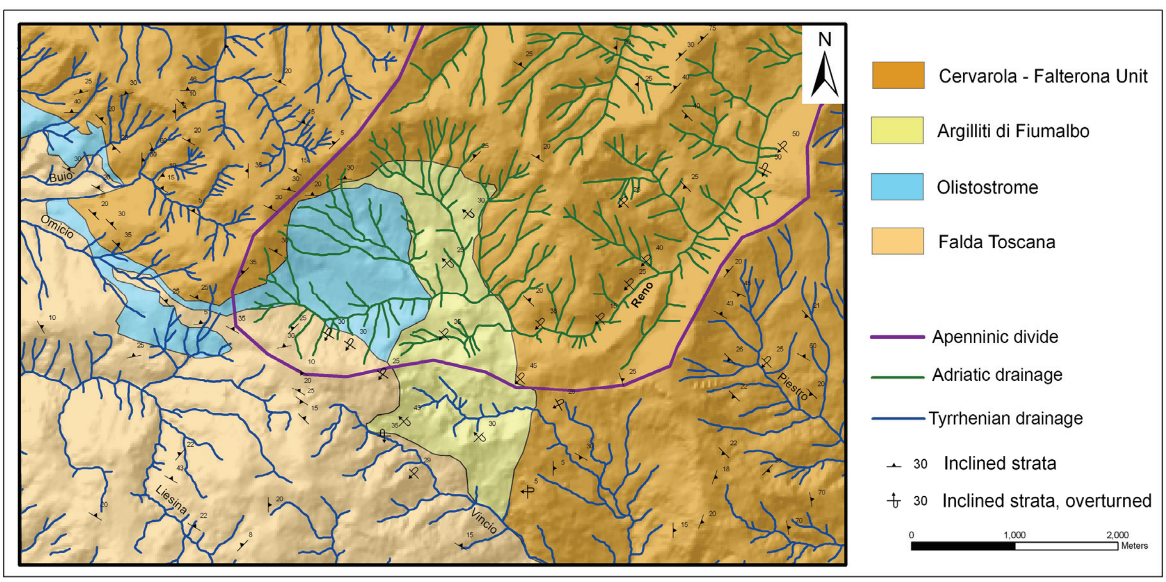

Fig. 18 - Drainage pattern and geological sckech map of the Reno River upper reach area, modified after Dallan et al., (1981).

of the outcropping belt are fairly homogeneous". According to these authors, "the highest peaks are generated by tectonics, minus erosion". This statement is criticized by Bartolini (2012).

3. 2. Ombrone Pistoiese vs, Reno River

The baselevel of the Ombrone River, a right hand tributary of the Arno River (Fig.1), is located on a plain - to which Florence also belongs - i.e. on the subsiding floor of an intermountain basin. Due the proximity of the plain to the Tyrrhenian-Adriatic watershed, the river profile is quite steep, mostly if compared with the Reno River (Fig. 16) which has its baselevel on the quite distant Adriatic sea. A flysch formation of homogeneous lithology (Cervarola Fm.) extensively outcrops in this particular sector of the watershed area, hampering any possible control of the lithology on the erosive processes occurring on either side. The asymmetry of the watershed originates, now as well as it did in the in the recent past, a wealth of minor captures (Fig. 17). A few of them affected small streams aligned along strike which are remnants of a former drainage, as it has been the case of the upper Dolo and Ozola reaches. As a result of the captures, the Reno River lacks right end tributaries.

To the NW, instead, the upper Reno River reaches are actively eroding upstream, thus pushing in this sector the watershed to the west and reversing the trend described above (Fig. 18). The Reno uppermost river profile appears accordingly fairly steep and incongruous with the following profile sector (see Fig. 16). Here the cause is lithologic, as Fig. 18 reveals: the prevailing argillitic lithology of two units interposed between Falda Toscana and Cervarola - Falterona Units drove the captures and thence the southwesterly bulge in the watershed.

4. CONCLUSIVE REMARKS

In the fringe of the present Northern Apenninic divide a few river segments trend along strike although in the progress of being beheaded by streams flowing at right angle. The occurrence of such segments, until present unaffected by the orographic consequence of the ongoing uplift, points both to its recent age (Bartolini 2003, references therein) and to its fast pace (Carminati et al., 1999; Zattin et al., 2002; Balestrieri et al., 2003).

REFERENCES

Argnani A., Bernini M., Didio G.M., Papani G., Rogledi S. (1997) - Registrazione stratigrafica di eventi tettonici a scala crostale nei depositi Quaternari del Nordappennino. Abstracts Convegno Tettonica Quaternaria del Territorio Italiano: Conoscenze, Problemi, Applicazioni. Parma, February 25-27.

Balestrieri M.L., Bernet M., Brandon M.T., Picotti V., Reiners P., Zattin M. (2003) - Pliocene and Pleistocene exhumation and uplift of two key areas of the Northern Apennines. Quaternary International, 101-102, 67-73.

Bartolini C. (2003) - When did the Northern Apennine become a mountain chain?. Quaternary International, 101-102, 75-80.

Bartolini C. (2012) - Is the morphogenetic role of tectonics overemphasized at times?. Boll. Geofisica Teorica e Applicata, 53, 459-470.

Bartolini C., D'Agostino N., Dramis F. (2003) - Topography, exhumation, and drainage network evolution of the Apennines. Episodes, 26 (3), 212-216.

Bartolini C., Fazzuoli M. (1998) - Ruolo della tettonica e della morfoselezione nell'evoluzione dell'idrografia nel bacino del Fiume Serchio. Il Quaternario, 10, 417-426.

Bartolini C., Forzoni A. (2009) - Northwesterly trending river segments of the northern Apennine within an uplifting chain. Proc. Congresso Fist Geoitalia, Rimini, Italy, Settembre 9-11, abstracts.

Bartolini C., Pranzini G. (1981) - Plio-Quaternary evolution of the Arno basin drainage. Zeitschrift für Geomorphologie N.F., Supplementband 40, 77-91.

Bettelli G., Panini F., Pizziolo M. (2002) - Note illustrative della Carta Geologica d'Italia, Foglio 236, Pavullo. SELCA, Firenze, pp. 168.

Bishop P. (1995) - Drainage rearrangement by river capture, beheading and diversion. Progress in Physical Geography, 19, 449-473.

Camerini C. (1942) - Probabile fenomeno di cattura dell'Alto Reno nell'Appennino Pistoiese. Rivista Geografica Italiana, 49, 126-137.

Carminati E., Giunchi C., Argnani A., Sabadini R., Fernandez M. (1999) - Plio-Quaternary vertical motion of the Northern Apennines: insights from dynamic modelling. Tectonics, 18, 703-718.

D'Agostino N., Jackson J., Dramis F., Funiciello R. (2001) - Interactions between mantle upwelling, drainage evolution and active normal faulting: an example from the central Apennines (Italy). Geophysical Journal International, 147, 475-497.

Dallan L., Puccinelli A., Verani M. (1981) - Geologia dell'Appennino Settentrionale tra l'alta Val di Lima e Pistoia. Bollettino della Società Geologica Italiana, 100, 567-586.

Mazzanti R., Trevisan L. (1978) - Evoluzione della rete idrografica nell'Appennino centro-settentrionale. Geografia Fisica e Dinamica Quaternaria, 1, 55-62.

Panizza M. (1968) - L'evoluzione geomorfologia e idrografica del territorio di Pavullo nel Frignano. S.T.E.M. Mucchi, Modena, 14 pp.

Panizza M., Mantovani F., (1974) - Geomorfologia del territorio di Pavullo nel Frignano (Appennino Modenese). Atti Società Naturalisti e Matematici di Modena, 105, 85-117.

Salustri Galli C., Torrini A., Doglioni C., Scrocca D. (2002) - Divide and highest mountains vs subduction in the Apennines. Studi Geologici Camerti, 1, 143-153.

Twidale C.R. (2004) - River patterns and their meaning. Earth-ScienceReviews, 67, 159-218.

Zattin M., Picotti V., Zuffa G.G. (2002) - Fission-track reconstruction of the front of the Northern Apennine thrust wedge and overlying Ligurian Unit. American Journal of Science, 302, 346-379.

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