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Published version:

DOI:10.1080/17445647.2015.1027481

M.Gabriella Forno, Stefania Lucchesi, Relicts of the Pleistocene Po Plain on the Western and Southern slopes of Turin Hill (NW Italy), Journal of maps, 2016, vol. 12, issue 2, 394-406, DOI:10.1080/17445647.2015.1027481

Relics of the Pleistocene Western Po Plain on the Southern Slope of Turin Hill (NW Italy)

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Abstract

A detailed geological survey of the Southern slope of the Turin Hill reveals a Pleistocene terraced fluvial succession consisting of flat surfaces separated by scarps with associated fluvial clayey-sandy and gravelly sediments. This succession is not linked to the present N-S hilly stream, but is instead due to a major Pleistocene W-E river. The collected regional data suggest an ancient trend of the Po River flowing across the Turin Hill, previous to his present trend to the north of the hill.

The Pleistocene terraced fluvial succession of the Western slope of the Turin Hill is also reported, based on a previous survey to permit a full reconstruction of the ancient rivers. The collected regional data and the mineralogical analysis show that this succession is related to an ancient tributary of the Po River (Dora Riparia River). Evidence suggests that the same river has also shaped the main watershed between the Southern and Western slopes, where some wide fluvial saddles are preserved.

The settings of different soils on the fluvial sediments and landforms indicate that the whole of the terraced successions correspond to a large range of time (Middle-Upper Pleistocene). Therefore, the reported geologic successions and the current morphology of the relief result from the deformation of the Pleistocene Po Plain and the Dora Riparia Plain before the Po River shifted to the north of the relief. The comparison of the chronological reference of the fluvial morphological features and sediments with their altitude suggest a remarkable uplift of the Turin Hill during the Quaternary.

1. Introduction and previous work

The remains of Pleistocene fluvial landforms and sediments on the slopes of the Turin Hill (the Western portion of the North-Apennines chain) have been observed and reported over the last few years. Specifically, the fluvial terraced successions on the Western, North-Western and Northern slopes have been widely mapped and described (Forno et al., 2002; Forno and Lucchesi, 2005; Barbero et al., 2007) and the heavy mineral analysis of the fluvial sediments, on the Western and North-Western slopes have demonstrated their link with ancient trends of the Dora Riparia River and the Stura di Lanzo River (Vezzoli et al., 2009). In detail, the Dora Riparia River changed direction in overtime: its southward trend in the Middle Pleistocene transitioned to a northward trend in the Upper Pleistocene (see sketch 1 in the main map). The distribution of these successions and their relationship to an ancient hydrographic network with a very different trend than the present one also suggest a different relief morphology that was lower than the current height. These features, therefore, testify to a remarkable Quaternary tectonic deformation in this area (Boano et al., 2004). A subsequent reconstruction recent deformation of the Turin Hill derived from studies on the migration of tributary streams involved in a gradual adjustment to the tectonic uplift of the area (Forno and Boano, 2006).

The fluvial sequence on the Southern slope of the Turin Hill, however, has been only roughly mapped and briefly described in the geological map *157 "Trino"* and *156 "Torino Est"* of the Geological Map of Italy at scale 1:50,000 (Dela Pierre et al., 2003a; Dela Pierre et al., 2003b; Forno et al., 2008; Festa et al., 2009a; Festa et al., 2009b) and was later reported in a field trip guidebook on the Turin Hill (Carraro et al., 2005). The only detailed research regarding the Pleistocene fluvial succession on this slope focused on the petrographic composition of the locally outcropping gravelly deposits. In detail, the composition of the gravels allowed the identification of the catchment basin of the Po River as a tributary draining the Lanzo Ultramaphic Massif (Sangone, Dora Riparia or Stura di Lanzo rivers). The provenance from this basin is evidenced by the overall composition and by some peridotite clasts of the Lanzo Ultramaphic Massif (Compagnoni and Forno, 1992).

Because a detailed mapping of the Southern slope of the Turin Hill is missing, the goal of the present study is to complete the cartography of the fluvial succession in the entire hilly area. This contribution is necessary for a full reconstruction of the Quaternary evolution of the Turin Hill and, more generally, the analysis of the tectonic activity of the Apennine edge in North-Western Italy.

2. Morphological and geological setting

The Turin Hill is a SW-NE elongated ridge rising to an altitude of 715 m a.s.l., located in the central side of the Po Plain. It is highly perched on the plain (approximately 500 m), consisting of the Turin Po Plain to the north and to the west (with an elevation of 190-220 m a.s.l.) and the Poirino Plateau to the south (with an elevation of 240-280 m a.s.l.).

The morphology of the relief is remarkably asymmetric as evidenced by the presence of a relatively steep (10-15%) W-NW slope and a much less inclined (5-10%) Southern slope (Fig. 1). In detail, the lower side of the Southern slope (between 240 and 350 m a.s.l.) shows a very flat morphology, preserving most of the trend of the original plain (see sketch 2 in the main map). The current hydrographic networks developed on the two slopes, are variously entrenched; they mainly flow towards the NW in the Western and North-Western slope and, on the contrary, towards the SSE in the Southern slope.

The Turin Hill consists of a marine succession between the upper Eocene and the Pliocene in age (Bortolami et al., 1969) (Fig. 2). This Tertiary sequence lies on the Alpine metamorphic bedrock (Gelati and Gnaccolini, 1988; Castellarin, 1994) and, according to the most recent studies , on a Sudalpine metamorphic bedrock (Mosca, 2006). On the top of the marine sediments, a discontinuous cover of incoherent silty sediments is well described and related to the Upper Pleistocene aeolian loess cover widespread all over the Po Plain (Bortolami et al., 1969; Cremaschi, 1990; Forno, 1990). In contrast, the presence of fluvial sedimentary bodies interposed between the Tertiary marine succession and the Upper Pleistocene loess cover is mostly unknown, which the current research aims to address.

The whole sedimentary succession of the Turin Hill is variously deformed, forming an asymmetrical anticline with a SW-NE oriented, NW verging axis. This structure overthrusts onto the Po Plain foredeep towards the NW along the Padan Frontal Thrust currently buried by the Quaternary fluvial sediments of the Po Plain (Castellarin, 1994; Festa et al., 2009a) (Fig. 2). The succession is also bound to the East by the “Rio Freddo Deformation Zone” a left transpressive shear zone dividing the Turin Hill from Monferrato Reliefs (Piana and Polino, 1994) (Fig. 2).

The described asymmetrical morphology of the relief is essentially due to both the asymmetrical anticline deformation of the Turin Hill and the buried thrusts belt that bounds the North-Western slope of the hill towards the Po Plain. The implication in the deformation of the entire sedimentary succession of the Turin Hill comprising the Pleistocene sediments suggests that tectonic activity affected the succession almost between the late Neogene and the late Quaternary (Boano et al., 2004). The recent tectonic activity observed in the study area is in accordance with the strong uplift observed at the North-Apennines foothills along the Padan Frontal Thrust (Bertotti et al., 1997; Benedetti, 2003; Benedetti et al., 2003; Burrato et al., 2003; Mutti et al., 1995).

3. Methods

A detailed geological and geomorphological survey on the field and a traditional and digital analysis of aerial photos were carried out to map the Quaternary fluvial landforms and sediments. The distribution of the fluvial succession and landforms was mapped on the Carta Tecnica della Regione Piemonte of the Regional Agency for the Protection of the Environment (A.R.P.A. Piemonte), first at a scale of 1:10,000, and then simplified at 1:20,000 scale in the final document.

Into the Quaternary fluvial succession different units have been distinguished on the basis of allostratigraphic, morphostratigraphic and pedostratigraphic criteria. In detail, the different units were defined according to the features of the terraces (lateral continuity, elevation, morphology) and of the fluvial sediments (sedimentary facies, degree of soils development). A detailed description of the different configuration of the fluvial terraced surfaces and of the criteria used for their morphological analysis are reported in the previous research about the Quaternary succession of the Turin Hill (Fig. 7 in Forno and Lucchesi, 2005).

The main difficulties regarding the mapping of the fluvial sediments were connected with the lack of wide outcrops, the large distribution of the aeolian loess and of the colluvial deposits, both covering the fluvial succession. In addition, during the field surveys some local manmade modifications of the original morphology, related to the recent urban expansion, were detected. As previously indicated for the NW slope (Boano et al., 2004), these modifications have mostly enhanced the natural flat morphology of some terraced surfaces.

4. The geological map

A detailed geologic survey of the Quaternary succession of the Southern slope of the Turin Hill (extending approximately 70 km^2) has been performed and depicted on the geological map (see the main map). The Quaternary succession of the Western slope of the hill (concerned by a previous survey, Forno and Lucchesi, 2005) has also been reported to allow a correlation between the fluvial successions of the two areas and a full reconstruction of the ancient rivers. The fluvial landforms (terraced surfaces and the saddles) and the related fluvial sediments have been mapped in the final document at a 1:20,000 scale. The fluvial remains (landforms and sediments) with different altitude distribution and different soils have been distinguished in units of various age, presented in different strong colours. Their information regarding the presence or absence of deposits and the occurrence of soils has been reported with different symbols (colours for sediments, horizontal stripes for surfaces without sediments and vertical stripes for surfaces without sediments but with soils). A reconstruction of the possible original distribution of the fluvial terraced surfaces associated with the different units, prior to the current cutting by the tributary streams has also been made and mapped using different pale colours.

The terraced surfaces have been numbered starting from the more recent units (from 5 to 16), as reported for the Western-Northwestern slope (Forno and Lucchesi, 2005). The lower units (from 1 to 4) are not distributed on the hilly slope but are preserved in the Poirino Plateau, located immediately to the south of the study area. The topographic map (1:10,000 scale) of the Regional Agency for the Protection of the Environment (A.R.P.A. Piemonte, edition 1991-2005) had been used as a topographic support and it is the most detailed available map of the area.

5. The fluvial succession

The Southern slope, although shaped in the Tertiary marine sediments, shows a diffuse cover of Quaternary sediments, which are not yet mapped in detail, along with associated typical landforms. This slope shows numerous secondary ridges stretched in the approximately NNW-SSE direction, due to the incision of the present hilly valleys, which also have a NNW-SSE trend. From west to east the low elongated ridges of Moncalieri, Villa Fossati, Villa Maggi, Madonna del Rocciamelone, Cascina Proglio, Revigliasco, Sauglio, Pecetto, Cascina Albera, Tetti Rosero, San Felice, Tetti Finetta, Villa Luigina and Chieri are recognized (Fig. 3). The summits of these secondary ridges have similar altitude profile with typical morphologies. They have an overall slope toward the south (5-10%) and they show many very slightly inclined sectors of various sizes (between about 100 m^2 to 500000 m^2), separated by narrow steep sectors and wide counter-slope depressions (see sketch 2 in the main map). The morphology of these summits, therefore, preserves a series of flat surfaces (Fig. 4), scarps and counter-slope depressions (as locally observed for the Unit 14 and the Unit 11 in the main map).

The individual flat sectors have a NNW-SSE elongation; in contrast joining together the flat sectors preserved on the different ridges at the same range of altitudes and with the same pedological and morphological features, we obtained numerous strips elongated in the W-E direction and separated by narrow scarps. These strips (mapped with different pale colours in the main map) represent, then, the relicts of the wide ancient flat surfaces.

The described evidence is also present on the main watershed between the Southern and the Northwest-Western slopes, partly corresponding to the Moncalieri ridge (Fig. 3). It preserves some wide depressions (Fig. 5), which are particularly remarkable for their high location. The depressions form wide saddles visible from great distances resulting in the typical profile of the hill (see Fig. 9).

A set of elements allows the interpretation of these landforms as fluvial terraced surfaces:

a. the flat morphology separated by scarps, typical of the fluvial terraced surfaces;

b. the local preservation of arched depressions corresponding to remains of meanders;

c. the presence of clayey-silty or gravel sediments, likely deposed on the bedrock by a river.

The preservation of the ancient fluvial morphology on only the summit of the secondary ridges, and not on the overall slope, is connected to their subsequent erosion by the present hilly streams.

The distribution of these succession is relatively homogeneous considering that the different NNW-SSE elongated ridges preserve approximately the same number of terraced surfaces (up to 12 units between Unit 16 and Unit 5). Their morphology, with the top weakly inclined towards the SSE, along with the presence of sediments that appear progressively less weathered from north to south, suggest that these surfaces form a succession of stratigraphic units that are progressively more recent towards the plain (to the SSE). In detail, most of the described terraced surfaces lie on the summits of the main ridges, forming a degrading terraced succession towards the plain. Locally some surfaces are entrenched in the slope, preserved within counterslope depressions and located around some isolate reliefs that emerge from the fluvial succession.

Although numerous small terraced surfaces are also visible entrenched in the current valleys, only the terraces preserved on the summit of the NNW-SSE elongated ridges are mapped because they are the only ones connected to the ancient fluvial modelling. Therefore, they are significant for the reconstruction of the progressive trend of the main ancient rivers that shaped the Southern slope. In contrast, the terraced surfaces entrenched into the valley, which are obviously linked to the current hilly streams, are, instead, only significant for the reconstruction of the tributary network. The latter surfaces have been the subject of specific research regarding the gradual adjustment of the hydrographic network to the tectonic deformation of the area (Forno and Boano, 2006). Some NW-SE saddles are also reported on the elongated ridges and they can be considered to be connected to the subsequent incision by ancient tributaries (see the main map).

Taking into account all the flat surfaces preserved on the summit of the NNW-SSE ridges, a lot of fluvial terraces (corresponding to 12 units) are preserved in a 450-m altitude range (between 715 and 260 m a.s.l.). The terraced surfaces set in the upper sector of the slope predominantly preserve the original fluvial cover, but some of these are without sediments and are currently shaped in the Tertiary marine succession exclusively preserving soils with various degree of evolution. The local erosion of the fluvial sediments is evidence from a strong remodelling of the terraces. In contrast, the terraced surfaces set in the lower sector always preserve the fluvial sediments, which are between one and ten meters thick, indicating the prevailing conservation of the primary features. A reconstruction of the possible original distribution of the fluvial evidence, prior the current cutting by the tributary streams, has also been noted and mapped with different pale colours (see the main map).

For the different terrace morphologies and the diffusion of fluvial sediments, we can distinguish a relatively steeper upper range (from 715 to 360 m a.s.l.), in which a succession of small and discontinuous terrace relicts is recognisable (Units between 16 and 7) and a less inclined lower range (from 350 to 280 m) that preserves the relics of more wide and continuous terraces (Units between 6 and 5). The correlation of the various relicts of the same terrace is more uncertain in the upper sector as a consequence of the more intense remodeling; in contrast, the correlation in the lower range is very obvious. The more wide preserved terrace is located in the altitude range of approximately 350-280 m (Fig. 1), along the San Felice ridge (Unit 6). Finally, the lower terrace (Unit 5) can be correlated with the wide terraced surface of the Poirino Plateau.

The fluvial sediments forming the different terraces fill elongated depressions shaped in the Tertiary sediments (Fig. 6). They are mostly clayey-silty deposits without stratification or other sedimentary structures and show only a prismatic cracking (Fig. 7). They have a high clay content (about 50%), high silt content (about 40-45%) and a small sand content (about 5-10%).

Locally, gravelly sediments outcrop below the clay-silty sediments (Fig. 8), showing a clast support structure, with a scanty clayey-silty-sandy matrix. These sediments are formed by centimetric to decimentric clasts (between 5 to 30 cm) with low sphericities and high rounding; they are imbricated and showing a concave cross bedding. The prevalently elongated clasts consist of serpentinite (predominant), prasinite, gabbro and metagabbro (very abundant), eclogite (abundant), peridotite (poorly abundant), rodingite, metabasite s.l. and quartzite (scanty) (Compagnoni and Forno, 1992).

The sediments show different features at different altitude, due especially to differences in weathering. The higher terraces have sediments with very evolved soils, clay texture, very thick clay skins, red colour (Fig. 6) (2,5-5 YR Munsell Soil Color Charts) and a strong cementation by iron oxides. In contrast, the lower terraces show, instead, sediments characterised by slightly evolved soils with a prevailing silty-sandy texture, thin clay skins, yellowish-brown colour (7,5 YR Munsell Soil Color Charts) and a soft consistence (Fig. 7).

The fluvial sediments are covered by a continuous body of loess, with maximum thickness of 6 m. They are widespread in the Western sector of the slope, between the Moncalieri and the

Tetti Rosero ridges (Fig. 3). The presence of the loess preserves the underlying fluvial sediments, but often prevents their observation. Locally a more recent cover of aeolian sands, with maximum thickness of 8 m further hides the fluvial bodies. Both these sediments, which are been described in previous studies (Forno, 1990), are not represented in the geological map devoted to the mapping of the fluvial succession.

6. Discussion

The morphology of the Southern slope of the Turin Hill is characteristic for the presence of numerous flat surfaces preserved on the NNW-SSE secondary ridges. Joining together the flat sectors at the same range of altitudes and with the same pedological features, we obtain numerous strips, that are elongated in W-E direction, and correspond to a succession of terraced surfaces subdivided in different units. This succession is not linked to the present hilly streams, that are strongly entrenched in the valleys and flowing from the NNW to the SSE. The elongation of these strips is, instead, in agreement with an important river trending from west to east, namely, from the Alps toward the Po Plain (Fig. 2). In detail, the Southern slope preserves the terraced succession of an ancient trend of the Po River, flowing in the Southern slope of the Turin Hill towards the East (Fig. 9). This reconstruction is proven by the following evidence:

a) the composition of fluvial gravel preserved on the Southern slope, which is associated with the terraced succession, indicates a supply by the Po Basin with a tributary in the Lanzo Ultramafic Massif (Sangone, Dora Riparia or Stura di Lanzo rivers) (Compagnoni and Forno, 1991);

b) the reconstruction of the rivers in the central Piedmont, which are related to the Middle and Upper Pleistocene, suggests the absence of the Po River along the Northern edge of the Turin Hill, where the Po River is currently draining (Carraro et al., 1995).

In this time the Po River flowed through a plain sector that subsequently became the present Southern slope of the Turin Hill (see sketch 1 in the main map). It can be assumed that this river had a large tributary (Dora Riparia River draining from north to south), as evidenced by the terraced succession preserved on the Western slope (Fig. 9). In detail, the mineralogical data regarding these fluvial successions are in agreement with the shaping by the Dora Riparia River (Forno and Lucchesi, 2005; Vezzoli et al., 2009), to form a tributary of the ancient Po River on the Southern slope. The fluvial saddles preserved on the main watershed between the Southern and the Northwest-Western slopes are most likely also connected to ancient trends of the Dora Riparia River, indicating that this ancient river has repeatedly crossed the Turin Hill.

The very different degree of weathering of the sediments in the various strips indicates that the rivers developed over a large time scale likely comprised between the middle Pleistocene to the Upper Pleistocene (Arduino et al., 1984). The large number of terraced surfaces separated by narrow scarps is connected to the wide migration of the ancient river. The features of the fluvial succession, which prevalently degrades toward the south suggest a gradual southward shifting of the rivers between the watershed of the hill and the plain sector. The local presence of isolated relief, that emerge from the fluvial succession suggests a connection with slightly entrenched rivers with occasionally more articulated-W trends, before southward slide.

Most of the units are characterized by the presence of the fluvial sediments. Only some of the upper surfaces (Units 16 and 15) are modeled in the bedrock, indicating a subsequent strong erosion. The relatively continuous distribution of fluvial cover is connected to the subsequent erosional deepening.

Currently, the distribution of the ancient fluvial succession is discontinuous because it was cut by the torrential valleys connected to the present hilly streams. This cutting is consequent to the gradual tilting of the relief, which is significant in the watershed and more minor towards the plain. The local presence of NW-SE saddles on the elongated ridges shows that the fluvial terraced succession was affected by the erosion of some ancient tributaries of the ancient main meandering river (as observed in Unit 6 near C. Proglio).

7. Conclusions

The described fluvial terraced succession is the result of the uplift and deformation of the original Po Plain before the Po River displacement to the North of the Turin Hill. The chronological comparison of fluvial morphological features (in the order of some hundreds of thousands of years) and the altitude distribution of the fluvial sediments (in a range of 450 m, between 715 and 260 m a.s.l.) indicate a remarkable uplift of the Turin Hill.

The morphological and sedimentological evidence reported in this work suggest an important change in the morphology and structure of the Turin Hill, allowing the reconstruction of the Pleistocene plain landscape of this area. This evidence also suggests that Hill was barely visible at that time.

The present day southward feeble slope of the terraced surfaces is due to the progressive deformation (mainly uplift) of the Southern slope of the Turin Hill. The involvement of Pleistocene fluvial landforms in the deformation indicates a recent age for this evolution. The occurrence of similar strong uplift is indicated in other hilly sectors of the Apennine edge, along the Padan Frontal Thrust, where fluvial successions analogous to the one observed in the Turin Hill are reported (Bertotti et al., 1997; Benedetti, 2003; Benedetti et al., 2003; Burrato et al., 2003; Boano et al., 2004; Mutti et al., 1995).

8. Software

The map drawing and the database construction were carried out using ESRI ArcGIS™ 9.3.

The final graphical elaboration of the map was realized using Adobe® Illustrator® CS2.

Figure captions

Fig. 1 - Different morphologies of the Southern slope of the Turin Hill high sector (a, steeper) and the low sector (b, very flat), observed from the San Felice Church (Unit 6S).

Fig. 2 - Structural model of the Piedmont hilly sector; the dotted square represents the study area (modified from Dela Pierre et al., 2003).

Fig. 3 - The NNW-SSE ridges of the Southern slope of the Turin Hill.

Fig. 4 - Wide terraced surface (Unit 7S) of Cascina Moglia di Tana observed from Castelverde.

Fig. 5 - Saddle of Eremo in the watershed and abandoned valley (arrow) (Unit 13 W), shaped by an ancient Dora Riparia River, a tributary of the ancient Po River.

Fig. 6 - The Pleistocene fluvial silty sediments (brown) fill a wide depression shaped in the Tertiary marine sediments (grey) (Unit 7S, Pecetto Torinese 500 m S of Cascina Albera).

Fig. 7 - Silty sediments diffusely outcropping (Unit 8S near Cascina Long). They show a prismatic cracking and a reddish-brown colour.

Fig. 8 - Fluvial cross bedded gravel locally outcropping (Unit 6S, Trofarello near Sauglio).

Fig. 9 - In the low sector of the Southern slope of the Turin Hill some ancient trends of the Po River are preserved (white arrow). The numerous saddles on the main watershed are instead linked to the shaping by ancient trends of the Dora Riparia River (black arrows).

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