UNIVERSITÀ DEGLI STUDI DI TORINO

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Quaternary International, 171-172, 2007, doi:10.1016/j.quaint.2006.12.009

Pleistocene terraced fluvial succession, northern slope of Torino Hill

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Abstract

A Pleistocene terraced fluvial succession is found on the northern slope of the Torino Hill. This succession consists of many relics of flat surfaces, separated by scarps, often associated with sandy and silty deposits, perched from 30 to 400 m on the Po Plain.

Terraced surfaces at high levels are more deformed, dissected and mostly deprived of their original sediments; lower ones are less deformed, more continuous and preserved. In the western sector of the area, these surfaces form a degrading terraced succession towards the plain. In the eastern sector they form a terraced succession entrenched within the relief.

The succession is not linked either to the present hilly watercourses, or to the Po River now developed to the north of hilly relief, because during the Pleistocene the river flowed south of the Torino Hill. On the contrary, it is connected with modification by ancient North Piemonte Plain watercourses. This succession is the result of deformation of original plain sectors prior to the Po River shifting north of the relief. The comparison of chronological reference of fluvial morphological features and sediments with their altimetric distribution, suggests a mean uplift of the Torino Hill of about 1 mm/year: the present morphology connected with this evolution favours landslides phenomena.

1. Introduction

Previous studies about Quaternary evolution of the western and northwestern slopes of the Torino Hill revealed the presence of ancient fluvial landform and deposit relics, distributed at different elevations (Boano and Forno, 1997; Forno et al., 2002; Boano et al., 2004; Forno and Lucchesi, 2005). These relics, variously perched on the Po Plain, constitute a terraced succession. They are connected with Middle to Late Pleistocene North Piemonte Plain watercourses, with trends very different from the hilly hydrographic network now developed in the relief.

The extension of the geological survey to the northern slope, carried out in this study, identified various morphological relics of flat terraced surfaces, with elevations similar to those on adjacent slopes. Fluvial sediments are often associated with the flat surfaces: the degree of soil developed and the distribution of the surfaces in the hilly ridges suggest the presence of the terraced fluvial succession, a continuation of that described in the western and northwestern slopes. The results of the present study were synthesized in a geological map that allowed a detailed reconstruction of the distribution of the fluvial succession.

2. Geological setting

The Torino Hill rises to an altitude of about 700 m, 500 m above the Po Plain (200 m a.s.l.) (Fig. 1). This relief is developed in a Cenozoic terrigenous marine succession deposed in an episutural basin (according to Bally and Snelson, 1980): the deposition of the Eocene to Pliocene sedimentary succession is a consequence of syn-orogenetic demolition of the Alpine range during its evolution. In the Torino Hill, the Tertiary sediments, with thickness of 2-3 km, lie on an Alpine substratum and were eventually involved in the Apennine deformation.

Structurally, the Torino Hill corresponds to an asymmetric anticline verging to the NW, with SW-NE oriented axis. The buried Padan Thrust overthrust it onto the Po plain foredeep (Consiglio Nazionale delle Ricerche, 1990) The "Rio Freddo Deformation Belt", a left transpressive shear zone, separed the Torino Hill from the Monferrato Relieves (Piana and Polino, 1994) (Fig.1).

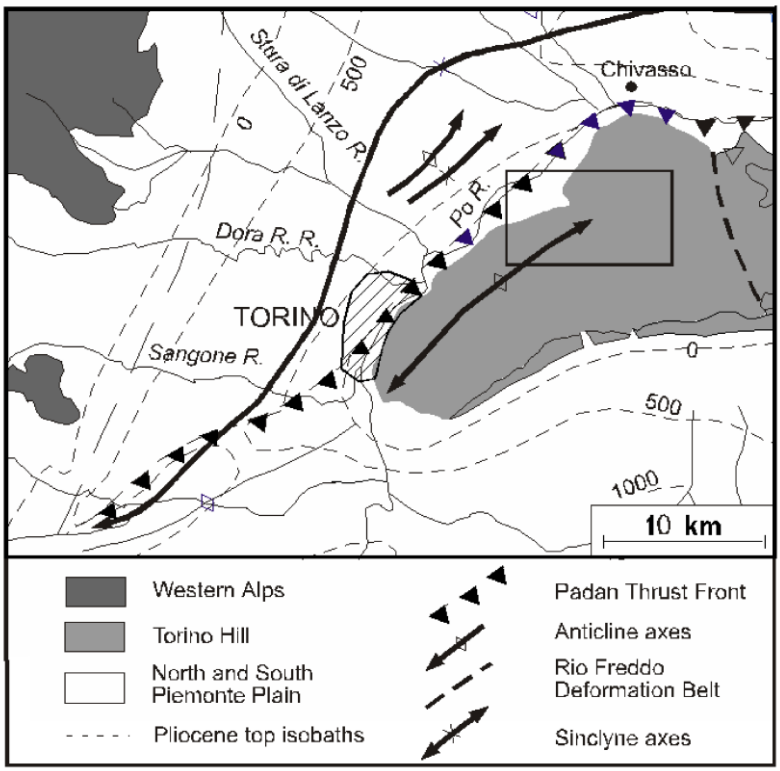

Fig. 1 - Structural sketch of the Torino Hill (Consiglio Nazionale delle Ricerche, 1990).

3. Previous studies

Carraro (1976) hypothesized the aggradation of the plain sector north of the Torino Hill (North Piemonte Plain) by Northern Piemonte Plain watercourses (Dora Riparia, Stura di Lanzo, Orco and Dora Baltea Rivers) and the absence of the Po River north of the relief during most of the Pleistocene. Subsequent detailed studies (Forno, 1980; 1982; Compagnoni and Forno, 1992) established the palaeo-Po River south of the Torino Hill. Several abandoned entrenched meanders on the southern slope of the relief and on the Poirino Plateau , with silty and lesser gravely deposits, are connected to this collector (Fig. 2). The current setting of the Po River, north of the Torino Hill, is very recent and linked to a fluvial diversion occurred at the end of the Late Pleistocene (Carraro et al., 1995).

Contemporary regional research has suggested the different geodynamic evolution of the hilly sector and the plain sector: a marked uplift during the Plio-Quaternary in the Torino Hill and a moderate lowering during the Early Pliocene as well as a weak uplift during the Middle-Late Pliocene and Quaternary in the plain sector (Carraro et al., 1987). The different recent evolution of these two areas caused the re-organization of the hydrographic net during the Quaternary (Carraro et al., 1994).

Subsequent research on the morphological and geological evolution of the western and northwestern slopes of the relief (Forno et al., 2002; Boano et al., 2004; Forno and Lucchesi, 2005) revealed the existence of a complex Pleistocene terraced fluvial succession. This evidence is distributed with different elevations and variously perched on the Po Plain. The mineralogical analyses of the related fluvial deposits suggested a genetic link with the Stura di Lanzo and Dora

Riparia Basins (Vezzoli et al., 2005). More specifically, the trends of the upper terraces indicated that during the first part of the Middle Pleistocene the watercourses whose relics are now involved in the western slope of the relief flowed to the south, whereas those involved in the northwestern slope flowed to the northeast. The trends of the lower terraces indicated that during the upper part of the Middle Pleistocene and during the Late Pleistocene the whole area was part of a single basin drained by a NE-flowing watercourse (Boano et al., 2004; Forno and Lucchesi, 2005).

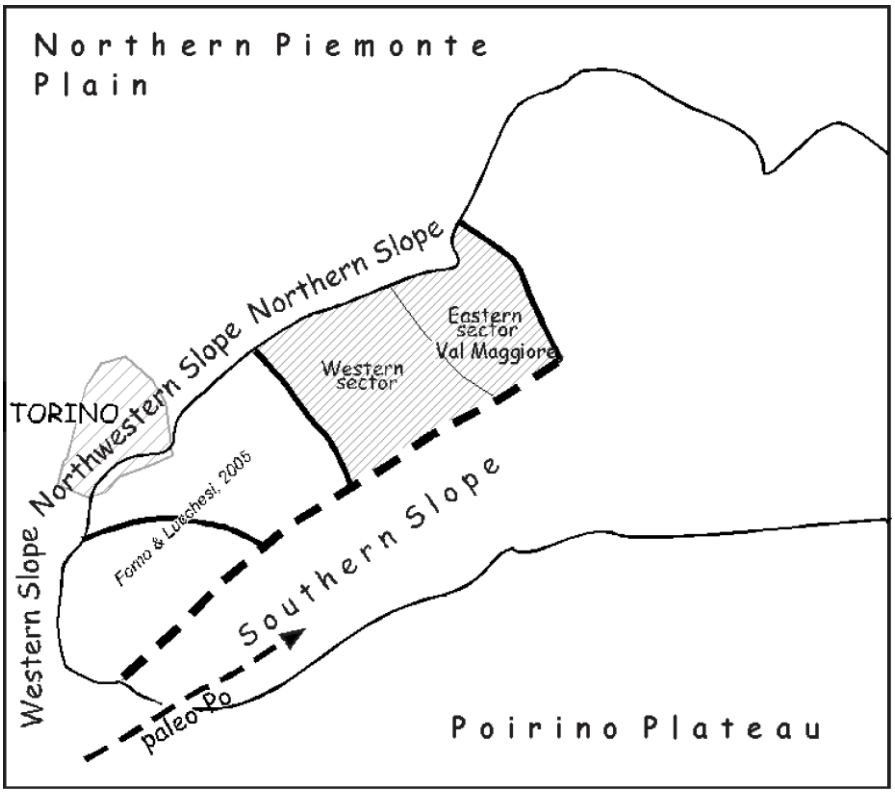

Fig. 2 - Sectors of the Torino Hill: the relics of palaeo-Po occur in the Southern slope.

4. Methods

A detailed geological survey and observation of aerial photos was carried out to map the Quaternary fluvial sediments and their morphological features (Barbero et al., 2005). The distribution of the fluvial succession was first mapped at a scale of 1:10,000 and then simplified in schematic form (see Fig. 3).

The Plio-Quaternary sequence was distinguished on the basis of allostratigraphic, morphostratigrafic and pedostratigraphic criteria. In detail the various units were identified on the base of the characters of the terraces (similar elevation, lateral continuity, analogous morphology) and of the fluvial sediments (analogous facies and degree of conservation, similar degree of soils development).

The difficulties encountered were connected with extensive building and local manmade modifications of the original hilly morphology. As previously indicated for the western and northwestern slopes (Boano et al., 2004), the modifications have not created new flat surfaces but caused a modest change in the extension of the natural terraced surfaces. Other difficulties were connected with the scarcity of outcrops and distribution of colluvial deposits that diffusely cover fluvial sediments.

5. The terraced fluvial succession

The aim of the work is to extend the studies to the northern slope of the Torino Hill as a continuation of previous studies and try to reconstruct the recent geological evolution of this sector.

The relief, stretching SW-NE and W-E, shows several secondary ridges separated by deep incisions, some hundreds of metres high, modelled by the present day hilly watercourses (Fig.3). The geological survey extended to the northern slope allowed identification and mapping a fluvial terraced succession formed by several relics of flat surfaces, preserved on the secondary ridges, and perched from 30 to 400 m on the Po Plain (Fig. 3).

The relics of terraced surfaces are modelled in the Cenozoic marine succession or in a very thin cover of fluvial sediments. The tops of the units, corresponding to the terraces, are clearly visible, although erosional bases of the units are exposed only locally. Single surfaces, with extents ranging from 1500 to 50,000 m^2, show elevations between 240 and 600 m a.s.l. They are separated by scarps some tens of metres high. The terraces have a lateral continuity, interrupted only by the incisions modelled by the current hilly watercourses (Fig. 3). The fluvial deposits, where visible, form lenses some metres thick with a clear erosional bases. They mainly consist of an unstratified sandy-silty succession, whereas gravelly sediments appear only locally.

The pedogenetic evolution of sediments gradually decreases towards the lower surfaces. The Munsell colour index of the soils developed or on the deposits or directly on the Cenozoic marine terms ranges from 2.5 YR to 10 YR. The degree of evolution of the sediments is indicated by the high content of clay, which is responsible for thick and continuous clay coating, by the degree of degradation of the pebbles, which is variable depending on the petrographic composition, by the presence of a cementation caused by iron oxides and by frequent manganese oxides coating.

Mapping of the relics has been followed by their correlation, with account being taken of possible changes in the original elevation due to erosion by run-off waters and tectonic deformation. Two criteria were used: the pedostratigraphic criterion for the deposits, and the elevation for the erosional surfaces supporting the fluvial outliers.

The distribution and the inclination of the terraced fluvial surfaces indicate that they are not linked to the current drainage pattern, but suggest that they are connected with previous Northern Piemonte Plain watercourses with very different trends. In detail, in the western sector of the northern slope (currently drained by San Mauro, Dora and Crivella Rivers) the fluvial surfaces form a degrading terraced succession towards the plain: single relics are only distributed on the ridges within the present incisions. The morphological features show a NE-SW trend, parallel to the main watershed, and a constant slight inclination (0,2-0,3%) towards NE (Fig. 4a).

In the eastern sector of the northern slope (Maggiore Valley) the fluvial surfaces form a terraced succession entrenched within the relief. Single relics are distributed on both slopes of the valley and have a trend WNW-ESE, normal to the main watershed. At high levels, the fluvial landforms dip ESE, whereas at lower levels they are characterized by an opposite inclination towards the WNW (Fig. 4b). The present degree of preservation of the surfaces and of the fluvial sediments is different: the relics at high levels are more deformed, modified, dissected and mostly deprived of their original fluvial sediments; lower ones are less deformed, more continuous and often maintain the fluvial cover.

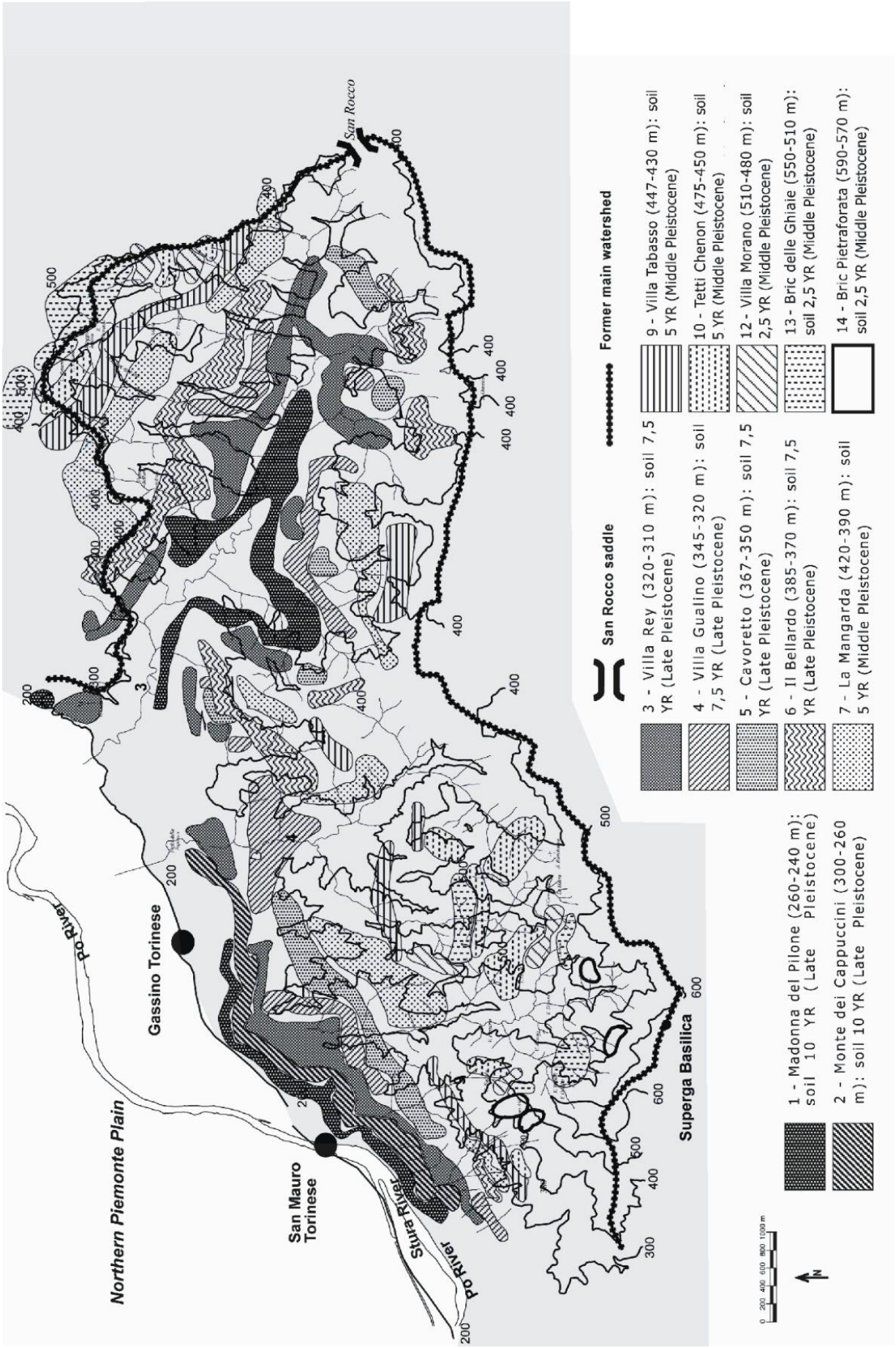

Fig. 3 - Geological map of the Pleistocene terraced fluvial succession of the Northern slope of the Torino Hill: the surfaces are numbered from the most recent to the oldest; the Unit 8 is recognized in the adjacent area only (Forno & Lucchesi, 2005).

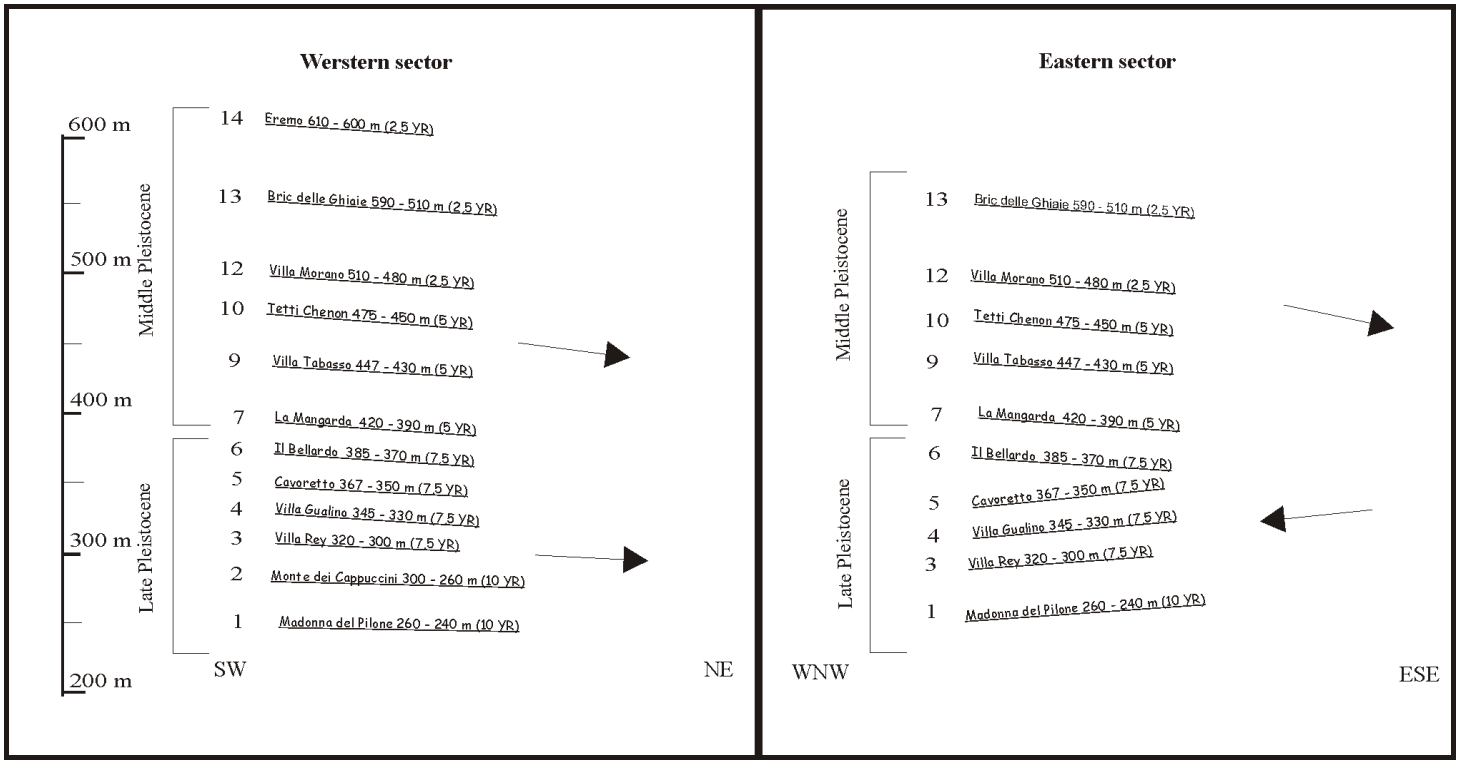

Fig. 4 - Simplified longitudinal profiles of the terraced succession of the Western and Eastern sectors of the Northern slope. The arrows indicate the drainage directions of the watercourses responsible of the modelling of the fluvial succession.

6. Conclusions

The data collected in this study allow reconstruction the Quaternary evolution of the northern slope of the Torino Hill. Application of local pedostratigraphic scale (Arduino et al., 1984) to fluvial deposits indicates that the fluvial succession is assigned to the Middle and the Late Pleistocene.

By correlating laterally all these relics, it is possible to reconstruct a series of long and narrow belts at various elevations above the Po Plain (Fig. 5).

The preferential orientation of the belts and their distribution, prevalently very different from the trend of the current local hydrographic network, suggest that they were shaped by ancient watercourses that drained the plain before the establishment of the present Po River. In contrast, the fluvial terraces preserved at lower levels of the Maggiore Valley show a preferential orientation similar to the current watercourse.

Although the distribution of the fluvial relics is very close to the present Po River, the succession can not be ascribed to this hydrographic collector yet because the palaeo-Po flowed south of the Torino Hill and in the Poirino Plateau at the same time (Fig. 2) (Forno, 1982). The fluvial morphological features and deposits preserved are connected with the modelling of alpine watercourses that drained the North Piemonte Plain.

The correlation of the fluvial surfaces mapped in the western sector of the northern slope with ones already described in the northwestern slope (Boano et al., 2004; Forno & Lucchesi, 2005) and the mineralogical analyses of the deposits prove a genetic link with the Stura di Lanzo and Dora Riparia Basins. Heavy minerals of the deposits are dominated epidote and includes amphiboles (actinolite and horneblende), high pressure minerals (chloritoid and glaucophane), few pyroxenes and locally garnets (Vezzoli et al., 2005). This suite suggests the calschists and meta-ophiolites of the oceanic Piemontese Zone as the source areas.

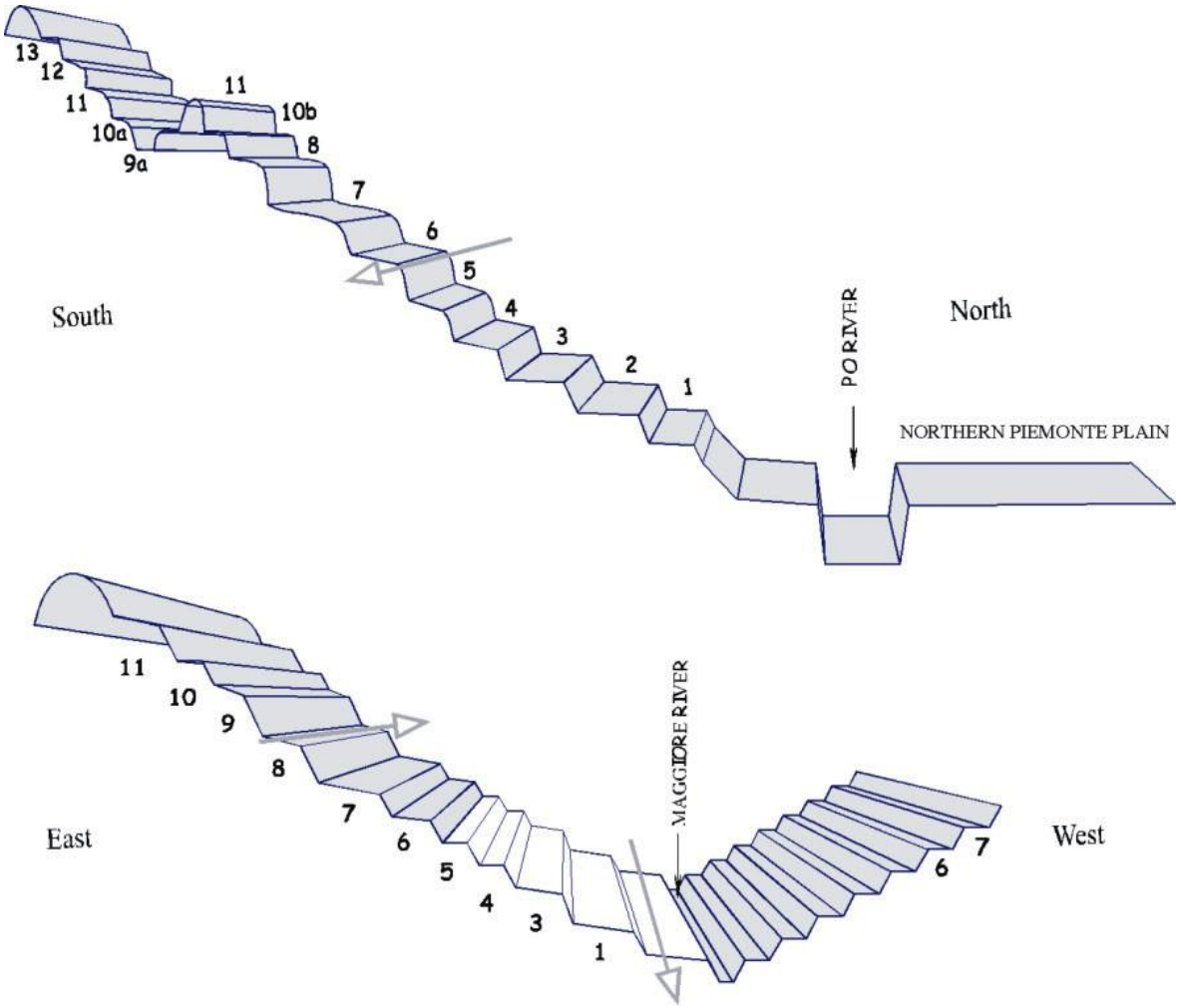

Fig. 5 - Prospected cross-section, not in scale, of the Western sector of the Northern slope (a), where the surfaces form a degrading terraced succession towards the Northern Piemonte Plain, and of the Eastern sector (b), where the fluvial succession is entrenched within the relief.

In the eastern sector, the provenance basin of the deposits is deducted on the bases of morphological evidences and the absence of mineralogical studies. The trend of the ancient Maggiore Valley and their position on respect of the alpine valleys suggest a genetic link with the Orco Basin (see Fig. 8). In the western sector of the area, the fluvial surfaces form a degrading terraced succession towards the Po Plain that suggests a progressive shifting with shifting to the NE of the collector (Fig. 6). This evolution is linked to the gradual uplift of the external margin of the hilly relief that also involved a restricted sector of the plain. In the eastern sector the distribution of terraced surfaces, entrenched within the relief and distributed on both slopes of the present Maggiore Valley, suggests that the uplift of the relief was so strong that it caused the entrenching of the watercourse within the relief, without lateral shifting (Fig. 7).

The occurrence of two groups of terraced surfaces with different inclination suggests the modelling by two successive rivers. Fluvial terraces preserved at higher levels (older units, 6-13 in Fig. 3) show an inclination towards ESE: they are connected with the modelling of an ancient watercourse (probably the palaeo-Orco River) (Fig. 8). Fluvial terraces preserved at lower levels (younger units, 1-5 in Fig. 3) are characterized by an opposite inclination to WNW that agrees with the current hydrographic network. This valley, previously formed by an alpine watercourse, now hosts a new stream net, the Maggiore River, visibly underfit. The drainage change is underlined by the counter-

slope saddle of San Rocco (370 m), stretching N-S. This is the higher relic of the valley, formed by the previous hydrographic network (palaeo-Orco River), now suspended on the bottom of the valley at about 170 m. The current elevation of the saddle is connected to a strongly uplift of the watershed, induced by the recent tectonic evolution of the hilly relief, responsible of the re-organization of the hydrographic network (palaeo-Orco) and of the setting of the local stream net (Rio Maggiore).

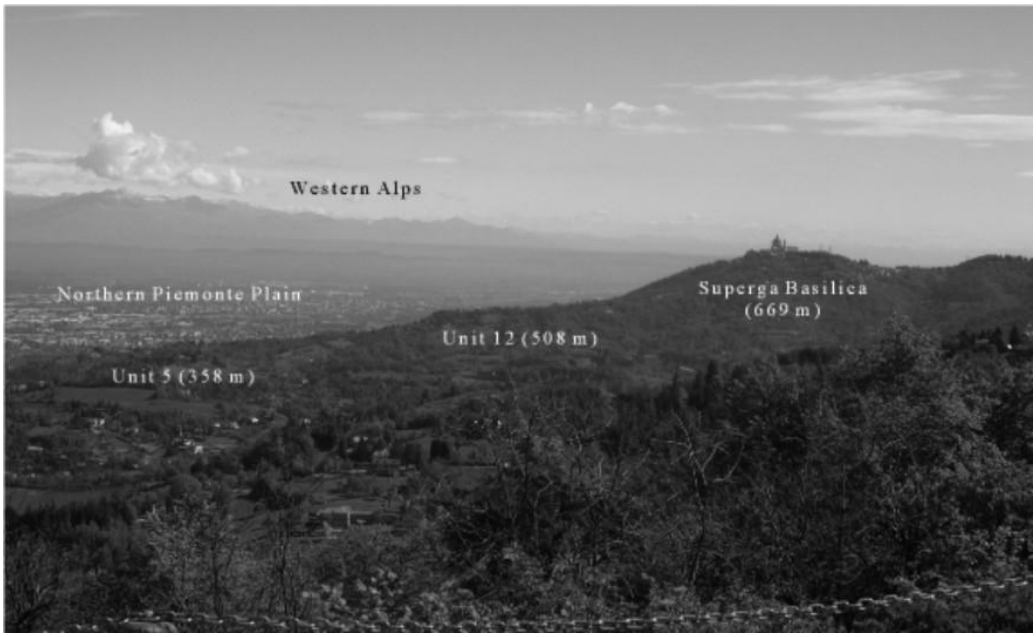

Fig. 6 - View of the terraced succession of the Superga ridge: three fluvial terraces are recognizable, separated by high scarps.

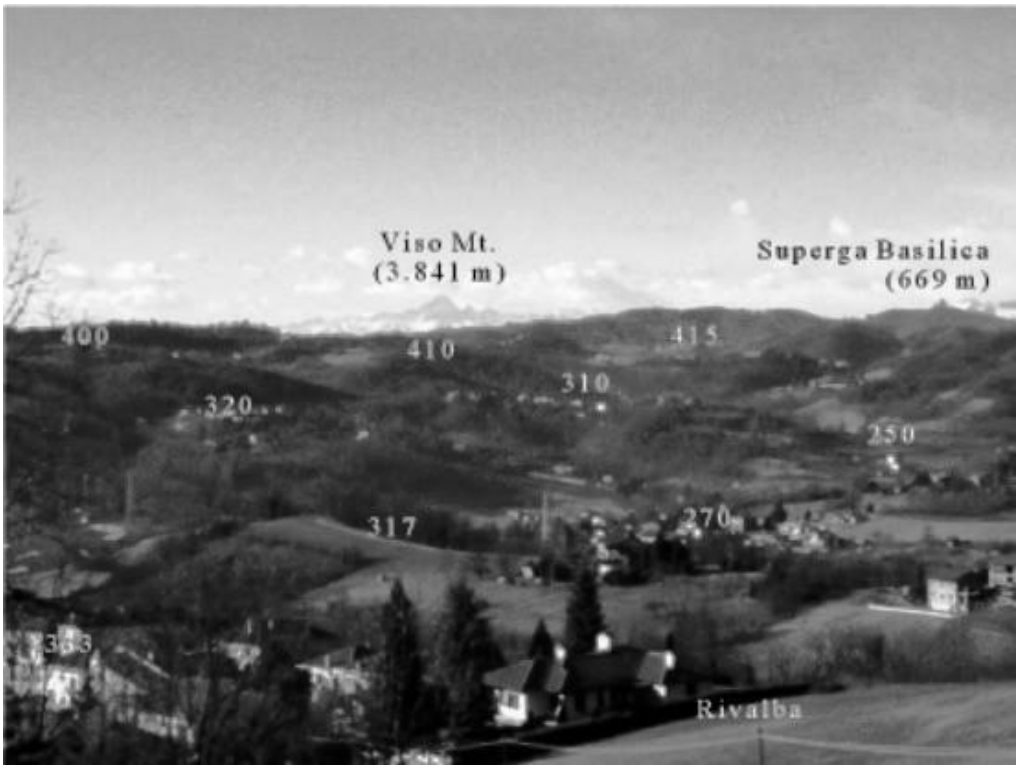

Fig. 7 - View of the Rio Maggiore Valley: the fluvial terraces indicate two different flow directions.

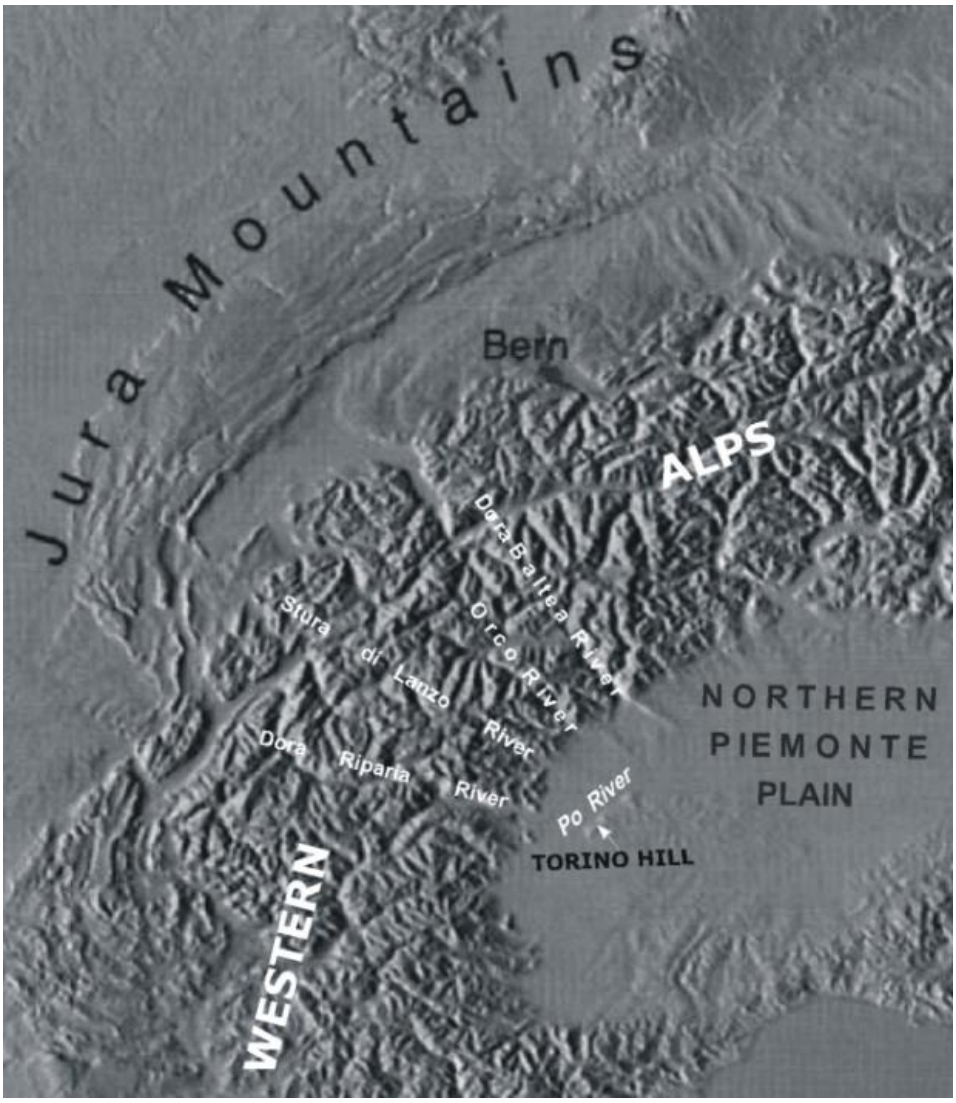

Fig. 8 - Satellite image of the Torino Hill, Northern Piemonte Plain and Western Alps.

The preservation of the fluvial succession on the ridges only and the small extension of relics are connected to the dissection of the originally continuous forms by the present local tributary watercourses. They were set up in those sectors that became progressively "hilly": in the western sector, the current San Mauro, Dora and Crivella Rivers, flowing North, and in the eastern sector the present Maggiore River, flowing to WNW, progressively developed.
This reconstruction agrees with the different degree of preservation of the terraces and with the different soil development of the associated fluvial sediments: the older units are preserved at high levels, whereas the younger ones are distributed at lower levels (Fig. 3).
The fluvial described succession, perched beyond 400 metres on the plain, is the result of the deformation of the original plain sectors modelled by alpine watercourses, prior to the shifting of the palaeo-Po River to the north of the Torino Hill. The progressive realization of the hilly relief and the NW migration of its external edge, caused the involvement of the Alpine fan distal sectors and their deformation. These phenomena are in agreement with the most recent structural reconstructions of the area (Piana & Polino, 1994).
Carrying out a comparison between the data collected in this study with the ones deducted from the adjacent areas, a reconstruction of the trend of the Pleistocene hydrographic network can be carried out. The alpine watercourses (palaeo-Dora Riparia, palaeo-Stura di Lanzo and palaeo-Orco Rivers) flowed through the Northern Piemonte Plain, lapping the distal sector of the Alpine fans against the

hilly relief. The contemporary rising of the anticline structure caused northwestward shifting of the alpine watercourses and a progressive re-organization of the drainage network. Initially the palaeo-Stura di Lanzo and palaeo-Orco Rivers flowed towards northeast. In contrary the palaeo-Dora Riparia River was a tributary of the palaeo-Po draining south of the Torino Hill. Subsequently the palaeo-Dora Riparia River flowed towards NE, the Po River acquired its the current setting, and the alpine watercourses become its direct tributaries (Fig. 9).

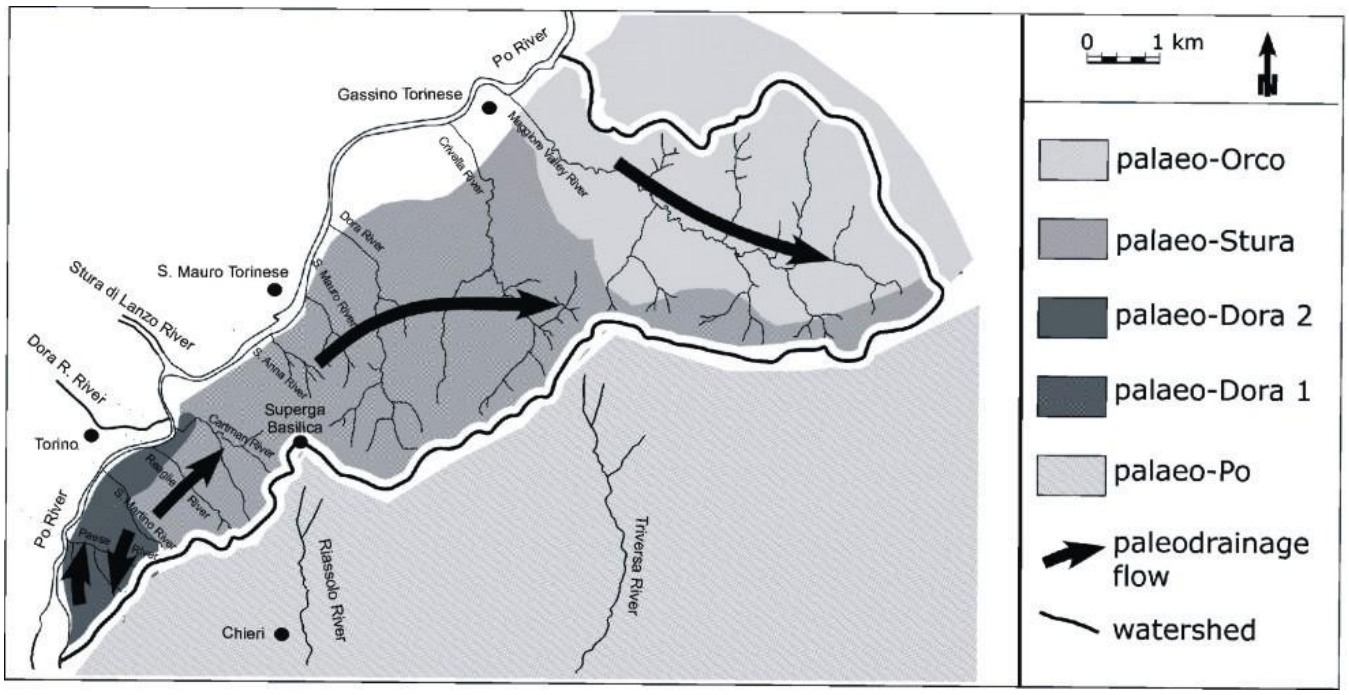

Fig. 9 - Reconstructed changes in the drainage network of the Torino Hill.

The comparison of the chronological reference of the morphologic elements and associated sediments with their altimetric distribution suggests that the rate of uplift from the Middle Pleistocene to the Holocene is about 1 mm/year. This rate of uplift agrees with previous works in adjacent areas (Boano et al, 2004). This rate is in agreement with the values drawn from the geodetic measurement related to the 1897-1957 period (Arca and Beretta, 1985), which identify the present maximum uplift values of the entire Piemonte area in the Torino Hill (1-3 mm/yr).

The distribution of the terraced fluvial succession in the Torino Hill suggests that the current morphological expression of the anticline is entirely Quaternary.
The recent progressive tectonic uplift of the Torino Hill, responsible for the creation of steep gradients, increases the risk associated with landslide and erosional processes favoured by poor geomechanical features of the substratum, formed by non-consolidated marine Tertiary sediments. Landslides and erosional processes are frequent in the scarps, where the slopes are steeper; on the other hand, the flat surfaces linked to the presence of fluvial terraced succession are conservative sectors, as suggested by the presence of ancient villas.
In the eastern sector the palaeo-watercourses, responsible of the modelling during the Middle-Late Pleistocene, don not show a trend parallel to the hilly edge, as in the adjacent areas, but they are entrenched in the relief. The authors intend to continue research in order to carry out a complete reconstruction of this ancient network.

Acknowledgements
We are grateful to Francesco Carraro and Giuseppe Orombelli for useful suggestions.

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