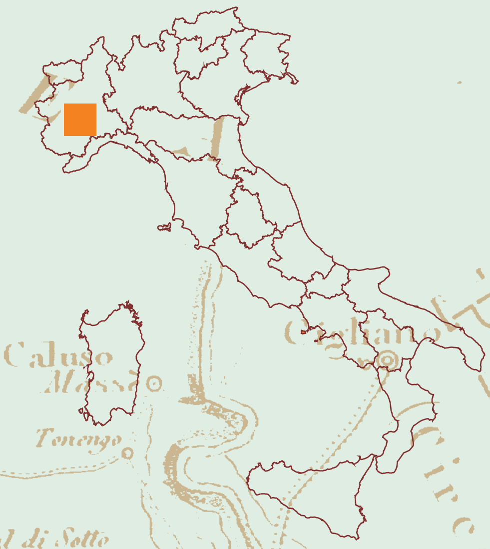

Application of integrated allostratigraphy to the geological survey of the central Piedmont plain

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ABSTRACT

A geological survey of the central Piedmont plain was carried out *ex-novo* by applying the allostratigraphic method. Different successions for different catchment basins have been identified, although without sufficient chronological data a proper correlation between these successions is not possible. The various informal units have been defined by combining both surface and subsurface data. In the map, the depositional units of comparable age as defined by pedostratigraphic data are shown in the same colours, obtained from the use of different graphic textures specific for each basin.

AIMS

The geological map shown in Fig. 1 aims to provide an example of the allostratigraphic method (NASC, 1983), whose application in several mountainous, hilly and plain areas of northern Italy has shown that:
- many stratigraphic successions can be found in a same area,
- these successions are the result of the different weight and composition of controlling factors;
- the erosional phenomena that occurred during sedimentation prevent bounding of the whole area of distribution of the depositional units; therefore, the allostratigraphic successions are referred, by first approximation, to the different catchment basins in which they are contained.

The ultimate purpose of the map is:
- to provide a more exhaustive and correct information regarding the geological evolution of the area,
- to highlight certain important river deviations, such as the palaeo-Po diversion, which could not be shown in a map obtained using the formational method.

KEY WORDS

Allostratigraphy, Quaternary, Po Plain, fluvial deviation, River Po

RIASSUNTO

Il rilevamento geologico della Pianura Piemontese centrale è stato effettuato ex-novo applicando il criterio allostratigrafico. Sono state riconosciute successioni diverse per bacini idrografici diversi; in mancanza di sufficienti ed adeguati elementi di datazione non é stato possibile stabilire correlazioni tra esse. Le diverse unità informali sono state definite utilizzando congiuntamente i dati di terreno con quelli Del sottosuolo. La loro appartenenza ai diversi bacini è stata rappresentata in carta rendendo con specifiche retinature la tonalità di colore con cui si è indicata l'età approssimativa desunta da dati pedostratigrafici. La carta geologica così realizzata, oltre che fornire informazioni più complete e più corrette sull'evoluzione geologica dell'area, consente di cogliere alcuni eventi particolarmente importanti dell'evoluzione dell'area come la diversione del Po non percepibile in una rappresentazione cartografica realizzata utilizzando il metodo formazionale.

GEOLOGICAL MAP OF THE CENTRAL PIEDMONT PLAIN

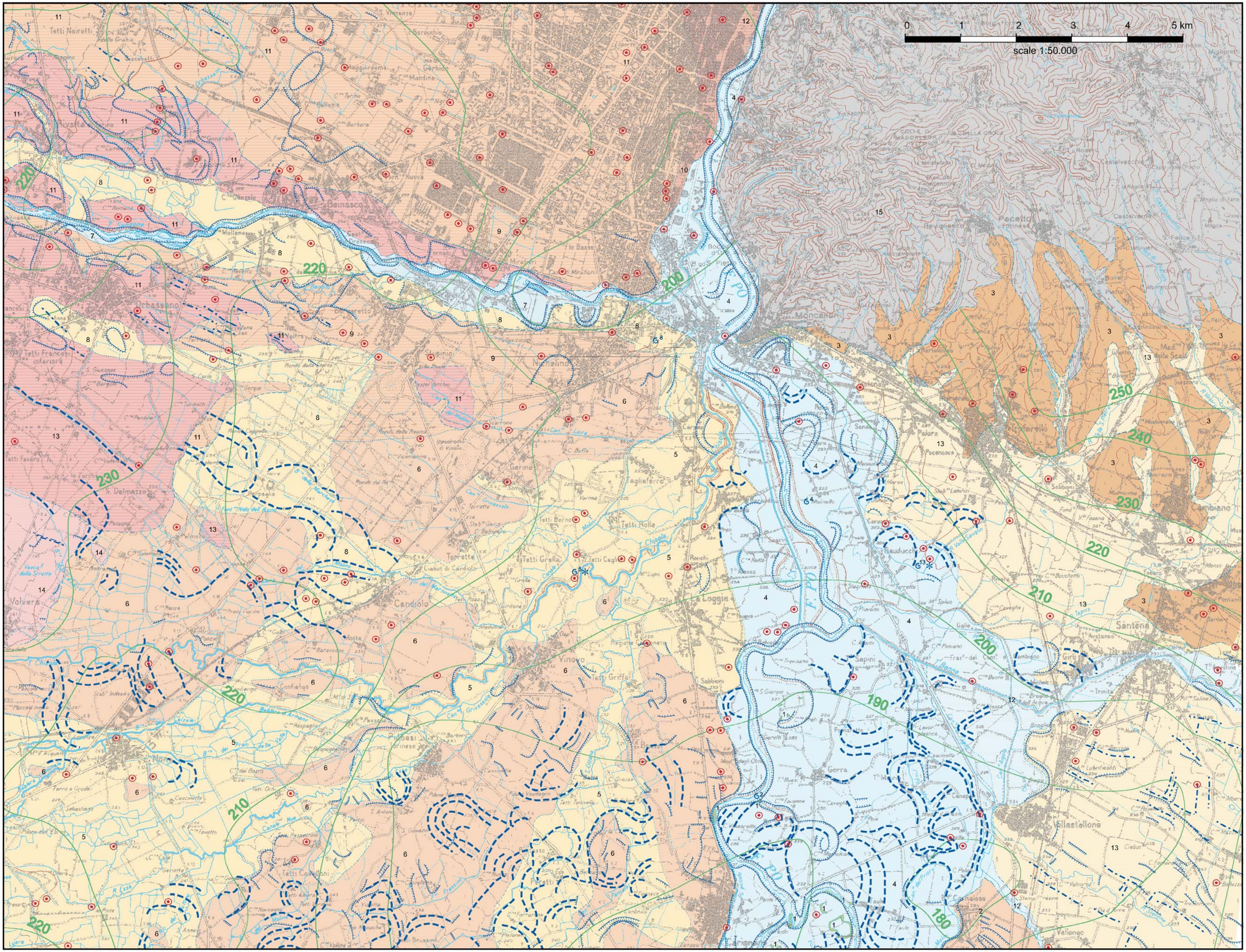


Fig. 1 - *Geological map of the central Piedmont plain (Italy)*

PALEO-TANARO+PO BASIN

RELICT UNITS

1 ***Madonna del Gerbido Alloformation*** Coarse gravels with sandy intercalations and heterometric "anagenitic" (quartzitic conglomerates), quartzitic and limestone clasts. Include *Elephas primigenius* remains. Soil colour index: 10YR 4/4 ÷ 4/6 (*fluvial deposits*) (UPPER PLEISTOCENE).

2 ***Carmagnola Alloformation*** Cross bedded silty sands with peaty intercalations and rare quartzitic, "anagenitic", dark limestone and serpentinic clasts. Soil colour index: 7.5 YR 5/6 ÷ 10YR 4/4(*fluvial deposits*) (LOWER?- UPPER PLEISTOCENE) .

3 ***Sommariva Bosco Alloformation*** Sandy gravels with quartzitic and "anagenitic" clasts; sandy and clayey-silt cover. Include *Elephas primigenius* and *Megaceros giganteus* remains. Soil colour index: 5 YR 5/4 ÷ 5/6 (*fluvial deposits*) (UPPER MIDDLE PLEISTOCENE).

NEO-PO BASIN

UNITS IN FORMATION

4 ***Sassi Alloformation*** Silty sands and sandy silts. Include flooded trunks. Soil colour index: 2,5 Y ÷ 10 YR 4/4(*fluvial deposits*) (UPPER PLEISTOCENE-HOLOCENE).

PELLICE-CHISONE BASINS

RELICT UNITS

5 ***Osasio Alloformation*** Silty sands with peaty-silty intercalations and quartzitic, serpentinitic and "pietre verdi" clasts. Soil colour index: 10 YR 4/2 ÷ 4/3 (*fluvial deposits*) (UPPER PLEISTOCENE-HOLOCENE?).

6 ***Castagnole Alloformation*** Weakly cross bedded silty sands with rare quartzitic, serpentinitic and "pietre verdi" clasts. Soil colour index: 7.5 YR 5/6 ÷ 10YR 4/4 (*fluvial deposits*) (UPPER PLEISTOCENE).

SANGONE BASIN

UNITS IN FORMATION

7 ***Cascina Mellano Alloformation*** Gravelly sands with serpentinitic, gneiss, quartzitic, gabbric and calcschists clasts. Soil colour index: 10 YR 4/2 ÷ 4/3 (*fluvial deposits*) (HOLOCENE).

RELICT UNITS

8 ***Nichelino Alloformation*** Cross bedded gravelly sands with clasti serpentinitic, gneiss and quartzitic clasts. Include flooded trunks. Soil colour index: 10 YR 4/2 ÷ 4/3 (*fluvial deposits*) (UPPER PLEISTOCENE - HOLOCENE?).

DORA RIPARIA BASIN

RELICT UNITS

9 ***Grugliasco Alloformation*** Coarse sandy gravels with heterometric rounded quartzitic, serpentinitic, gneiss, "pietre verdi", calcschists and gray marble clasts; sandy silts and loess thin cover. Soil colour index: 10 YR 4/3 ÷ 4/4 (*outwash deposits*). (LOWER UPPER PLEISTOCENE).

10 ***Piazza Castello Alloformation*** Sandy gravels with serpentinitic, gneiss, quartzitic, gabbric, anfibolitic, prasinitic, micaschists and marble clasts. Soil colour index: 7.5 YR (*outwash deposits*) (LOWER UPPER PLEISTOCENE).

11 ***Rivalta Alloformation*** Weakly stratified sandy gravels and sandy silts with heterometric rounded serpentinitic, gneiss, quartzitic, anphibolitic, prasinitic, micaschists and peridotitic clasts. Soil colour index: 7.5 ÷ 2.5 YR (*outwash deposits*) (LOWER MIDDLE PLEISTOCENE).

UBIQUITOUS UNITS

UNITS IN FORMATION

12 ***Tributary basins Complex*** Weakly plain-parallel stratified sandy silts. Soil colour index: 2.5 Y ÷ 10 YR 4/3 (*fluvial and fluvio-lacustrine deposits*) (HOLOCENE).

RELICT UNITS

13 ***Villastellone Alloformation*** Cross bedded silty sand with peaty intercalations and rare quartzitic, "anagenitic", dark limestones serpentinitic clasts. Include pulmonate gastropods shells and fossil trunks. Soil colour index: 10 YR 4/4 (*fluvial deposits*) (UPPER PLEISTOCENE - HOLOCENE: 30.000÷11.000 anni b.P. after Tropeano & Cerchio, 1984).

14 ***Piossasco Alloformation*** Sandy silts with rare serpentinitic, gneiss and "pietre verdi" clasts. Soil colour index: 5 YR 4/8 ÷ 10 YR 5/6 (*torrential-colluvial deposits = bahada*) (LOWER MIDDLE PLEISTOCENE).

15 Pre-Quaternary substratum (Turin Hill) (EOCENE - LOWER PLEISTOCENE).

SYMBOLS

reliable boundaries

uncertain boundaries

scarp edges

abandoned fluvial channels tracks

axes of main elongated reliefs

6[4] fossiliferous sites and provenance unit

* isotopic-geochemical dates

main water wells or drillings with stratigraphic log

190 isobath of the lower bounding surface of Quaternary deposits (m a.s.l.)

INTRODUCTION

It has been noted in continental Quaternary surveys that the number of fluvial terraces or morainic ridges at the mouth of different valleys varies, even when these are adjoining. Moreover, the maturity of soils developed on the sedimentary deposits shows that in adjoining valleys even the number of episodes that occurred within a same period of time is different.

These situations highlight the fact that geological evolution during the Quaternary in a continental environment is also controlled by geodynamic activity and many other elements-such as the geolithologic (e.g. nature of the bedrock, geomechanic characteristics) and geomorphic (e.g. dimensions, topography and exposure of catchment basins, past geomorphic evolution, geological framework) characteristics of a specific area - in addition to climatic forcing, previously considered the only governing factor. These controlling factors in many cases are not related to each other and often play independent roles, resulting in a complex geological evolution.

The response of geomorphic and sedimentary processes to tectonic or climatic variation occurs with a certain time-delay. This strong inertia of the system can lead to different conditions even in short time spans and in neighbouring catchment basins, which can thus generate different stratigraphic successions.

These same considerations have been made in the past for pre-Quaternary marine successions, and led to the conclusion that physical stratigraphic units do not correspond to chronostratigraphic units, but rather to lithostratigraphic units.

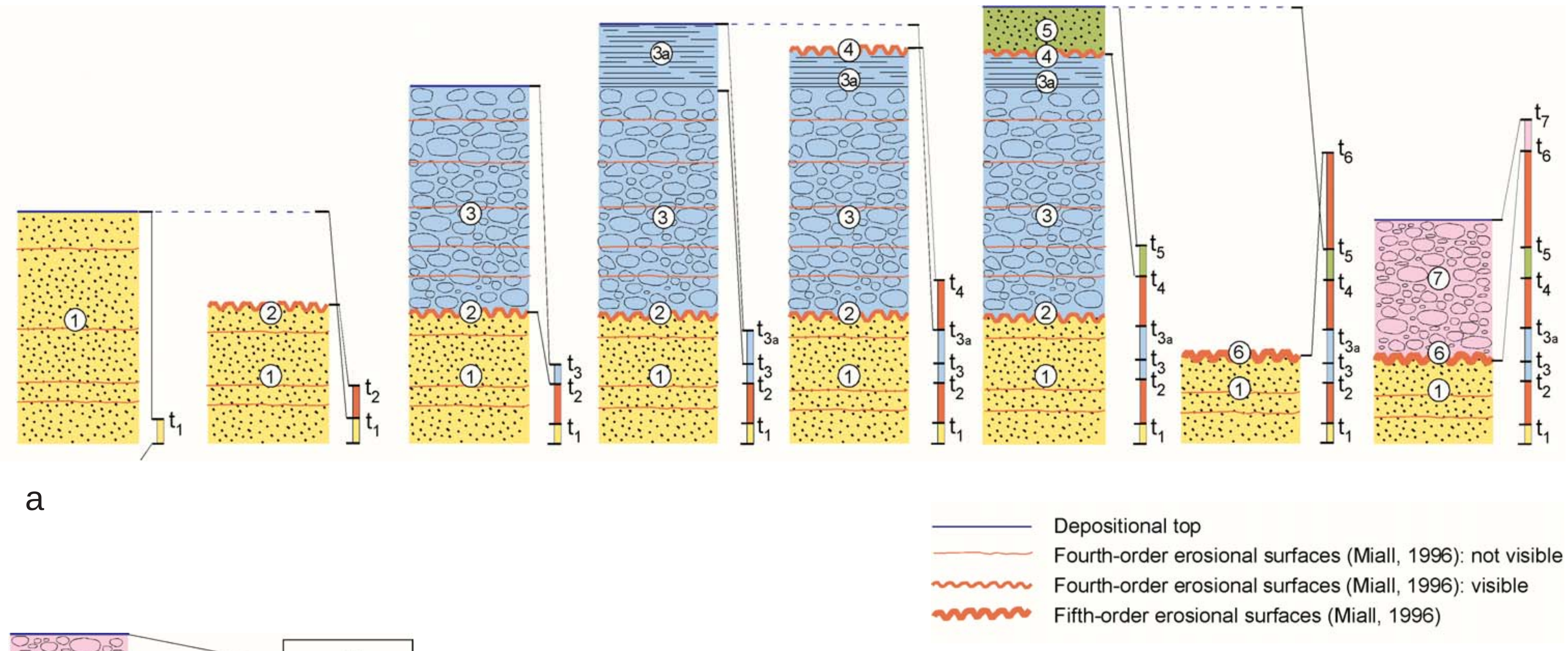
These evidences show that even if single levels of diverse formations of different basins can certainly be correlated, the immediate correlation between the formations themselves, and even more so between whole successions, is not possible.

Correlation in continental successions is even more complex owing to the occurrence of several erosional surfaces, which could represent long time intervals during which significant sedimentation episodes might have occurred and which are now not represented by stratigraphic record (Fig. 2).

As a consequence of the complexity of different factors which control the geological evolution of continental environments, the formation of any specific sedimentary body or erosional surface is diachronic and may be very limited in lateral extension.

The definition in space and time of a given sedimentary body (stratigraphic unit) related to a specific depositional event is theoretically possible only by locating and following in all their spatial distributions the discontinuities (e.g. erosional surfaces) that form the boundaries of such a stratigraphic unit. These surfaces, however, are often obliterated in most of their extension by subsequent erosional processes, or are not visible because they are buried by younger deposits. Finally, the extension of the area affected by erosional or depositional processes is often difficult to identify due to the shortage of outcrops.

When starting field work for the purposes of the geological mapping of Quaternary continental sediments in a new area, it seems fair to assume that, inside a specific catchment



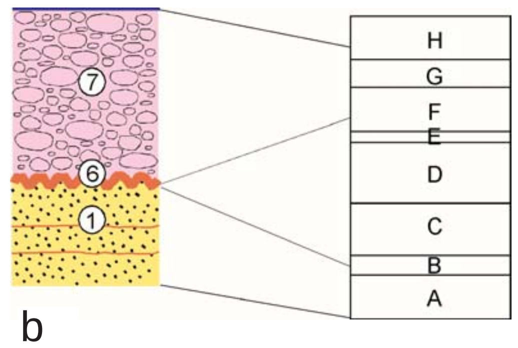


Fig. 2 - a) *Chronological steps (from the left to the right) of the construction of an imaginary stratigraphic succession deriving from the composition of depositional and erosional episodes. Numbers indicate the single episodes and their corresponding geological answer (sedimentary body or erosional surface);* t1, t2, ... t7 *the time spans.*
Note: there is no relation between the thickness of the sedimentary bodies and the corresponding time spans; the complete obliteration of 3, 3a, 4 and 5 bodies due to erosional episode 6 demonstrates that, even without taking into account the others motivations mentioned in the text, there is no direct comparability between the stratigraphic succession preserved (1, 6 and 7) and the sequence of events (1--7);
b) *Possible correlation between the final stratigraphic succession of Fig. 2a and the relate succession of events. Note the not exact chronological correspondence and the lack of representation of some episodes.*

basin, the evolution of a river represents a "unifying" factor of the evolution of the basin itself.
This approach therefore will generate as many successions as the number of catchment basins, that will be correlated later only where chronological data are available, as is usually done for marine successions.
The geological map of the area of the Piedmont plain reported in Fig. 1, was generated by using the allostratigraphic method suggested by the North American Commission on Stratigraphic Nomenclature (1983).
The allostratigraphic unit is defined as "a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities" and therefore, as previously discussed, can be satisfactorily used to represent Quaternary continental sedimentary successions.

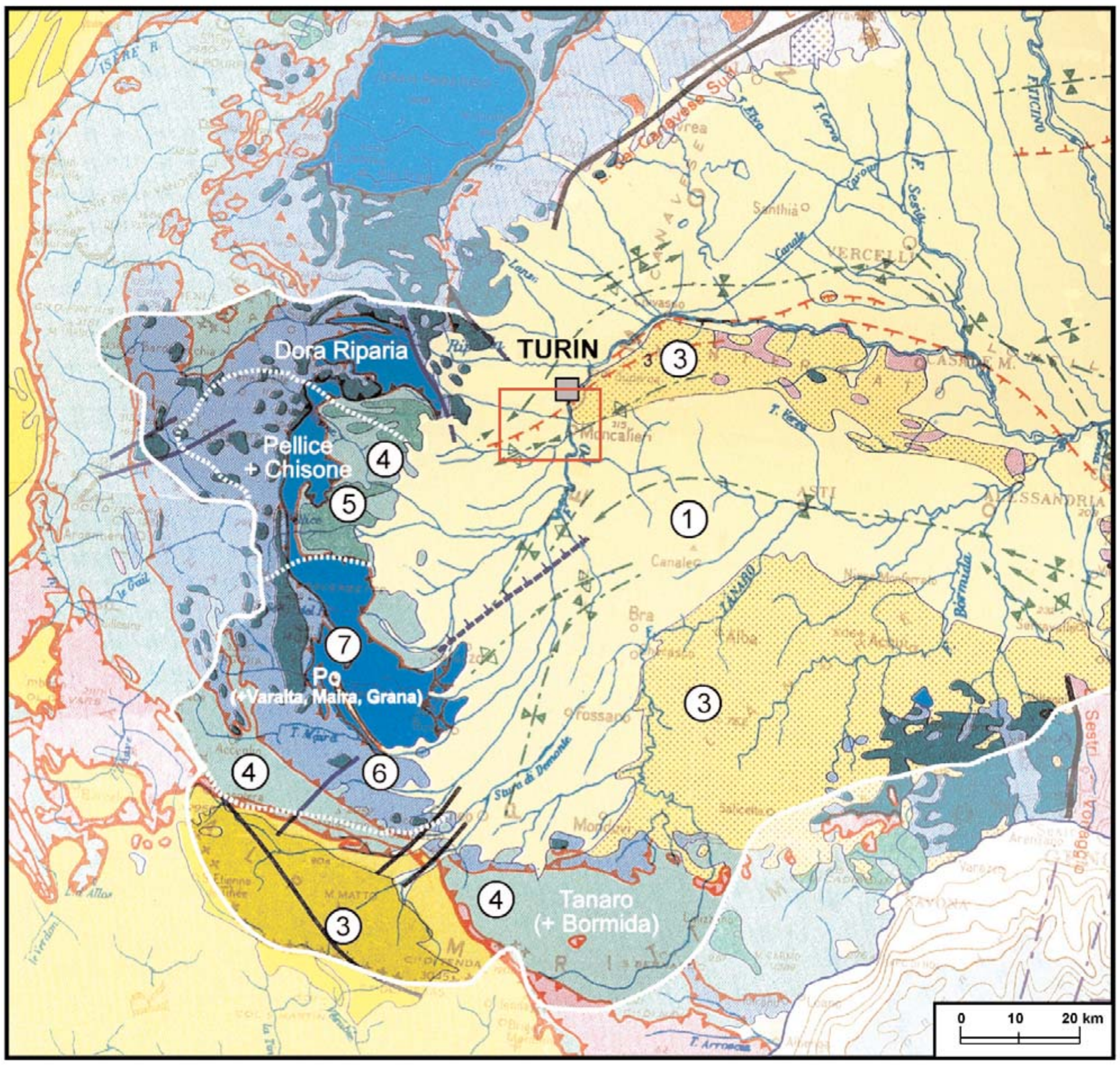


Fig. 3 - *Fluvial catchment basins of the study area (red square) (after CNR, 1981, simplified and modified).*
1 - *Post-orogenic marine and continental Units.* 2 - *Late orogenic Units.* 3 - *Dauphinois-Helvetic Zone, outer crystalline massifs.* 4 - *Brianáonnaise Zone, cover units.* 5 - *Brianáonnes Zone, basement units.* 6 - *Piedmont Zone, cover units.* 7 - *Piedmont Zone, basement units.* 8 - *Piedmont Zone, ophiolites.*

GEOLOGICAL FRAMEWORK OF THE PO RIVER PLAIN

The study area corresponds to the central sector of the Piedmont plain (Fig. 3).
During the Quaternary, two different basins developed in the western sector of the Po Plain: the Northern Piedmont Basin, corresponding to the western termination of the Po Plain, and the southern Piedmont Basin. The latter, starting from the Middle Pleistocene, acted as an intermountain close basin. Indeed, at that time the Northern and Southern basins were separated by a topographic high; this was represented both by the Rivoli-Avigliana Moraine Amphitheatre, which was under construction at the mouth of the Susa Valley and by the surficial expression of the SW termination of the Turin Hill structure (buried at present), that was undergoing an intense structural uplift at that time.
The area represented in Fig. 1 experienced two important river deviation events (Fig. 4) (see CARRARO *et alii*, 1995). In the upper Late Pleistocene, the deviation of the former River Po course (palaeo-Po diversion) took place due to a series of concomitant causes (the overflooding of the Southern Piedmont Basin, the building-up of the Rivoli-Avigliana Morainic Amphitheatre, the SW tilting of the Turin Hill structure axis). Until that moment the palaeo-Po had drained the Southern Piedmont Basin, flowing SE of the Turin Hill relief towards the sites of the cities of Asti and Alessandria, after it had crossed the plain area currently corresponding to the Poirino

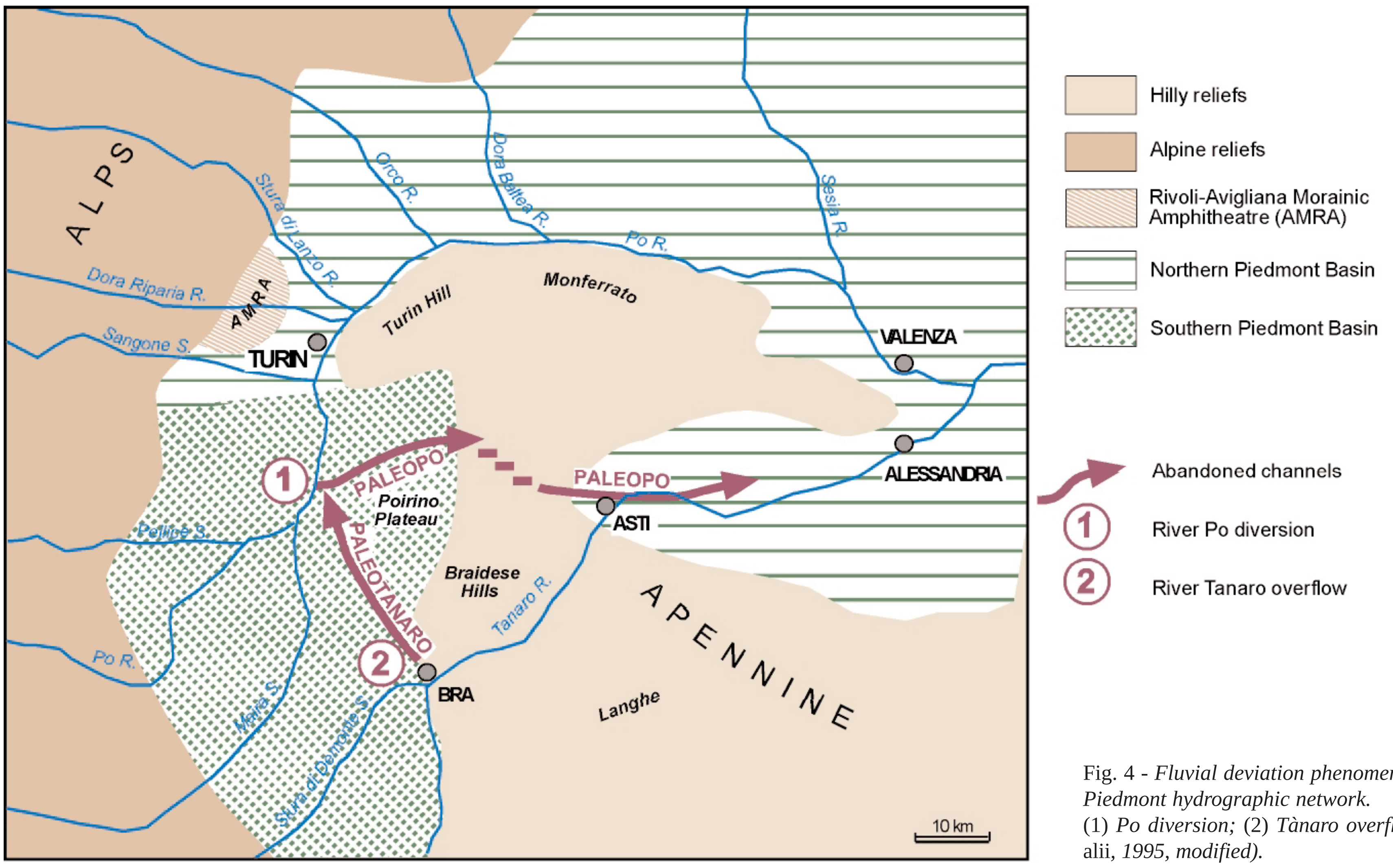


Fig. 4 - *Fluvial deviation phenomena experienced by the Piedmont hydrographic network.*
(1) *Po diversion;* (2) *Tànaro overflow (from* Carraro et alii, *1995, modified).*

Plateau, and joined the Po Plain at the present Tànaro outlet. Following this diversion phenomenon, the new river (neo-Po) assumed its present day course, passing north of the hills relief (see Fig. 4).

Later on -about 40,000 years ago- the continuous evolution of a marginal structure in the Langhe Hills caused the progressive migration to the east of the course of the river Tànaro, which flowed into the palaeo-Po. This process was associated with a gradual lateral erosion by the Tànaro that planed out the western marginal sector of the Braidese Hills, until the river reached a deep sector in the relief bounding the Southern Piedmontese close depression and spilled over (Tànaro overflow). The new river (neo-Tànaro) occupied the course of the palaeo-Po in the area between the town of Astiand its outlet in the Po Plain, leaving an abandoned channel (palaeo-Tànaro) still identifiable downstream (point 2 in Fig. 4). Thus the neo-Po lost the water and sediment contributions from the palaeo-Tànaro.

GEOLOGY OF THE AREA

The local bedrock is made of siliciclastic marine succession, Eocene to Middle Pliocene in age, separated by an erosive angular unconformity from a succession of fluvial-lacustrine deposits (Middle Pliocene - Lower Pleistocene = "Villafranchian" *Auct.*) The latter is bounded at the top by an erosional surface on which lays a succession of Middle-Upper Pleistocene fluvial deposits. These have a thickness varying between 10 and 80 m.

The cover mostly consists of well sorted gravel deposits ranging in grain-size between 5 and 20 cm and genetically related to fluvial and/or fluvio-glacial depositional systems. The gravels are covered by a 0.5 to 3 m thick blanket of fine-grained fluvial overbank and loess deposits widespread over the whole southern Piedmontese plain, and then outcrop only locally, in correspondence to natural fluvial

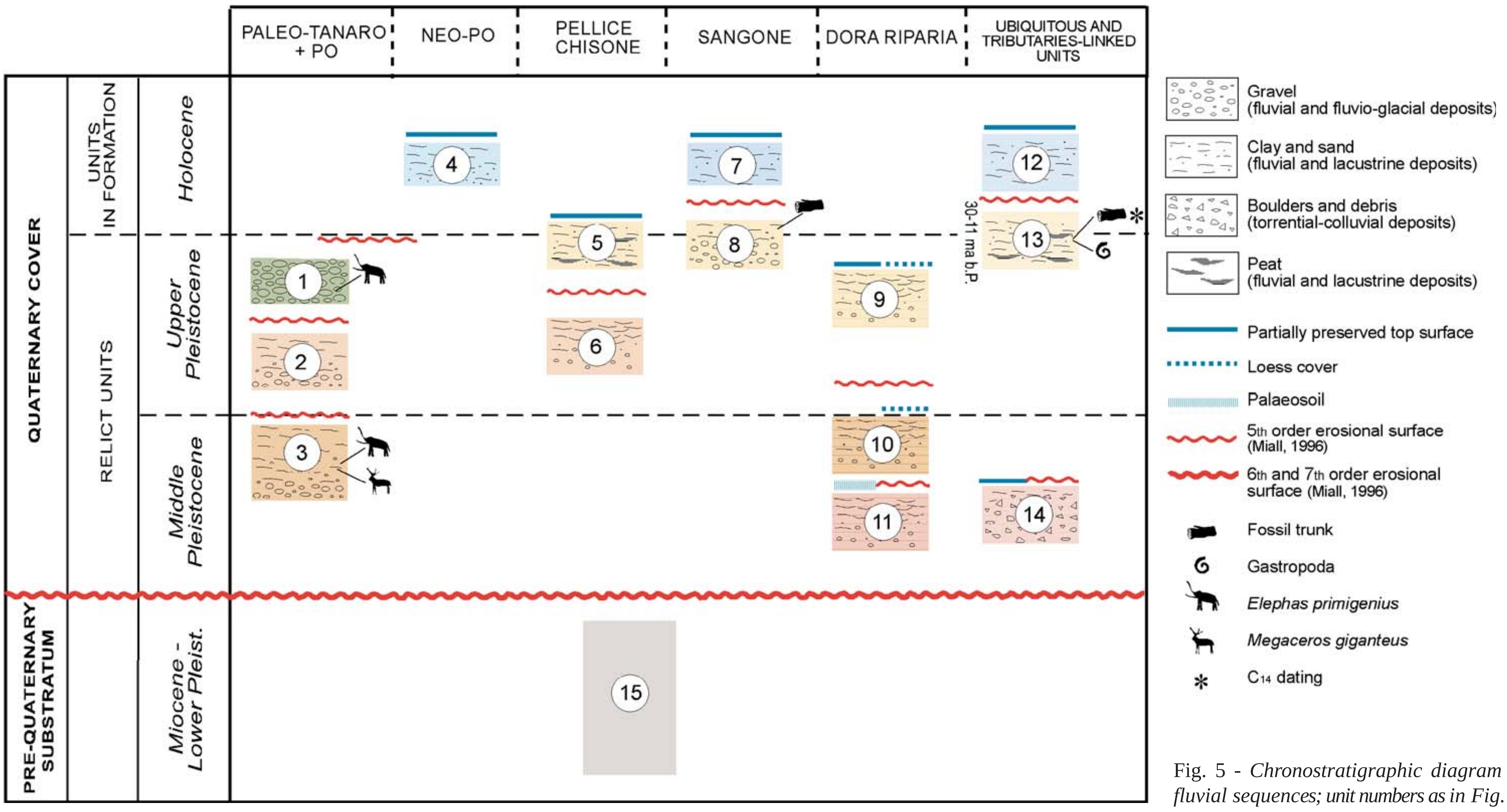


Fig. 5 - *Chronostratigraphic diagram of fluvial sequences; unit numbers as in Fig. 1.*

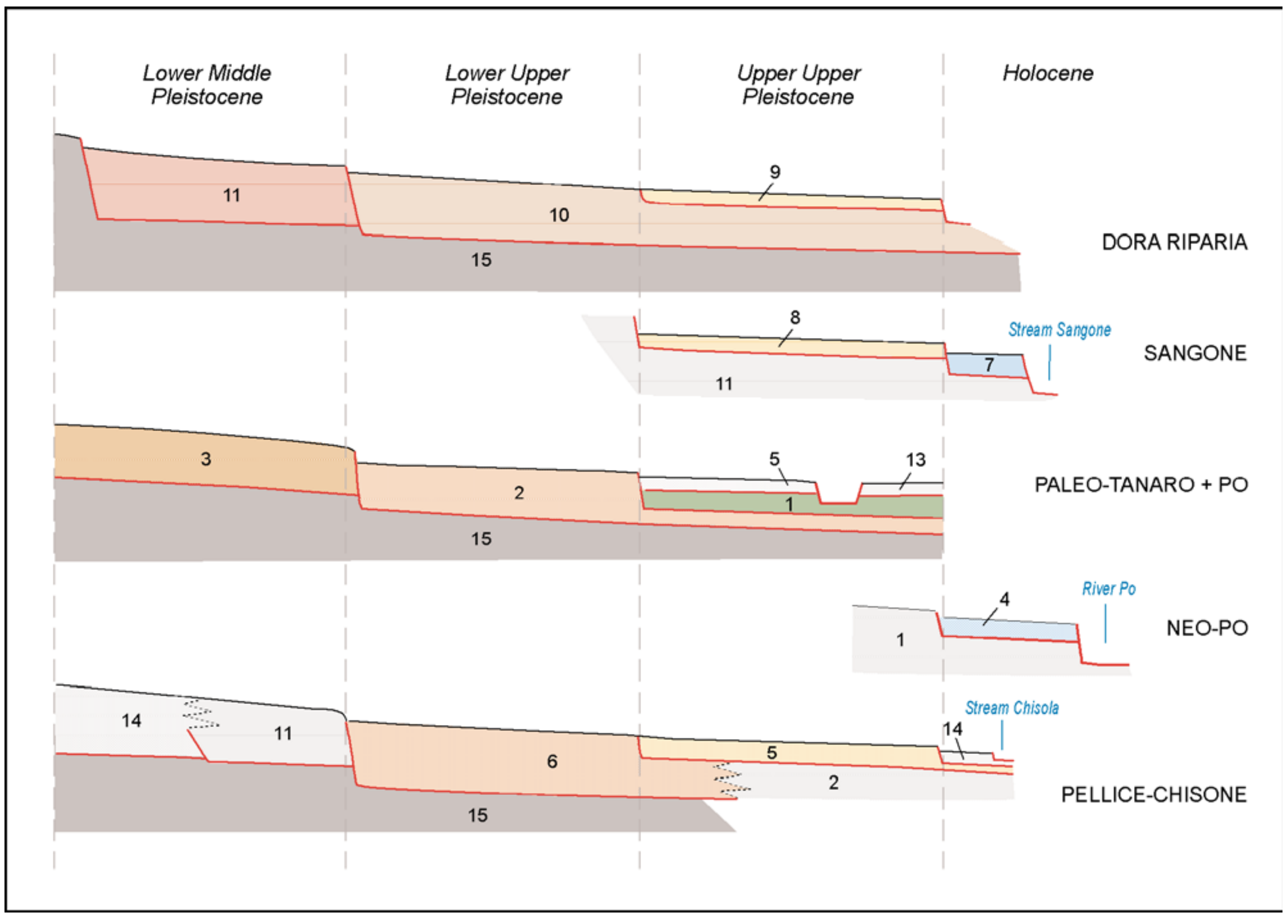


Fig. 6 - *Schematic representation of the stratigraphic relationships between the units of each catchment basin: the units not belonging to the basin are shown in light gray; dark gray shows the pre-Quaternary substrate and red lines represent erosional surfaces. Unit numbers as in Fig. 1.*

incisions or to artificial excavations or quarries. The Middle-Upper Pleistocene succession has been subdivided in several informal units by using the allostratigraphic approach. On the basis of mineralogical and/or petrographic markers (see Tab. 1) a specific stratigraphic succession was identified for each catchment basin (Figs. 5 and 6). The depositional units of comparable age, genetically related to different basins, are mapped in Fig. 1 with the same colour obtained by different graphic textures which are specific for each basin.

THE GEOLOGIC MAP

The map presented here provides the following information:

a) Distribution of the allostratigraphic units outcropping in the area, differentiated by age. In most cases, in the absence of direct chronological datings, the degree of maturity of the soil which is resting on top of the sedimentary units was used. This is calibrated on the local pedo-stratigraphic scale (see ARDUINO *et alii*, 1984), which is generally used to infer the age of sediments;

b) Catchment basin of each allostratigraphic unit;

c) main geomorphologic features of the area ("macro-" and "micro-relief"), such as scarps, abandoned channels, highs, depressions, etc...which are related to the geomorphic evolution of the region.

Similarly to what is generally done in geological maps of the bedrock, it was decided not to map any information related to the Quaternary sediment lithofacies. This because, besides from making the map even more complex from the graphic point of view, such information is derived from subjective interpretations which often are not supported by data bases, as in the case of long-distance interpolations between outcrops. This is also in conformity with the pre-Quaternary geological cartography to which the present approach mostly refers.

Only geomorphologic symbols, useful for the reconstruction of the past geological evolution of the area, are reproduced on the map. For instance, the symbol used for alluvial fans is not mapped as it is not significant for this purpose.

New symbols are used to represent those geomorphic features that at present are completely obliterated either by artificial or natural processes, but for which some historical accounts still exist (cf. Fig. 7). These are ancient river channels, topographic highs or erratics, whose traces can only be found in historical documents or old aerial-photographs.

All the various Quaternary stratigraphic successions have been reconstructed combining both surface and subsurface data. The latter were gathered from more than 1,300 stratigraphic logs of mechanical boreholes and water wells; these data have been processed using a 3D terrain modelling software which enabled the preliminary reconstruction of the Quaternary sediments lower bounding surface (Fig. 7).

The latter emerges as being polygenic and poly-chronological in nature, having been modelled in different areas and in different times by different river systems. The sedimentary succession of fluvial sediments was generated during episodes of aggradation, alternated with

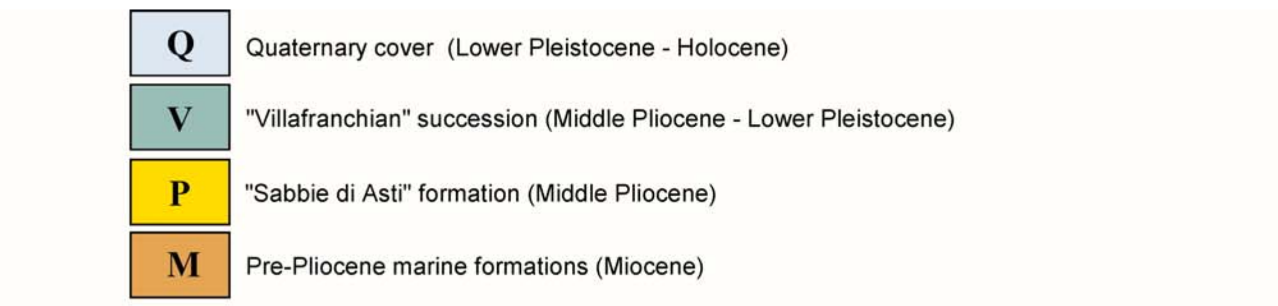
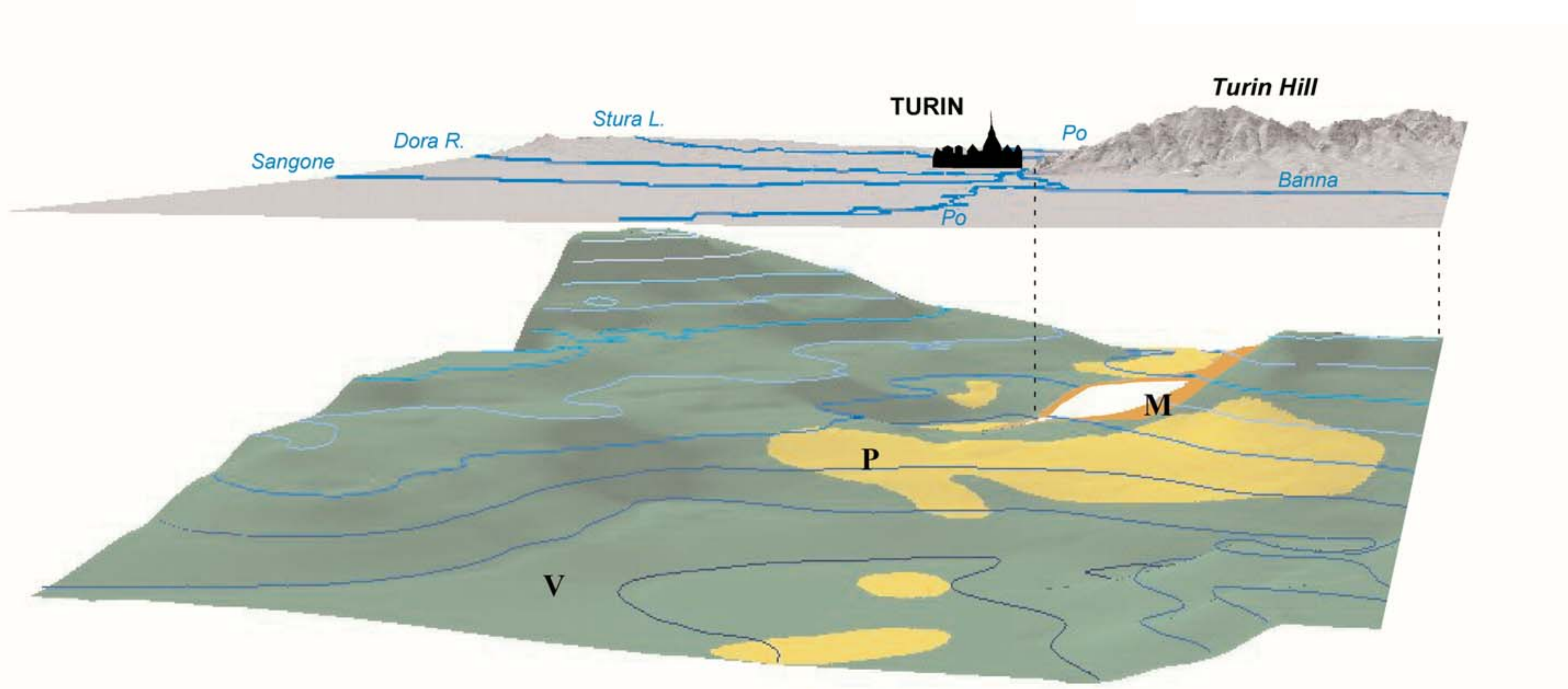


Fig. 7 - *Block diagram showing the pattern of the lower bounding surface of Quaternary deposits and the nature of the local bedrock.*



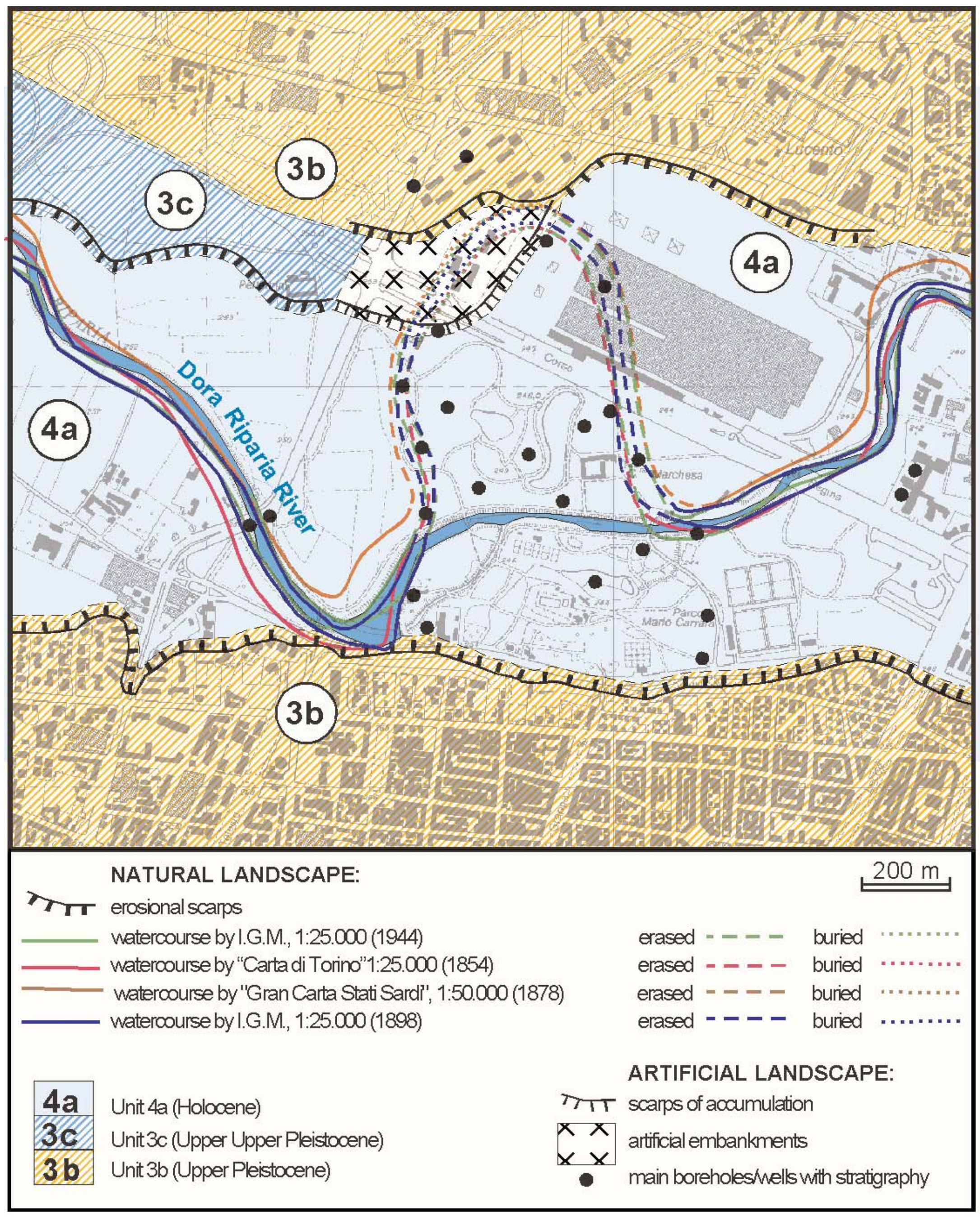


Fig. 8 - *Cartographic example of abandoned fluvial channel tracks, redrawn from historical documents.*

erosive events associated with lateral migration and avulsion.

The moderate thickness and generally coarse grain-size of the Quaternary deposits show that over time the recent geological evolution of this sector of the Po Plain was mostly characterised by erosive activity alternated with short and localised depositional episodes.

This suggests, therefore, that the geological evolution of this area took place during an active tectonic phase when the uplift of the main structural elements of the Turin Hill and Alps foothills mostly occurred.

RESULTS AND OUTSTANDING ISSUES

The advantages offered by this new way of mapping Quaternary continental deposits can be summarised as follows:

- The distribution of each stratigraphic unit of comparable age is visible at first glance, making this kind of map an easy-to-read and useful tool for geological understanding;
- The colour graphic textures used allow the identification of the catchment basins for each single unit;
- The use of a limited number of colours simplifies the legend at the side containing the colour palette.

As far as interpretation is concerned, this new type of geological map of the western River Po Plain -besides providing more correct and complete information on the geological evolution of the area as supported by geochronological and lithologic data- shows some key findings concerning the deviation of the River Po, which is the main event in the

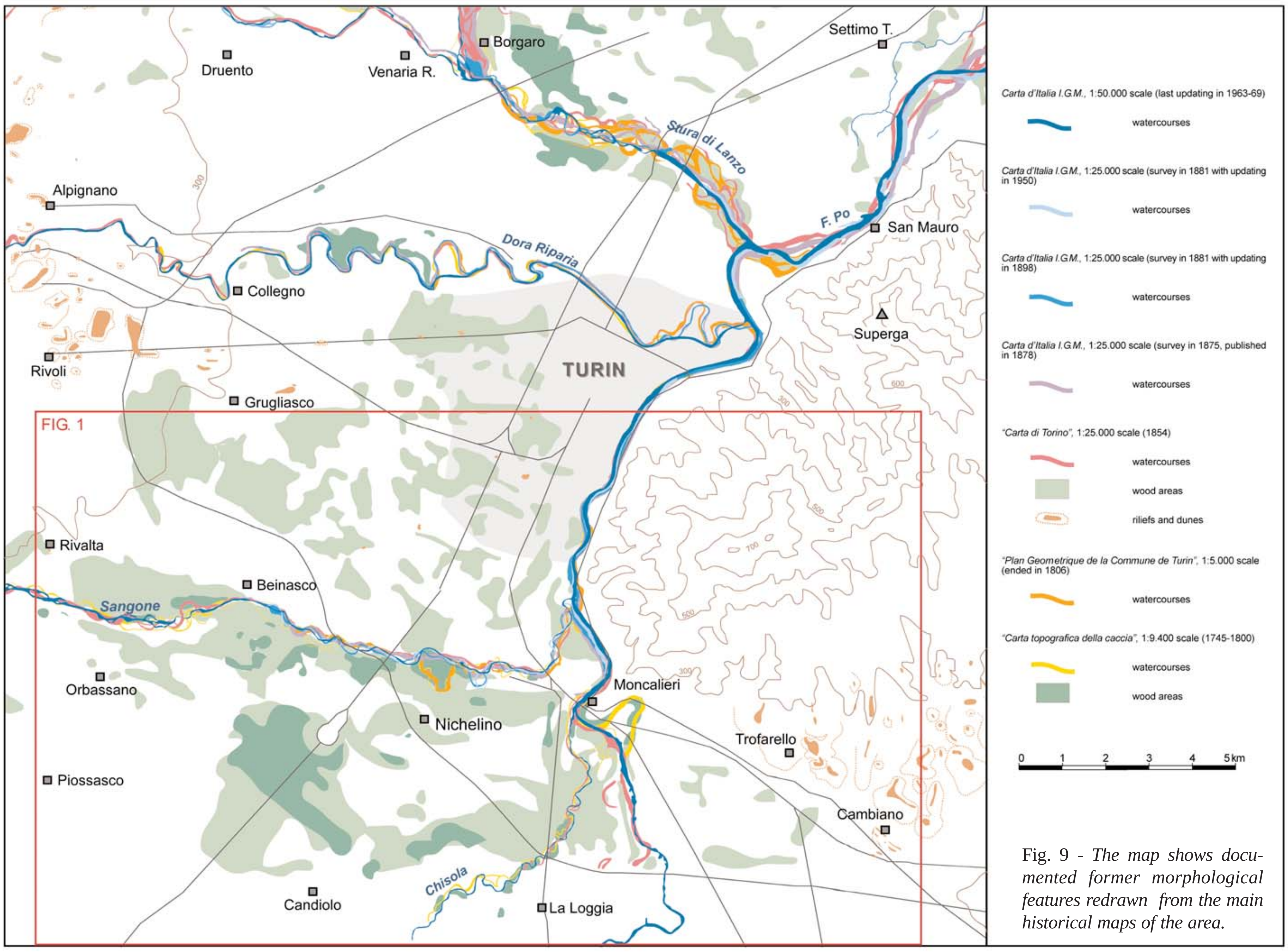


Fig. 9 - *The map shows documented former morphological features redrawn from the main historical maps of the area.*

Quaternary evolution of the entire area. This information would have been impossible to highlight on a traditional geological map where no distinction would be made between deposits genetically related to different catchment basins. This type of map also provides important information that can be used as reference for economic geology. For example, the segment of the River Po channel downstream from the point of the paleo-Po diversion (point 1 in Fig. 4) developed on coarse gravels overlaid by clayey silts. Based on the reconstruction suggested in Fig. 5, the gravels which belong to the Alloformation of the "Madonna del Gerbido" are genetically connected to the palaeo-Tànaro basin, when this river was still a tributary of the neo-Po . It is therefore clear that the potential removal of gravel from the Po bed in the Turin area could never be rebalanced by the sedimentation of the Po, since currently the junction of the Rivers Tànaro and Po occurs some 90 km downstream from the Turin area.

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