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Stratigraphic Revision of the Subsoil of the Southern Turin Plain for Hydrogeologic Purposes

Revisione stratigrafica del sottosuolo della pianura torinese meridionale a fini idrogeologici

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ABSTRACT - The paper describes the geologic and hydrogeologic framework of the subsoil of the Southern Turin Plain (Northwestern Italy). The analysis of borehole logs allows the construction of detailed lithostratigraphical cross-sections oriented E-W and N-S; their interpretation led to the recognition of a succession of sedimentary bodies, indicated as Term 1, 2, 3, 4 and 5 from the older (Lower Pliocene) to the younger (Holocene). Taking into account the literature data, their recognition has been made based on: stratigraphic position, texture, occurrence and distribution of fossils, compaction and color indexes. Each term is confined by erosion surfaces marked by sharp changes in lithology and occurrence of palaeosoils. From the stratigraphic reconstruction the base of the shallow unconfined aquifer has been singled out; such base is represented by the occurrence of fine-grained deposits adequately thick and continuous to provide the confinement of the underlying aquifers.

KEY WORDS: Subsoil, Stratigraphy, Hydrogeology, Turin Plain.

RIASSUNTO - La ricerca, basata sull'integrazione a fini idrogeologici delle numerose conoscenze geologiche sul sottosuolo della pianura torinese meridionale, è stata condotta attraverso l'analisi di numerose stratigrafie di pozzi per acqua e sondaggi geognostici. Le osservazioni circa la costituzione, la geometria e i rapporti reciproci dei diversi corpi sedimentari hanno permesso di effettuare una dettagliata ricostruzione stratigrafica del sottosuolo. In particolare, l'accurato esame delle descrizioni dei sedimenti riportate nelle stratigrafie e il confronto con i dati forniti dalla letteratura, hanno portato al riconoscimento di una successione di corpi sedimentari delimitati da superfici di erosione a scala regionale. La geometria e lo spessore di tali unità allostratigrafiche, suddivise in cinque termini riferibili all'intervallo temporale Pliocene inferiore - Olocene, sono state definite sulla base di un insieme di elementi tra cui l'andamento delle discontinuità, la posizione stratigrafica, le caratteristiche litostratigrafiche, la distribuzione del contenuto fossilifero all'interno delle diverse facies, il grado di addensamento e di pedogenesi dei sedimenti. Sono state realizzate alcune sezioni litostratigrafiche di dettaglio, con scala 1:10.000 per le lunghezze e 1:1.000 per le altezze, ed una nuova ricostruzione stratigrafica in parte differente rispetto alle precedenti ricostruzioni, definite unicamente su base litostratigrafica. La ricostruzione del sottosuolo ha permesso di identificare la base dell'acquifero superficiale, i.e. della falda a superficie libera, grazie alla presenza di un livello di depositi fini adeguatamente continuo da fornire un certo grado di confinamento degli acquiferi sottostanti.

PAROLE CHIAVE: Sottosuolo, Stratigrafia, Idrogeologia, Pianura torinese.

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1. - INTRODUCTION AND PREVIOUS WORK

The aim of this paper is the description of the geologic and hydrogeologic framework of the subsoil of the Southern Turin Plain (fig. 1). The study is a joint project of Provincia di Torino and Università degli Studi di Torino. Its purpose is to provide the public administration of a map indicating the bottom of the unconfined aquifer for the enforcement of the Piedmont Regional law of April 30 1996, N. 22 entitled "Ricerca, uso e tutela delle acque sotterranee", an act aimed to protect the groundwater of the deep confined aquifers. In future regulations, the base of the unconfined aquifer will represent the maximum depth reachable by water wells for industrial and agricultural use, whereas deeper wells reaching the underlying confined aquifer will be used only for pumping drinking water.

A lot of research has been done on the Southern Turin Plain and adjacent territories. Among pioneer studies are those by SACCO (1890, 1912, 1924, 1933, 1935), SACCO *et alii* (1924) and GABERT (1962). Later, other important geological studies were conducted by BORTOLAMI *et alii* (1969), CARRARO & PETRUCCI (1969), CARRARO *et alii* (1969, 1995), CARRARO (1976, 1996), FORNO (1979, 1980, 1982), CARAMIELLO *et alii* (1996).

Investigations that include lithostratigraphical and hydrogeological reconstructions were conducted by BORTOLAMI *et alii* (1976, 1980, 1989, 1990), TROPEANO & CERCHIO (1984), TROPEANO *et alii* (1984), DE LUCA (1990), CORDERO HIDALGO *et alii* (1992), COLLO (1995), CANAVESE *et alii* (1999), LUCCHESI (2001).

Fig. 1 - Location of the study area in the Southern Turin Plain.
- L'area di studio nella pianura torinese meridionale.

2. - WELL DATA, METHODS

This work has been carried out in three distinct phases. A preliminary assessment of existing data represented by the critical examination of the specific scientific literature and the analysis of borehole logs. The latter have been acquired from Servizio Gestione Risorse Idriche-Provincia di Torino and Dipartimento di Scienze della Terra-Università di Torino. Well locations have been plotted on a 1:10.000 scale topographic map. Lithostratigraphical cross-sections directed E-W and N-S have been traced in the Southern Turin Plain, particularly rich in well logs.

Cross-sections have been realized projecting on the topographic profile scale 1:10.000 the logs occurring in a range of 250 meters from the trace of the section, using a 1:1.000 vertical scale. The stratigraphic logs provide the following lithologic characteristics: lithofacies, color and compaction of sediments, occurrence of fossils, palaeosoils, peat deposits and cemented levels.

The main problems encountered in this phase have been the scarcity of deep well logs and the terminology used for core descriptions. In particular, fine deposits such as fine sand, silt and clay are collectively described as "fines" and only the coarse deposits have been distinguished in coarse sand, gravel and cobble.

Sharp lithologic changes related to erosional surfaces have been interpreted with the help of existing literature data and correlated among cross-sections. The distinction between Pleistocene and Holocene fluvial deposits revealed to be extremely difficult and the two units were kept together.

The use made in this paper of erosional surfaces and allostratigraphic principles to interpret sedimentary successions is accompanied by the indication of the traditional stratigraphic units used by previous Authors (MATTIROLO *et alii*, 1913; BORTOLAMI *et alii*, 1969).

3. - STRATIGRAPHY

A careless interpretation of stratigraphic data has lead to recognize a succession of sedimentary bodies, indicated as Terms 1, 2, 3, 4 and 5 from the oldest to the younger. Their individuation has been made on the bases of elements like stratigraphic position, texture, occurrence and distribution of fossils, color index, correlated to the literature data. Each term results separated by the contiguous ones by erosion surfaces interpreted by stratigraphic data on the bases of quickly changes in lithology and occurrence of palaeosoils.

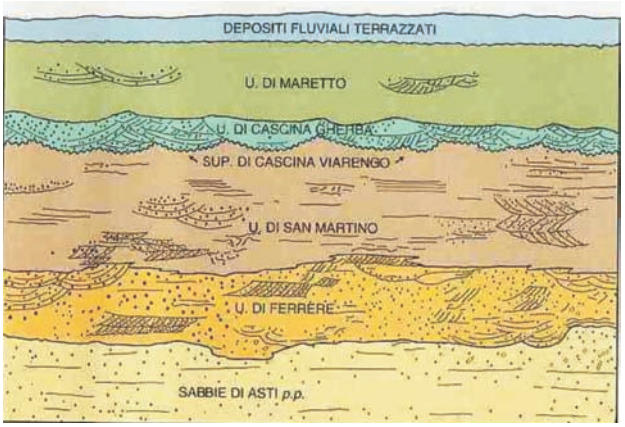

Fig. 2 - The Villafranchian stratigraphic sequence in the Villafranca d'Asti type-area.
- La sequenza stratigrafica villafranchiana nell'area-tipo di Villafranca d'Asti.

The Term 1a is represented by Lower Pliocene outer-shelf clay and clayey marls, known in literature as Argille di Lugagnano: these sediments, characterized by a grey-blue color and the abundance of fossils, occur in correspondence of the southern side of the Collina di Torino.

The Term 1b consists of Middle Pliocene sandy sediments, sometimes presenting slight silty levels, mainly corresponding to the littoral sediments indicated in literature as *Sabbie di Asti*. Generally, such sediments result well recognizable by stratigraphic data cause of their sandy texture and the diffusion of marine shells. At the top, the Term 1b is comprehensive of the stratified sandy sediments, interpreted like a delta front cross and indicated as Ferrere Unit (fig. 2, 3; CARRARO, 1996).

In continuous deposition with the underlying sediments of Term 1b, fine deposits (silts with subordinated gravelly and sandy bodies) constitute the Term 2 (fig. 2, 3, 4), corresponding to the delta plain sediments named San Martino Unit (CARRARO, 1996); they can be referred to the Middle Pliocene Lower Complex of the "Villafranchian" sequence, described in the type-area of Villafranca d'Asti. This lithofacies can be easily recognized by a typical grey-blue color and the occurrence of continental invertebrate fossils, peat and lignite into the silty layers. The Term 2 is cut on the top by an erosional discontinuity surface, named Cascina Viarengo Surface, as revealed from surface data in the type-area of Villafranca d'Asti (CARRARO, 1996).

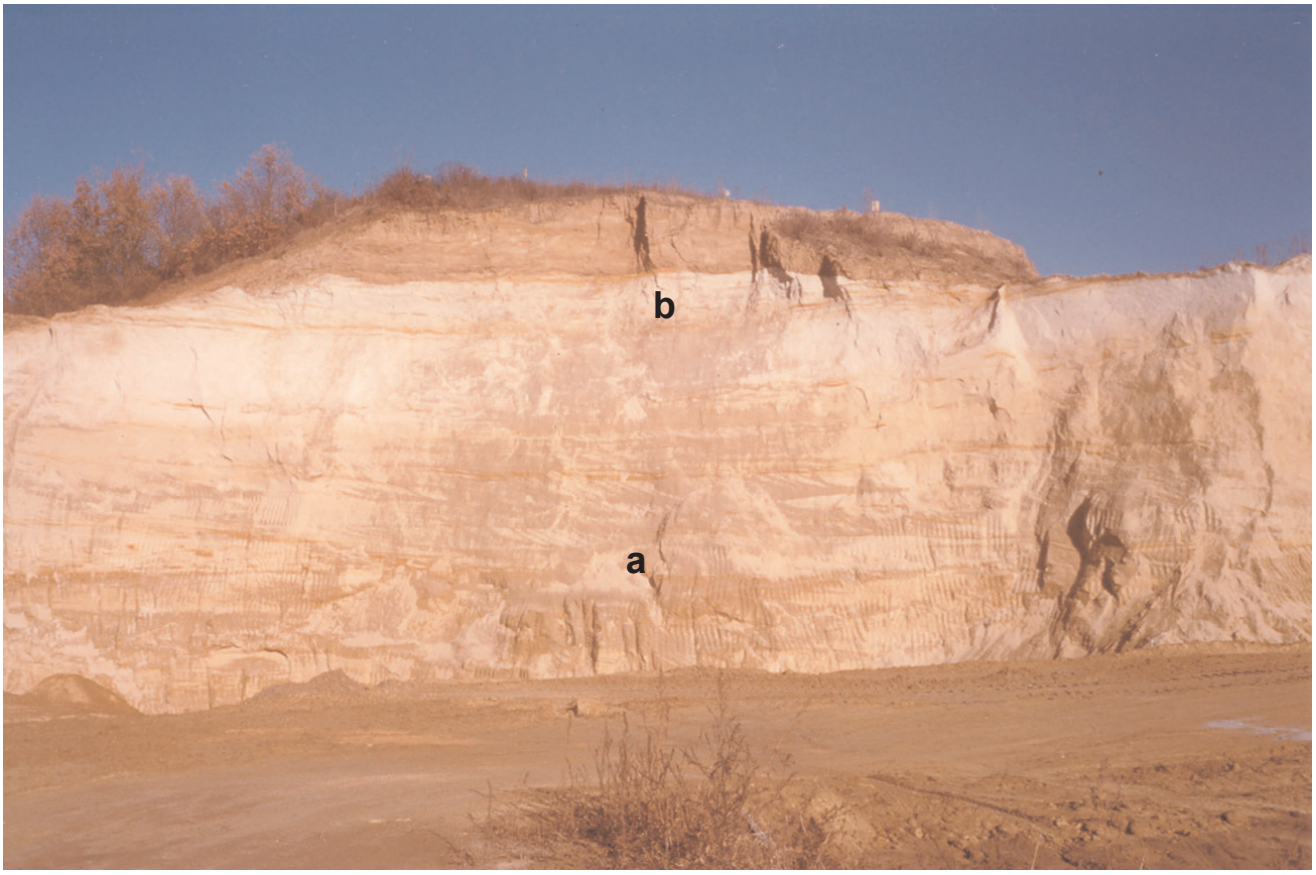

Fig. 3 - Term 1b and 2: delta front sediments of the Ferrere Unit (a) and delta plain sediments of the San Martino Unit (b).
- Termine 1b e 2: sedimenti di fronte deltizio dell'Unità di Ferrere e di piana deltizia dell'Unità di San Martino.

Fig. 4 - Term 2: delta plain sediments of the San Martino Unit.
- Termine 2: sedimenti di piana deltizia dell'Unità di San Martino.

On the sediments of Term 2 are placed the alternatively sandy-gravelly and silty-clayey deposits of Term 3 (fig. 2), corresponding to the fluvial deposits of Cascina Gherba Unit and Maretto Unit. They outcrop in the type-area of Villafranca d'Asti and are referred to the Lower Pleistocene Upper Villafranchian Complex. Also in this case, it has been impossible to distinguish the two units in the subsoil, cause of the lateral discontinuity of these sedimentary bodies. Even if structurally heterogeneous, these sediments are recognizable thanks to lack of fossils and their typical color, ranging from yellow to dark red, indicative of a developed pedogenesis. The Term 3 occurs only in the eastern part of the study area, because of erosion or lack of sedimentation westward (LUCCHESI, 2000, 2001). Between the Terms 3 and 4 are recognizable the S 3-4 erosion surfaces. They have local extent because linked to the different sedimentary basins of alpine fans. Besides, as expressions of fluvial terracing, such surfaces are very articulated and chronologically differentiated, depending on the sector considered (fig. 5, 6, 7).

The overlaying fluvial deposits of Term 4 corresponds to sediments generally indicated as Mindel fluvial and outwash deposits or locally as Altopiano di Poirino fluvial deposits. They are characterized by a high degree of pedogenesis. In the study area, Term 4 is comprehensive of heterogeneous outwash deposits of the Rivoli-Avigliana Morainic Amphi-theatre, outcropping between Sangone and Chisola Valleys, the gravelly fluvial deposits occurring between Chisone and Sangone Valleys and the gravelly fluvial deposits buried in the subsoil of Southern Turin Plain (COLLO, 1995) and outcropping on the Altopiano di Poirino (FORNO, 1982). Fluvial clayey silts locally occur on the sequence top (fig. 5, 6, 7). Slightly terraced surfaces represent the morphologic expressions of Term 4 deposits in which sediments of the overlying term can be found. The occurrence of coarse gravel more than 10 meters thick characterizes Terms 4 and 5 with respect the underlying ones (fig. 5, 6), and diachronous erosion surfaces separating these last two terms can be recognizable by surface surveys (COLLO, 1995; FORNO, 1980, 1982).

Fluvial and outwash deposits equivalent to Riss and Würm referred to Upper Pleistocene and fluvial holocenic deposits have been considered together in Term 5. They are represented by gravel, sand, silt and clay.

The Upper Pleistocene sediments constitute a

heterogeneous ensemble: coarse gravel of alpine fans, fluvial-lacustrine alternating clayey silt, sand and gravel (outcropping between La Loggia and Vigone and, in the subsoil, between Vinovo and Trofarello) and the sands of the southern slope of Collina di Torino (fig. 8).

The Holocene sediments are constituted by sandy gravel and eastward by prevalent sand and subordinated gravelly and silty lens. They fill wide incisions in underlying deposits representing their rearrangement in fluvial environment.

3.1. - Cross-sections

The silty-clayey deposits of Term 1a can be evaluated only in a cross-section (fig. 8) near Trofarello. You can distinguish the Term 1b deposits by the upper ones thanks to the abundance of fossils and sand with respect to fine sediments, more prevalent in Term 2. As one can see by the cross-sections, no drill reaches the bottom of Term 1, so its total thickness remains unknown. Near La Loggia the top of Term 1b

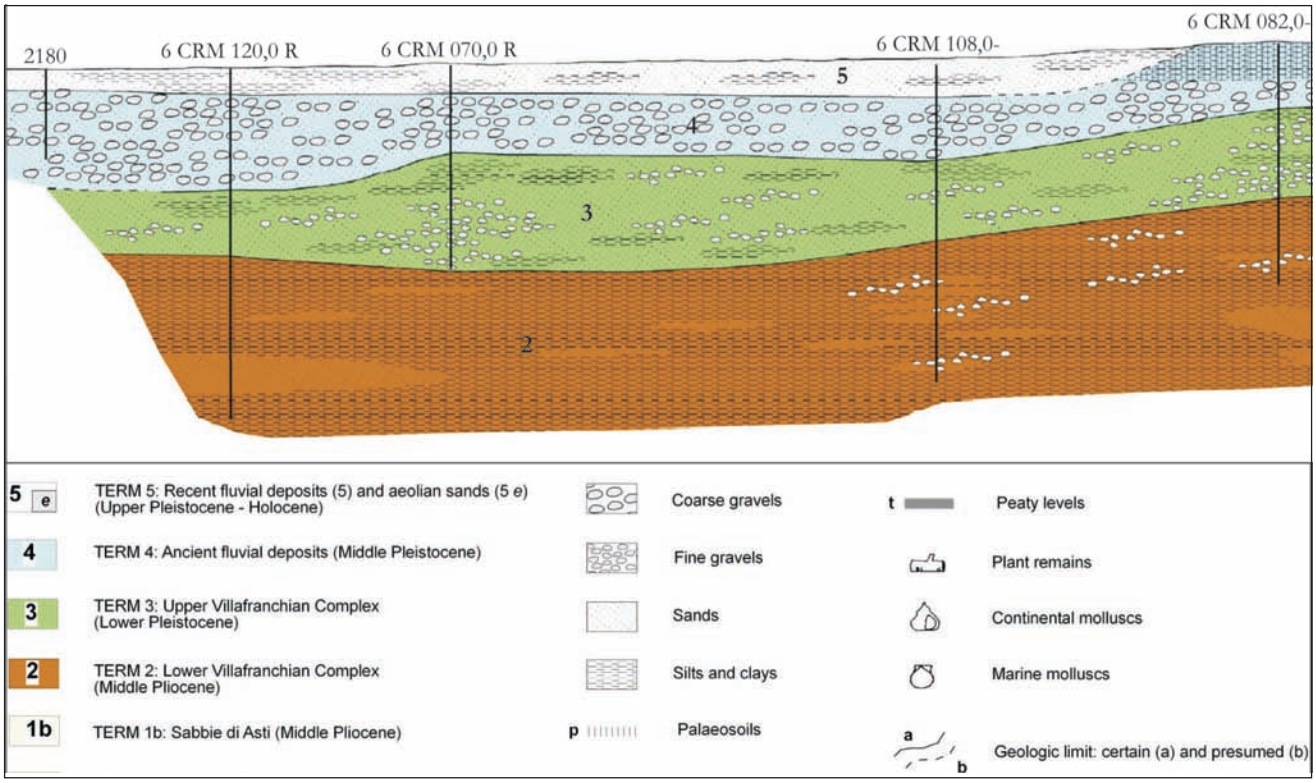

Fig. 5 - Cross-section in the Carmagnola Plain.
- Stralcio di sezione nella pianura di Carmagnola.

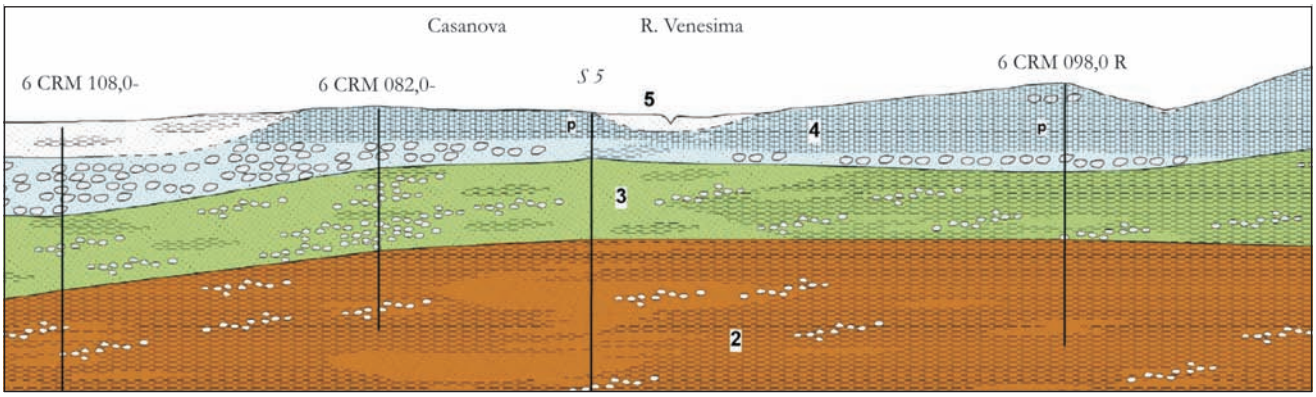

Fig. 6 - Cross-section in the Altopiano di Poirino (legend in figure 5).
- Stralcio di sezione nell'Altopiano di Poirino (legenda in figura 5).

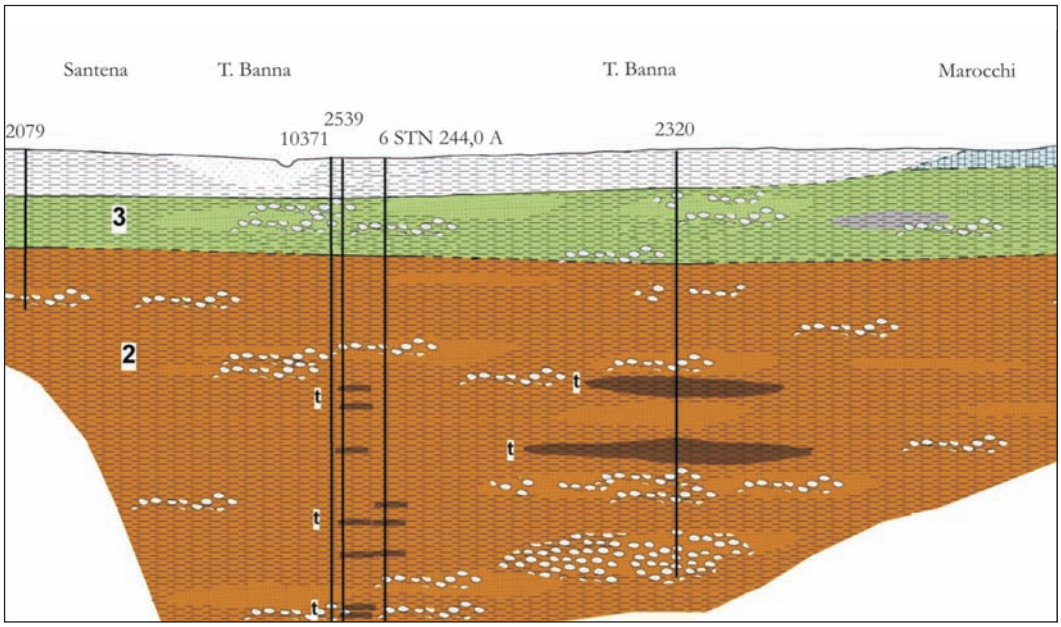

Fig. 7 - Cross-section in the Santena area (legend in figure 5).
- *Stralcio di sezione nell'area di Santena (legenda in figura 5).*

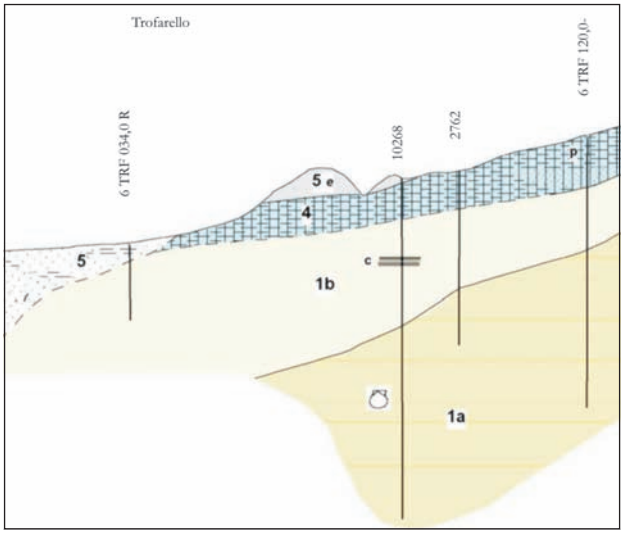

Fig. 8 - Cross-section of the southern slope of the Turin Hill (legend in figure 5).
- *Stralcio di sezione in corrispondenza del versante meridionale della Collina di Torino (legenda in figura 5).*

remount up to 30 meters below the ground surface and the Term 2 get thinner proceeding northward.

The deposits of Term 2, recognized in most of the stratigraphies, are distinguishable from the underlying ones cause of the prevalence of silt and clay, the grey and blue color, the lack of fossils in the sandy levels and the occurrence of vegetal remains and shells into the silty horizons. Lenticular bodies of gravelly sand of hectometric extent and metric thickness are distinctive of Term 2 (fig. 5, 6, 7), in accordance with the surface observations in the type-area of Villafranca d'Asti (CARRARO, 1996).

As emphasized by the cross-sections, the total thickness of Term 2 sediments is greatest in the center of the study sector, between Vigone and Carmagnola ranging from 100 to 180 meters and get steadily thinner northward by the buried extension of the Collina di Torino anticline.

Yellow-red color and lack of fossils distinguish the fine sediments of Term 3 from the underlain deposits, while the lens of gravel and sand are there more than 10 meters thick.

In most part of the study area, the thickness of Term 3 ranges from 30 to 40 meters (fig. 6, 7): it reaches 60-70 meters only by the southeastern border of the area.

According to CANAVESE *et alii* (1999), the relatively uniform thickness of Term 3 suggest a tabular shape for this sedimentary body.

The gravelly deposits of Term 4 occur in the study area along its entire extension. They are discontinuously covered by silty - clayey deposits showing a developed pedogenesis (fig. 6) by the outcrops of Altopiano di Poirino (FORNO, 1982) and Piossasco-Volvera sector (CARRARO & PETRUCCI, 1969). Surface studies indicate a thickness ranging from some to 20 meters.

The sediments of Term 5 outcrop to a large extent in the study area, filling the wide fluvial incisions of the underlain Terms. Generally they are represented by sands and subordinately lens of sandy gravel or clayey silt. A decrease of grain size can be noticed proceeding from West (Pinerolo) to East (Altopiano di Poirino). The extremely variable thickness ranges below 50 meters.

Difficulties in the distinction between Terms 4

and 5 have been encountered because of their lithofacies convergence and the lack of soil color data in the stratigraphies. In the cross-sections such a distinction has been made thanks to previous surface data and the occurrence of a gravelly sedimentary body, 20-30 meters thick and continuous on kilometric scale.

Peaty deposits can be found between Vinovo and Trofarello. Conglomerate levels of metric thickness seldom occur. On the bases of surface data (FORNO, 1979) aeolian sands showing a peak thickness of 10 meters have been identified.

4. - HYDROGEOLOGIC CONCLUSIONS

The subsoil reconstruction has allowed to identify the bottom of the shallow aquifer according to lithostratigraphic criteria. In the study example, such a surface is identifiable by the occurrence of the first level of fine deposits (silt, clay) adequately continuous to divide the set of coarse deposits representing the shallow aquifer from the sequence of alternating coarse fluvial deposits (gravel and sand) and fine lacustrine or swamp sediments (silt and clay) forming the deep aquifer complex.

In addition to the lithostratigraphy, other two criteria can be utilized for the reconstruction of the bottom of the shallow aquifer.

According to a hydrogeological criterium, the two aquifers can be differentiated by the confinement degree through rigorous well pumping tests. In the study case, the shallow aquifer is a retard drainage aquifer. The deep aquifer complex is characterized by aquifers with different confinement degree.

From a hydrogeochemical point of view, both major ions and isotopic composition (BORTOLAMI *et alii*, 1976) provide a good differentiation between shallow and deep aquifers. Pollution by human activities influences the quality of the groundwater of the shallow aquifer: the occurrence of chemicals (e.g. nitrates, pesticides, heavy metals, etc.) further differentiates its composition from the deeper aquifers one (fig. 9).

The geological reconstruction carried out in this work has allowed to apply the lithostratigraphic criterium by the individuation of the fine levels belonging to the Terms 2 and 3. They allow an effective separation between shallow and deep aquifers thanks to their lateral continuity. In this way, a map of the bottom of the shallow aquifer has been carried out covering the entire Turin Plain (fig. 10).

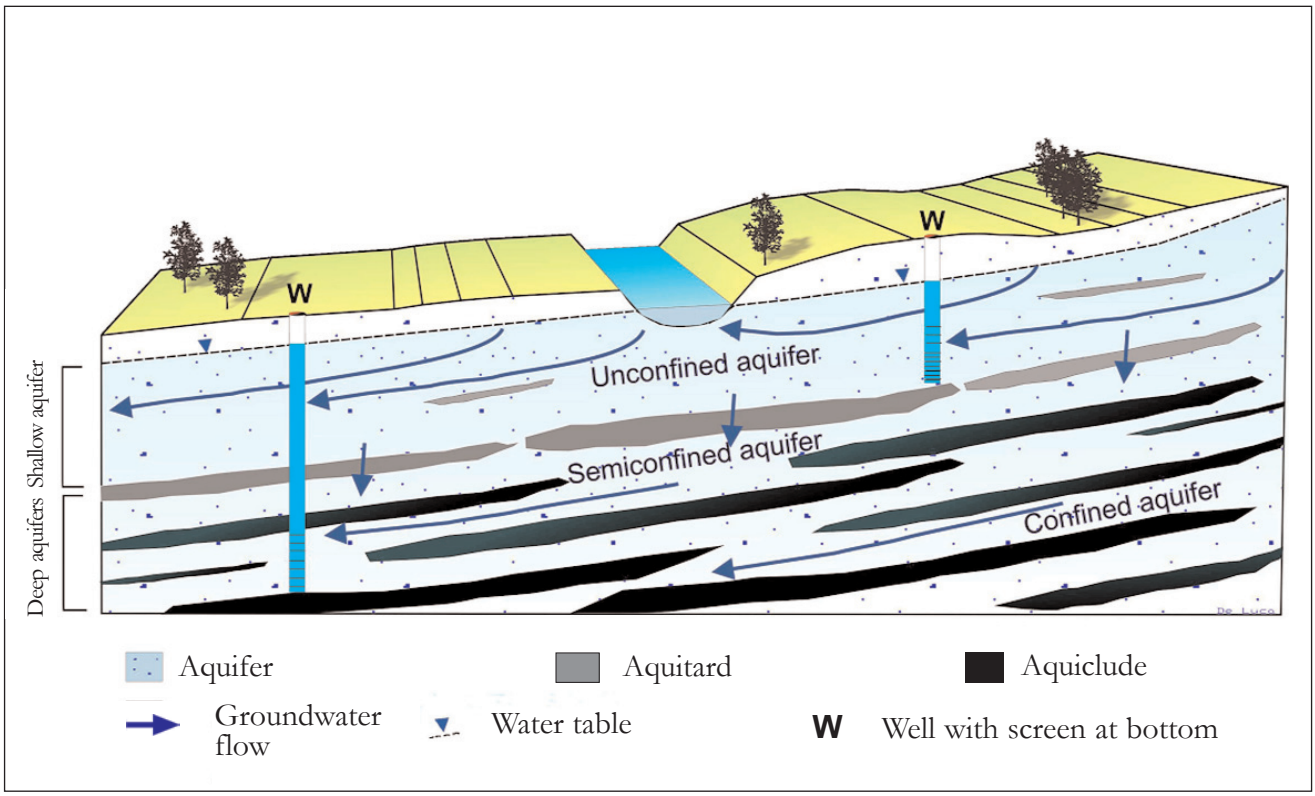

Fig. 9 - Hydrogeologic scheme of the study area.
- *Schema idrogeologico dell'area di studio.*

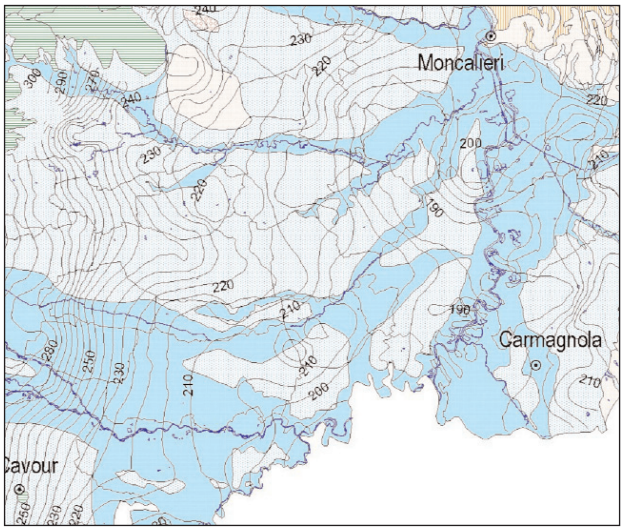

Fig. 10 - Contour map of the bottom of the shallow aquifer (m a.s.l.); Light blue: Late Pleistocene-Holocene alluvium; Gray: Middle Pleistocene alluvium. - *Carta della base dell'acquifero superficiale (m s.l.m.); Azzurro: alluvioni tardoplei stoceniche-oloceniche; Grigio: alluvioni mediopleistoceniche.*

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