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Stratigraphic revision of Brindisi-Taranto plain: hydrogeological implications

Revisione stratigrafica della piana Brindisi-Taranto e sue implicazioni sull'assetto idrogeologico

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ABSTRACT - The studied area is located at the eastern and western coastal border of the Brindisi-Taranto plain (Apulia, Italy). In these pages, new detailed cross-sections are presented, based on surface surveys and subsurface analyses by borehole and well data supplied by local agencies or obtained by private research and scientific literature, integrated with new ERT surveys. The lithostratigraphic units identified in the geological model have been ascribed to the respective hydrogeologic units allowing for the identification of the main aquifer systems:

- a deep aquifer that lies in the Mesozoic limestones, made of fractured and karstic carbonates, and in the overlying Lower Pleistocene calcarenite;
- a shallow aquifer that is formed by the middle-upper Pleistocene marine calcarenitic and sandy deposits overlying the lower Pleistocene clays, holding a phreatic ground water body.

The Brindisi sands are part of the shallow aquifer, constituting its lower hydrogeologic unit. The identification of this body permits the modification of previous models. The results of this research indicate the importance of the detailed geological mapping of the Brindisi – Taranto area particularly in order to clarify the stratigraphy and hydrostratigraphy of the Pleistocene successions. ERT data proved itself to be indispensable in the definition of the different hydrogeological units.

KEY WORDS: Brindisi – Taranto plain, Electrical Resistivity Tomography (ERT), Hydrogeologic units, Shallow aquifer, Stratigraphy.

RIASSUNTO - In questo articolo si propone una revisione stratigrafica delle unità della piana Brindisi – Taranto e se ne evidenziano le implicazioni sull'assetto idrogeologico. Rilievi geologici di superficie e del sottosuolo, sia attraverso l'osservazione diretta di carote di perforazioni sia mediante indagini ERT, hanno permesso di delineare gli assetti geologici e di reinterpretare i numerosi dati di sondaggi a disposizione. Definito il modello geologico sono state individuate le unità idrogeologiche che costituiscono i due acquiferi principali. Il primo, profondo, soggiace tutta l'area di studio ed è costituito dai Calcari di Altamura mesozoici, permeabili per fessurazione e carsismo, e dalle Calcareniti di Gravina pleistoceniche, permeabili per porosità. Il secondo superficiale, è costituito dai depositi pleistocenici calcarenitici e sabbiosi permeabili per porosità, ed è sorretto dalle argille anch'esse pleistoceniche. L'identificazione all'interno di questo secondo acquifero, della unità delle Sabbie di Brindisi, che ne costituisce la parte inferiore, consente di modificare i precedenti modelli geologici ed idrogeologici. Le ricerche effettuate mettono comunque in evidenza la necessità di maggiori studi di dettaglio con particolare riferimento ai depositi pleistocenici. A questo scopo, a causa dell'estensione nel sottosuolo di queste unità, quasi ovunque mascherate dalle coperture continentali recenti, indispensabile sarà l'uso e lo sviluppo delle metodologie ERT che si sono dimostrate altamente affidabili e risolutive.

PAROLE CHIAVE: Acquifero superficiale, piana Brindisi – Taranto, Stratigrafia, Tomografia Geoelettrica (ERT), Unità idrogeologiche.

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1. - INTRODUCTION AND PREVIOUS WORKS

The studied area is located at the eastern and western coastal border of the Brindisi - Taranto plain (fig. 1), that is part of the Apulian foreland. This is the emerged area of the Apulian Plate, consisting of a thick basement made of Mesozoic limestones (SELLI, 1962; D'ARGENIO *et alii*, 1973; D'ARGENIO, 1974; RICCHETTI, 1980; CIARANFI *et alii*, 1983). They are covered by Plio-Pleistocene deposits, resulting from the sedimentary cycle of the Bradanic foredeep (RICCHETTI *et alii*, 1988; RICCHETTI, 1967, 1980; DOGLIONI *et alii*, 1999). Gravina Calcarenite (yellowish calcarenites of Early Pleistocene) and subapennine Clays (grey-blue silty clays of Early Pleistocene) represent the litho-stratigraphic units of this cycle in the studied area (CIARANFI *et alii*, 1992). These deposits are covered by marine terraced bioclastic deposits (Middle-Late Pleistocene) (BENTIVENGA *et alii*, 2004) and by Holocene to recent continental deposits. In accordance with this geological model a deep regional karsic aquifer in mesozoic carbonate rocks and a shallow aquifer in Terraced Deposits have been identified (COTECCHIA, 1977; CHERUBINI *et alii*, 1987; RICCHETTI & POLEMIO, 1996).

Detailed biostratigraphical (COPPA *et alii*, 2002) studies have assigned to Early and Middle Pleistocene a sequence of yellowish muddy sands cropping up along the Brindisi sea–cliff about one kilometre south of our study site. The Authors do not identify contact with the overlying and underlying units and indicate the uncertain and discordant ascriptions of this sequence in literature (DI GERONIMO, 1969; GENTILE *et alii,* 1996) to formal lithostratigraphic units.

In the Taranto area, also BELLUOMINI et *alii* (2002) describe a transgressive clayey – sandy unit (about 4m thick) overlying the subapennine Clay Formation that is attributable to the Middle Pleistocene age; lack of borehole log data do not permit the assessment of the extension and thickness of this unit in the subsurface.

Our purpose is to clarify the geological and geophysical features of the subsoil for hydrogeologic purpose. This work has been carried out in five distinct phases. The first is the geological study that was organized in surveys of the surface and of the subsoil via direct observation of borehole cores (figg. 1, 2, 3); the second is characterized by the identification of existing wells in the area, collection of stratigraphical data (about 1000, figure 1 and 3) drawn from borehole cores and supplied by local agencies, from private research and from scientific literature (RADINA, 1968; TEDESCHI, 1969). The distribution of the data deriving from the well stratigraphic logs is homogeneous in the Brindisi – Taranto plain (fig. 1) but, in the Brindisi area numerous borehole and piezometer logs have been carried out to assess the contamination from some industrial sites (fig. 2). In the third phase these data have been processed taking into account the geological model. The collated data have been inserted in input to a Geographical Information System (GIS). In this phase, also the hydrological and geotechnical data (piezometric levels, flow, permeability of the various formations, physical and granulometric characteristics) available from private research and scientific publications (CHERUBINI *et alii*, 1987) have been processed. In the fourth phase, ERT surveys were carried out in particular selected areas in order to clarify the features of the shallow aquifer. The Electrical Resistivity Tomography (ERT) is widely used in the detection and investigation of shallow-depth targets. ERT has been applied with great success in solving geological (LEUCCI *et alii*, 2004, CARDARELLI, 2006) and hydrogeological (FURMAN *et alii*, 2004, MARGIOTTA & NEGRI, 2005) problems. In the fifth phase, the hydrogeologic units and the main aquifer systems have been defined and parametrized.

2. - MORPHOLOGICAL SETTING

The morphology of the area is characterized, both on the Adriatic and the Ionian coast, by a broad plain, slightly sloping towards the sea, in many places marked by a drainage network made of small natural and/or man-made channels. The altitude is between 30 and 40m asl, decreasing towards the coastal zone. The Adriatic coastline in the surrounding area of "Cerano" power station is composed of a vertical cliff that reaches a maximum height of 15m. Cliff height decreases northward until it gives place to a number of coastal depressions whose bottom is bsl (e.g. the "Salina Vecchia").

The drainage system in the area is well developed. It is characterized by numerous shallow channels that in many cases run directly into the sea (e.g. "Fiume Grande", "Foggia Rau", "Fiume Piccolo", "Canale Palmarini – Patri", "Canale Cillarese"). Some of them are cut by the present cliff whereas the lower course of main streams has been submerged due to Holocene sea level rise, forming narrow inlets like the "Canale Pigonati", "Seno di Levante" and "Seno di Ponente", which form the natural port of Brindisi.

Watersheds are hard to identify. Numerous smaller channels flow into broad depressions which are very prone to flooding. There is a broad marshy area near the mouth of the "Canale di Scarico".

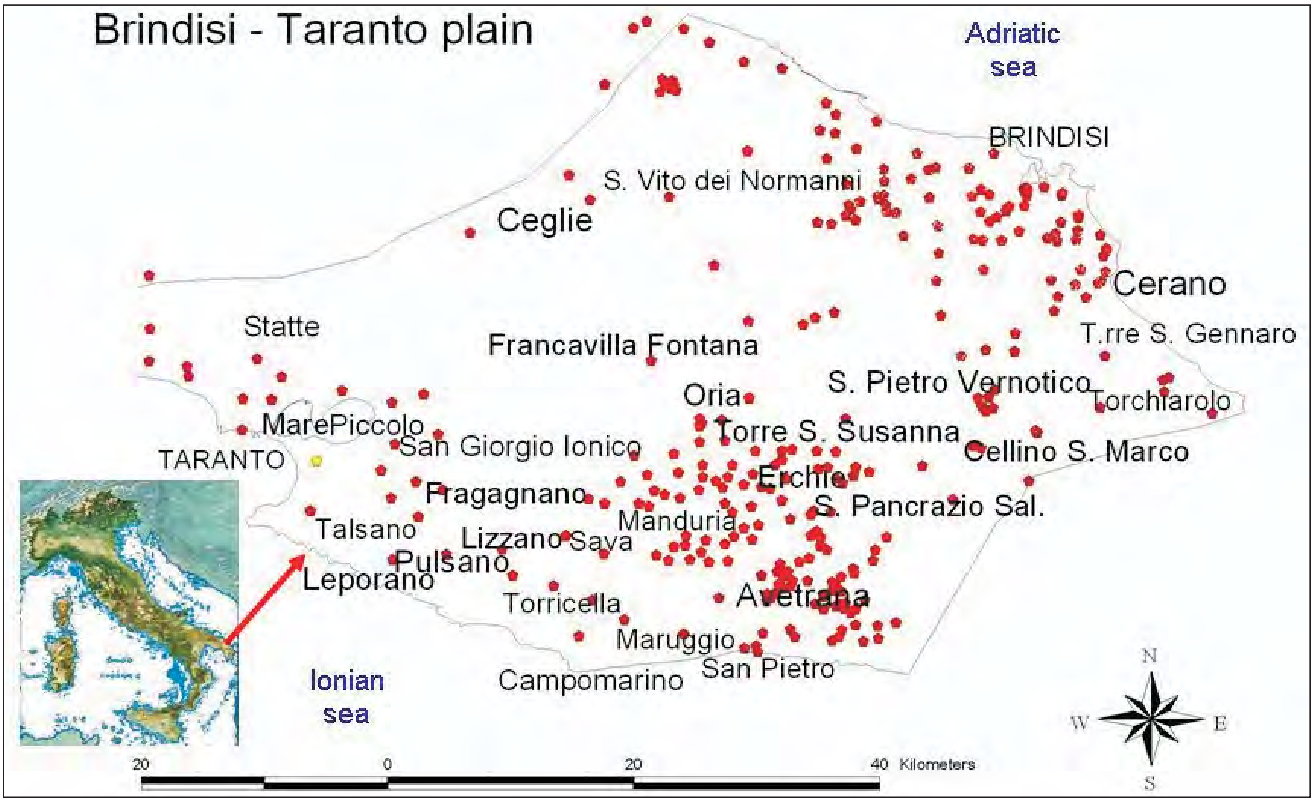

Fig. 1 – Collected well data in the studied area.
– *Area di studio con ubicazione dei dati a disposizione provenienti da carote di perforazione.*

On the Ionian coast, the area is marked by wet zones, dune belts, lagoon areas and coastal springs (fig. 4). The drainage system, in this area, is well-developed but, in many places, it has a temporary character; as usual in karst areas, it is of secondary importance compared to the ground water circulation. Infiltration of water through the most fractured zones in the carbonate rock mass enhanced the development of karstic phenomena as sinkholes. At these sites, rapid infiltration of surface water in the subsoil is prevailing.

This area has been strongly influenced by human activity. Especially over the last few decades, reclamation works have strongly modified the drainage network and have been responsible for the filling of the main depressions which marked the area.

3. - STRATIGRAPHY

The geological surveys integrated with borehole data (figg. 1, 2) have allowed us to define the geological models of the area (fig. 3, fig. 6), to determine the thickness of stratigraphic units (fig. 5), to realize numerous two-dimensional cross sections (figg. 7, 8) and to identify under-investigated areas.

Altamura Limestone (Late Cretaceous) outcrops corresponding to the Murge hills, immediately to the west of the Brindisi area, and to the east of the Taranto one; the succession is made of alternating limestones and dolomitic limestones, both micritic, compact and tenacious, whitish, light grey or hazel in colour, in layers from a few centimetres to about 1m thick. In places, the layers appear densely laminar; flakes may be easily broken off pieces of the rock. The outcrops have a thickness of a few metres only, in places covered by topsoil. Greater thickness (up to 30-40m) is visible in the quarries located near the area under study, some of which are still in use while others are used as waste dumps. In many places layers are fractured and disjointed. There are few macrofossils, characterized by fragments of rudist, with smaller amounts of coral and bivalves. The top of the carbonatic basement is found at variable depths in nearby areas, due to the presence of NW-SE striking faults with offsets of several decametres. In general, the top of this formation deepens mo-ving from the “Murge” hills, where the Cretaceous limestones outcrop out at elevations of about 35–40m, towards the sea. Along the Ionian coast, the top of this formation is at about 280 m (fig. 5) bsl while, on the eastern side (fig. 8), the top of the formation deepens from the south of the investigated zone (Cerano power station, where the top is 20 m

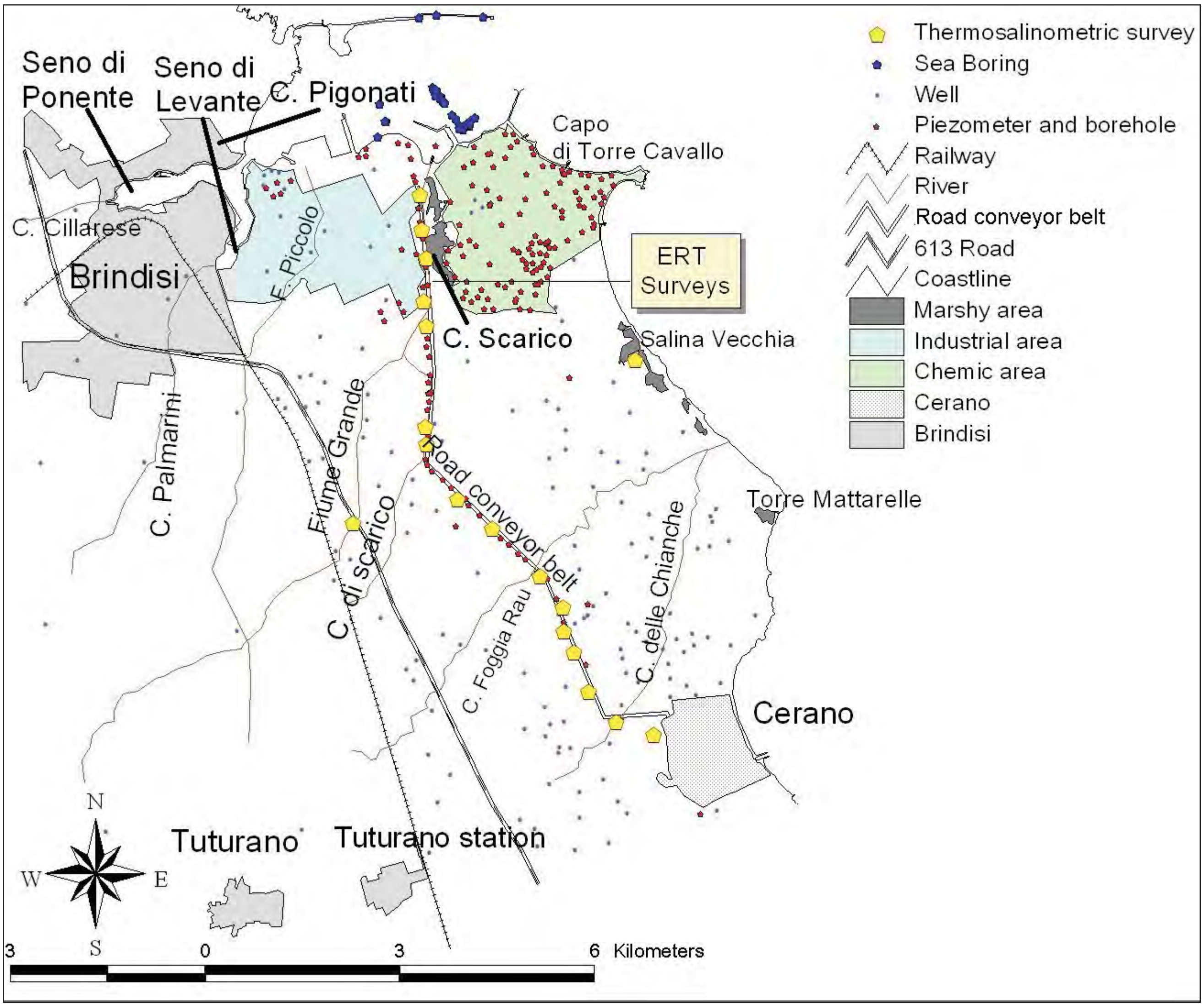

Fig. 2 – Brindisi area with location of the piezometer and borehole logs available.
– *Area di Brindisi con ubicazione dei dati a disposizione provenienti da sondaggi e piezometri.*

bsl) towards the north (Brindisi port, where the top is 90 m bsl).

A unit of whitish – greyish micritic limestone interbedded with centimetre-scale layers of whitish limestone and laminated yellowish calcareous marls, silt and clays, with paleosols and lignite layers was recognized in a borehole log near Talsano. It has been correlated with the Galatone Formation (Late Oligocene), that was recently formalized by BOSSIO *et alii* (1999) in the nearby Salento Leccese area. The permeability of Galatone Formation is variable, due to the different lithological types.

Gravina Calcarenite is the most ancient of the Early Pleistocene formations of the area. This unit outcrops in the inner part of the study area and can be observed in the quarries near Avetrana, Manduria and Sava, on the western side of southern Apulia, because the rock is used as building material. It overlies, with angular unconformity, the Cretaceous basement, and consists of yellow coarse-grained calcarenite with abundant fossils. The thickness of the formation varies considerably and reaches maximum values of more than 30 m at the eastern coast and 45m at the western one.

The subapennine Clays (Early Pleistocene) formation is made of clays and grey-blue sandy clays, rich in fossils. These deposits can be defined as sands with clay; nevertheless, there is considerable variation in the dimensions of the grains. The percentage of sand varies from 2% to 55%, that of silt about 10%; the average carbonate content is 31%; this value increases moving towards the underlying Gravina Calcarenite. Inside the formation, whose thickness is never less than several decametres, there are sandy layers of a grey-blue colour whose lateral and vertical extension is not easily measurable. The stratigraphical transition to the underlying Gravina Calcarenite has never been observed in outcrop. Along the eastern coast, the thickness of this formation varies greatly from a few metres to over 50 m. Specifically, the thickness increases moving from the "Cerano" power station (average 20 m), placed at the southern limit of the investigated area, to the port of Brindisi, which is at the northern limit (average 45 m). Moving from west to east, the tops of the Mesozoic limestones and of the overlying Pleistocene calcarenite deepens, and the thickness of the subapennine Clays, which overlie the Pleistocene calcarenite, increases.

The top of the subapennine Clays is above sea level in the zone near the "Cerano" power station, while elsewhere the top is found at a maximum elevation of 29 m bsl. Along the western side, two distinct intervals can be distinguished: the upper is made of grey to yellow-light brown, fine-grained sands with abundant diagenetic concretions. Moving downwards, there is an enrichment of the silty-clayey fraction, interlayered with sands from a few millimetres to centimetres thick. Overall thickness of this interval is about 10 m. The lower interval of the subapennine Clays can be defined as clays and grey-blue sandy clays. Within this interval, whose thickness is never less than several decameters, there are grey-blue sandy layers whose lateral and vertical extension is not easily measurable. This formation outcrops along several cliff faces along the Ionian coast. Along this side, the total thickness of the subapennine Clays increases, moving from the Murge towards the coast, reaching a maximum of 230 m in the subsoil (fig. 5).

The provisional and informal term of Brindisi sands is used by MARGIOTTA *et alii* (2008) to refer to sandy and silty-clayey deposits found in places between the Middle – Upper Pleistocene Terraced Deposits and the subapennine Clays along the coast of Brindisi. The type-section of this formation is located on the cliff near the "Cerano" power station (fig. 9) where it is about 12 m thick. The transition between the Terraced Deposits and this formation is characterized by an abrupt lithological variation (from diagenetic calcarenite to sands). The erosional contact with the underlying subapennine Clays is also visible here. In terms of granulometry, moving downwards, the transition

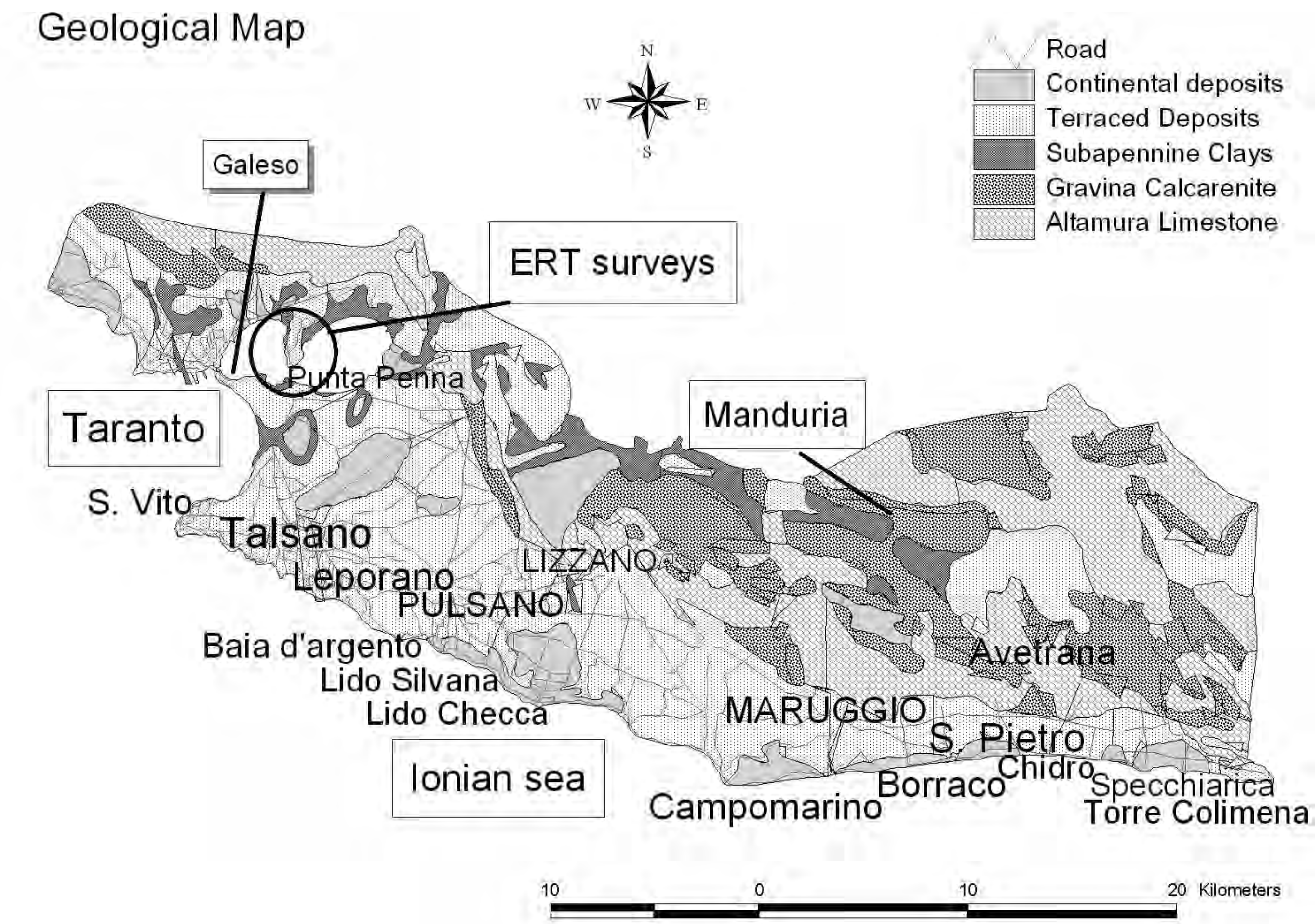

Fig. 3 – Schematic geological map of Taranto area.
– *Carta geologica schematica dell'area di Taranto.*

involves an enrichment of the silty-clayey fraction, interleaved with sandy layers a few millimetres or centimetres thick. The Brindisi sands are composed of fine-grained sands whose colour shifts from grey to yellow-light brown moving upwards; these sands contain abundant diagenetic concretions that are aligned in the upper part and become scattered moving downwards. The lower part of this formation is made up of clayey-sandy silts of grey colour, with carbonaceous fragments. In mineralogical terms, the grains of the sandy fraction are mainly made up of carbonate and quartz fragments. The clayey and sandy fractions comprise 35% to 38% of the lower part of the layer. The stratification is indistinct. The thickness of this formation varies from a few decimetres to 20 m. The mean thickness is about 13 m - 14 m. The age, according to its stratigraphic position, is Early-Middle Pleistocene.

Fig. 4 – Example of spring phenomena, the Chidro spring.
– *Esempio di manifestazione sorgentizia (Chidro).*

The Middle-Upper Pleistocene formation of the Terraced Deposits is lithologically composed of yellowish coarse-grained biocalcarenites with sandy layers or layers of organogenic limestones varying in thickness from a few centimetres to 15cm; in places, near the contact with the subapennine Clays, layers of very compact and tenacious limestones, a few decimetres thick, are present. The sandy facies is composed mainly of quartz grains, feldspars and carbonatic material of detritic and bioclastic origin; mica crystals are rare.

Grain-size of the sandy facies varies greatly de-

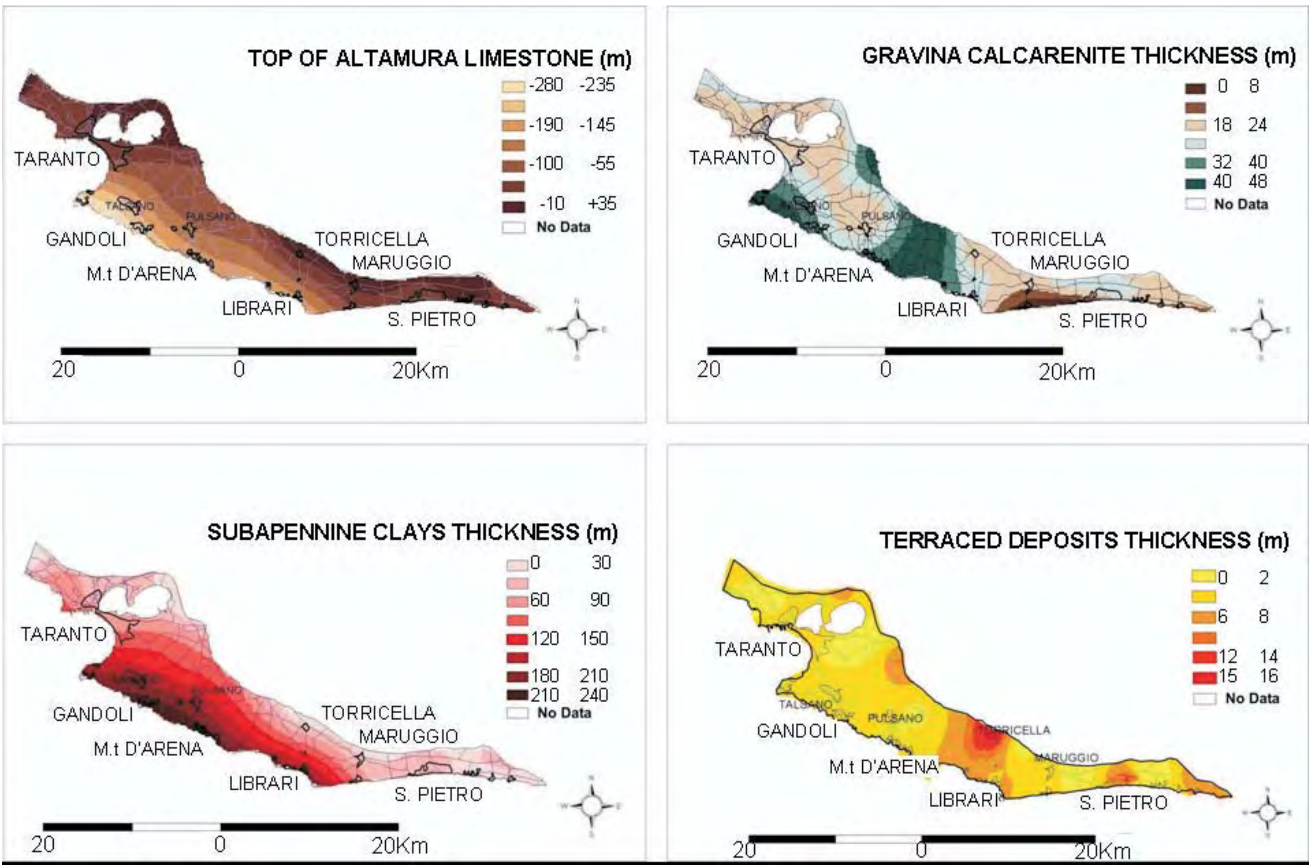

Fig. 5 – Thickness of the lithostratigraphical units and elevation map of the Altamura Limestone top in the Taranto area.
– *Spessori delle unità litostratigrafiche e mappa del tetto del Calcare di Altamura nell'area tarantina.*

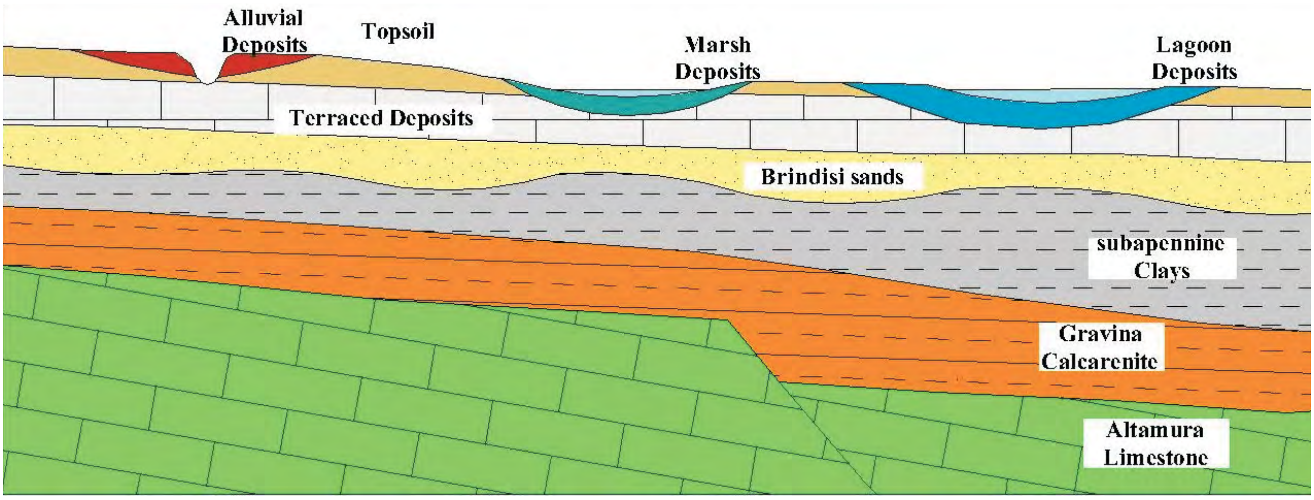

Fig. 6 – Stratigraphic scheme in Brindisi area.
– *Schema stratigrafico nel Brindisino.*

pending on the stratigraphical level (gravel: 0%-28%, sand: 3%-84%, silt: 2%-75%). The upper portion of the middle Pleistocene succession (Terraced Deposits) consists of marine sands and conglomerates forming several orders of terraces. These in turn are linked to sea level changes caused by the primarily glacio-eustatic phenomena that occurred in the Middle-Late Pleistocene age and/or to tectonic movement. The transition to the underlying subapennine Clays is in some places direct and in others through the interposition of Brindisi sands as described before (fig. 9). The contact of Terraced Deposits with the underlying subapennine Clays is characterized by an abrupt lithological variation (from diagenetic calcarenite to sands); this transition can be frequently observed in detail on the cliff of the western coast (fig. 10) near the "T.S. Vito, Leporano, Punta Penna, Baia d'Argento, Lido Silvana, Lido Checca" and inside some channels (for example S. Nicola channel). At Torre Castiglione and at the base of the Murge hillside, the contact with the Altamura Limestone is visible, characterized by evident angular discordance. It may be assumed that this formation extends discontinuous across the whole of the studied area. The thickness varies considerably, from a few decimetres to about 20 m, although the most frequent values are in the range of 5-6 m.

Continental deposits are constituted by marsh (maximum thickness of 25 m and degree of saturation very close to 100%), eluvial (maximum thickness of about 6.2 m and saturation level not high), alluvial (thickness between 40 cm and 8 m and saturation of 100%) and lagoon deposits (thickness between 60 cm and 9.6 m and degree of saturation of about 95%). Top soil lies over almost all the area under examination.

4. – ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT)

Geoelectrical prospecting was conducted in different places of the two studied areas aiming to determine the electrical properties of the units and to clarify the mechanism of formation of the spring phenomena. In this section we show two of the most important profiles conducted on the

eastern side of the Brindisi-Taranto plain, near two boreholes whose logs and stratigraphies were well-known and helpful for calibration of the geophysical model (fig. 2).

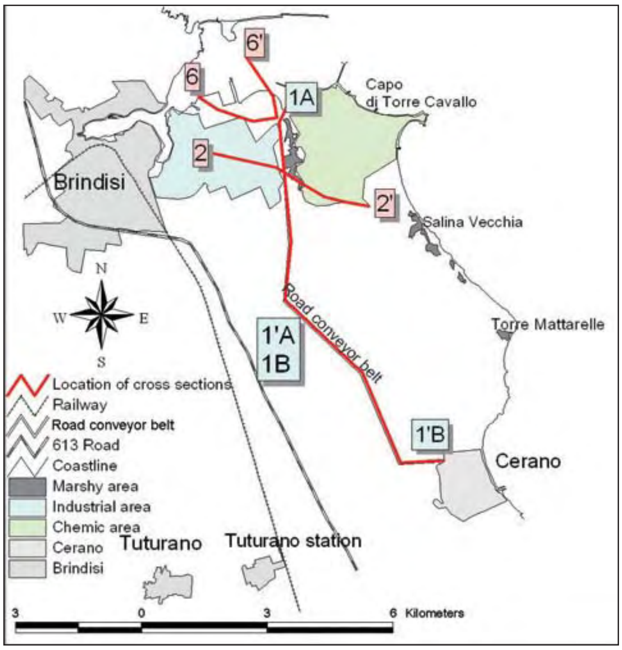

Fig. 7 – Location of the cross sections in the Brindisi area.
– *Ubicazione delle tracce delle sezioni geologiche del Brindisino.*

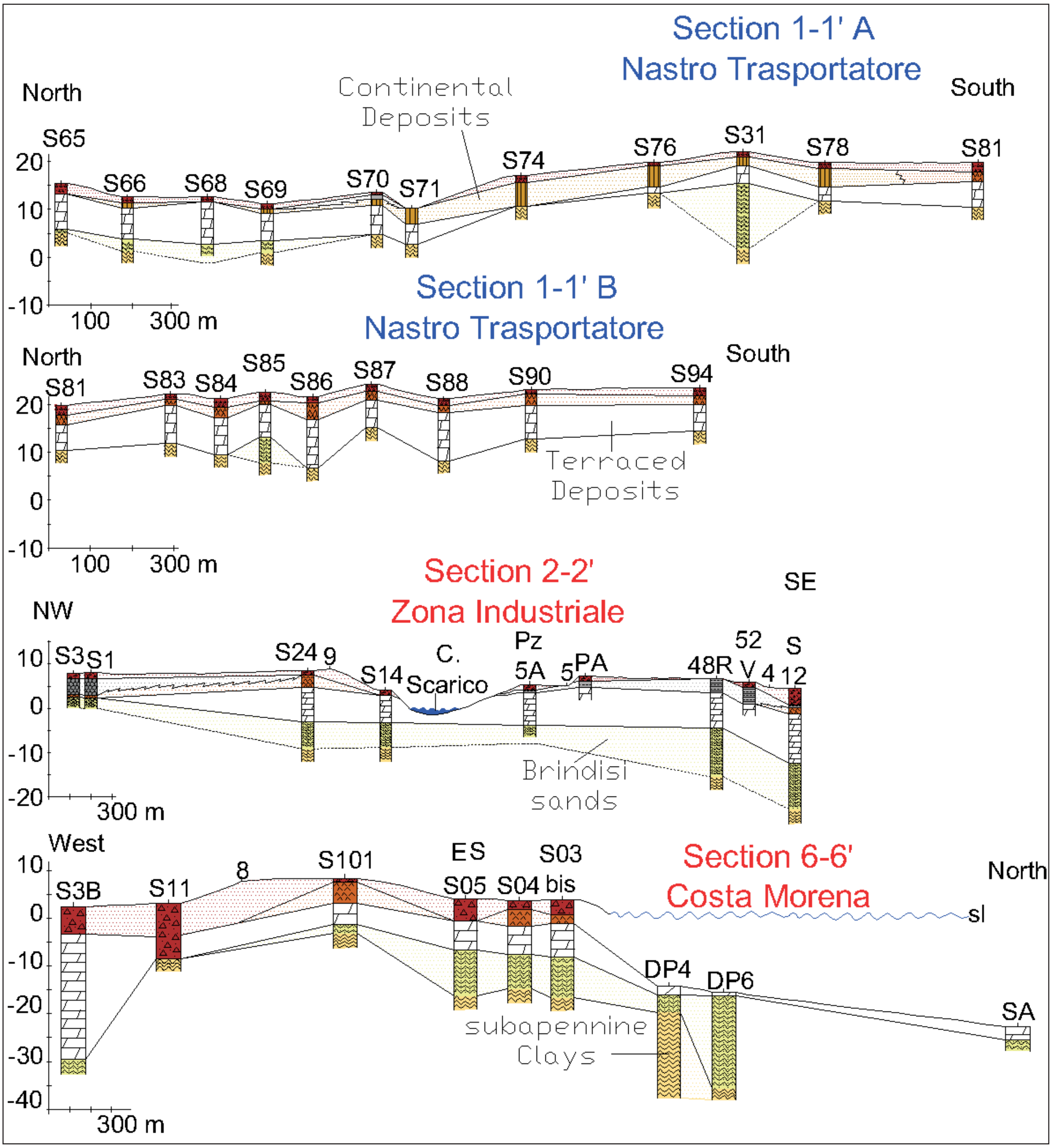

Fig. 8 – Cross sections in the Brindisi area.
– *Sezioni geologiche del Brindisino.*

Apparent-resistivity data were collected using a Syscal-R1 (manufactured by Iris instruments), in multielectrode configuration. To obtain 2D resistivity models, the measured data were processed using the smoothness constrained least square method. The finite-difference and finite-elements method was applied in order to calculate forward response of the geoelectrical models while Gauss–Newton optimization method was used to solve the inverse resistivity problem. The two software packets used were, in order, TomoLab, produced by Geostudi Astier s.r.l. and LOKE (2004) produced by Geotomo Software. The ERT results were compared with geological and hydrogeological data existing in the study area (boreholes S14 and S17).

The most significant ERT 2D models are shown in figure 10 related profile P5 and P6. The survey carried out for P5 and P6 using array dipole–dipole

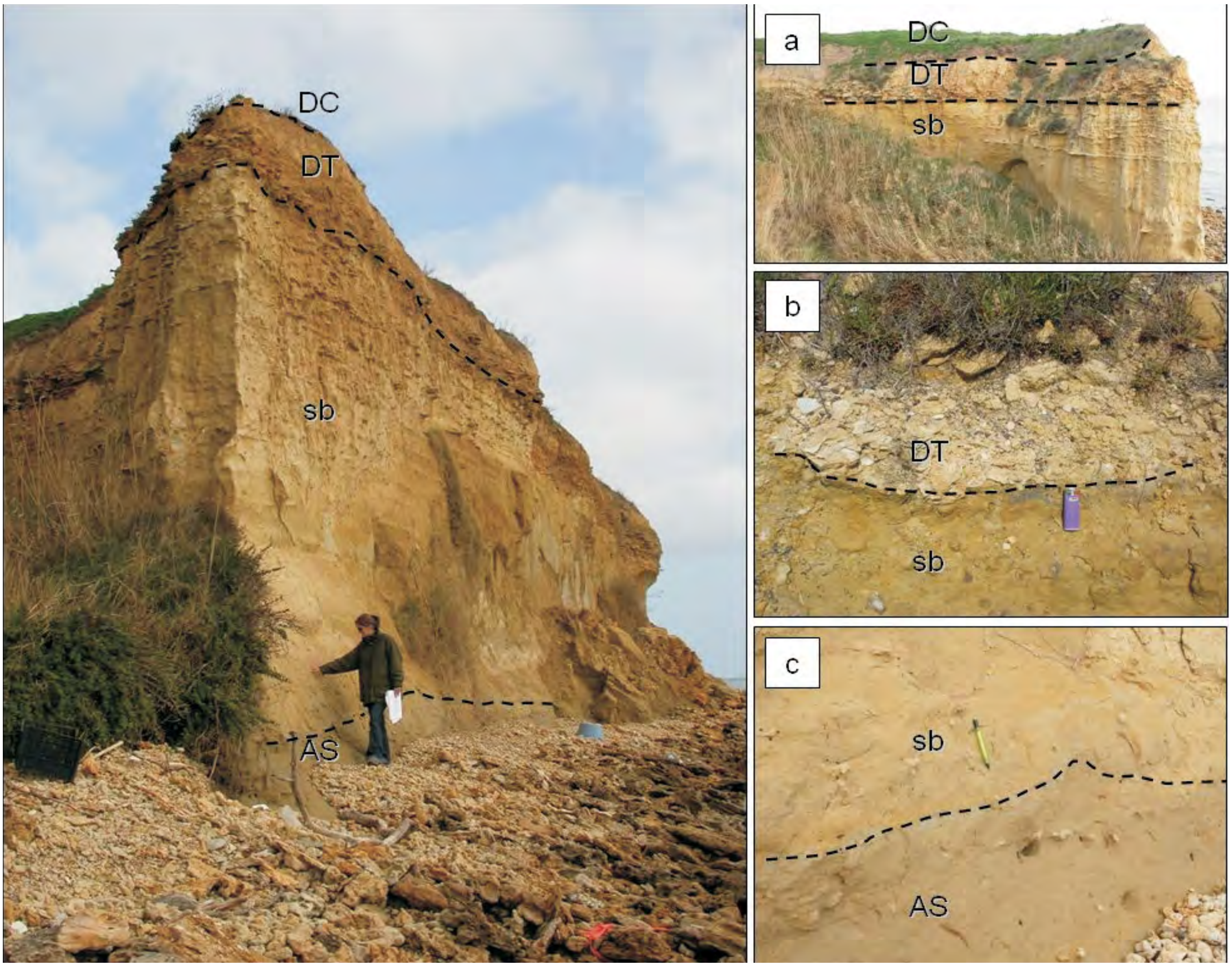

Fig. 9 – Cerano power station (cliff) type section of Brindisi sands. (a) contact between continental Deposits (DC), Terraced Deposits (DT) and Brindisi sands (sb), (b) contact between Terraced Deposits (DT) and Brindisi sands (sb), (c) contact between Brindisi sands (sb) and subapennine Clays (AS).
– *Sezione-tipo delle Sabbie di Brindisi presso la Falesia in località Cerano. (a) contatto tra I Depositi continentali (DC), quelli di Terrazzo (DT) e le Sabbie di Brindisi (sb), (b) contatto tra gli stessi Depositi di Terrazzo (DT) e le Sabbie di Brindisi (sb), (c) contatto tra le Sabbie di Brindisi (sb) e le Argille subappennine* (AS).

with 48 electrodes and the distance between electrodes along the lines was also 3 m. The subsoil can be subdivided into the following four distinct electro-layers (moving downwards from the surface):

Electro-layer 1: the thickness of this layer varies between 1 and 3m and its resistivity values between 10 and 20ohm*m. This layer is attributable to infill material at the surface;

Electro-layer 2: the resistivity of this layer varies between 50 and 200ohm*m, and its thickness from 6 to 8 m. In P5 the bottom of this layer lies at a depth of approximately 10.5 m. This layer is attributable to water-saturated calcarenite of the Terraced Deposits. These interpretations are supported by existing lithological and hydrogeological data;

Electro-layer 3: the thickness of this layer varies between 5 and 7m; the bottom lies at a depth of 18m and its resistivity values range from 8 to 20ohm*m. This electro-layer may geologically be associated with saturated Brindisi sands;

Electro-layer 4: the resistivity of this last electro-layer is characterized by values below 5ohm*m. This layer corresponds to the subapennine Clays. The resistivity values decrease with depth and this is certainly due, in the absence of vertical lithological variations, to the increasing salinity of the water content.

The ERT models are in accordance with the geological and hydrogeological data obtained from specific points (boreholes S14 and S17).

Another profile, conducted in the western side, near “Mar Piccolo” is shown (fig. 3 and 12). The survey was carried out using array dipole–dipole with 71 electrodes and the distance between electrodes along the lines was also 5 m. The electrical profile, conducted transversally to a spring (fig. 12) in an area near the shoreline, permits the clarification of the site geology. In this case, according to the geological surveys, the subsoil can be subdi-

Fig. 10 – Contact between the impervious subapennine Clays (AS) and the permeable Terraced Deposits (DT) along the coast near Lido Silvana.
– *Contatto tra le Argille subappennine (AS), impermeabili, ed i Depositi di Terrazzo (DT), permeabili, lungo la costa Tarantina in località Lido Silvana.*

vided into the following three distinct electro-layers (moving downwards from the surface):

1. a superficial electro-layer with a depth of about 0–12m and resistivity values of 1-5ohm*m. This layer is attributable to subapennine Clays;
2. an electro-layer with a depth of about 12–20 m and resistivity values of 5-20ohm*m. This layer is attributable to water-saturated calcarenite of the Gravina Calcarenite;
3. an electro-layer whose top is about 40m depth and resistivity values of 25-40ohm*m. This electro-layer may geologically be associated with saturated Altamura limestone. It is important to note that this electrolayer has a discontinuous top surface probably due to a fault. In correspondence of this discontinuity, where Subapennine Clays layers obstruction is interrupted, there is a spring.

5. – THE AQUIFER SYSTEMS OF THE BRINDISI – TARANTO PLAIN

On the basis of the previously described stratigraphic models and of ERT researches, several aquifer systems have been identified in the studied area. Both the eastern and the western areas con-

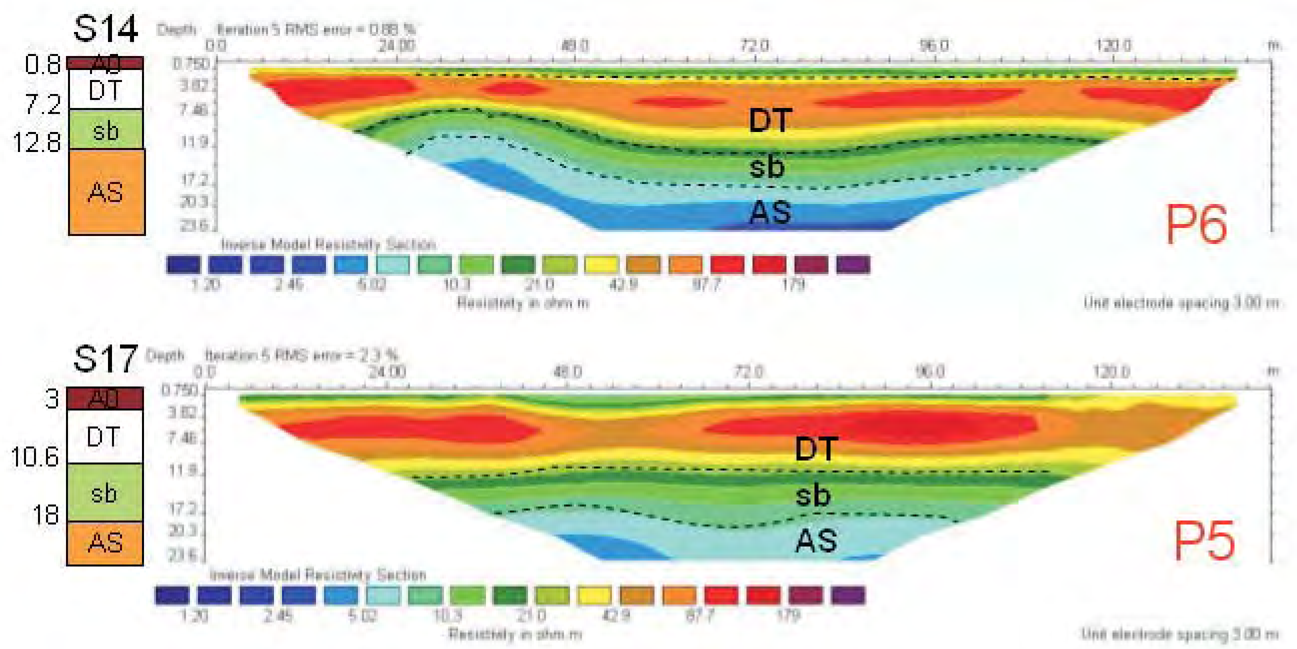

Fig. 11 – ERT Profile interpretation of 2D resistivity models realized in the Brindisi area. AS, subapennine Clays; DT, Terraced Deposits; sb, Brindisi sands. Location in the frame to the right and in figure 2.
– *Modelli di resistività 2D ottenuti dall'interpretazione di profili ERT, nel Brindisino. AS, Argille subappennine; DT, Depsoiti di Terrazzo; sb, sabbie di Brindisi. L'ubicazione è riportata nel riquadro a destra ed in figura 2.*

tain two overlapping and hydraulically independent aquifers.

A deep aquifer lies in the Mesozoic limestones (Altamura limestone hydrogeologic unit), made up of fractured and karstic carbonatic rocks, and in the porous (from 43% to 49%, ANDRIANI & WALSH, 2002) overlying Pleistocene deposits (Gravina Calcarenite hydrogeologic unit). Freshwater deep aquifer overlies more dense sea water and the thickness of this fresh water above the interface with saline water can be estimated based on the relationship of Ghyben-Herzberg. Unlike the shallow ground water, found only in places, the deep ground water extends across the whole of the Apulia region. The deep aquifer, lying below the subapennine Clays, contains water under pressure and is therefore of the Artesian type (fig. 14 and fig. 15). The deep ground water is replenished by rainfall where the Cretaceous formation outcrops, by underground outflows from the adjoining "Murge" hills, and by seepage from the shallow aquifer corresponding to the numerous wells used for drinking water, irrigation and industrial uses that are present in the studied area. The hydraulic

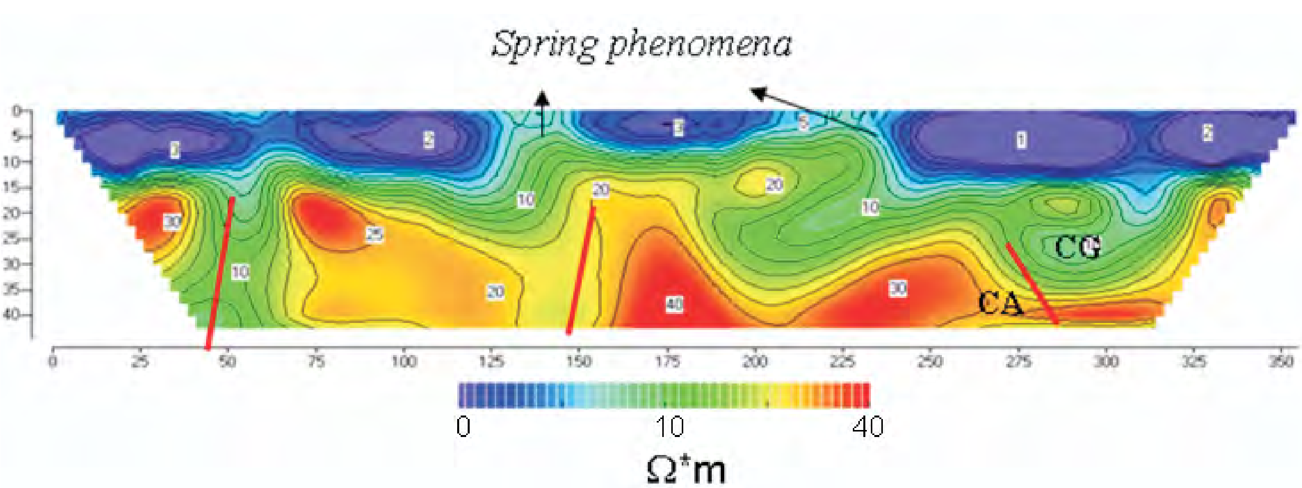

Fig. 12 – ERT Profile interpretation of 2D resistivity models realized in the Taranto area. Probable faults are signed with a red line. CA, Altamura Limestone; CG, Gravina Calcarenite.
– *Modelli di resistività 2D dall'interpretazione di profili ERT, nel Tarantino. Le faglie probabili sono segnate in rosso. CA, Calcare di Altamura; CG, Calcarenite di Gravina.*

Fig. 13 – Minor spring phenomena near Mar Piccolo.
– *Fenomeni sorgentizi minori presso il Mar Piccolo a Taranto.*

gradients, oriented toward the coast, are very modest (0,5 ‰), even at some distance from the coast.

A distinctive characteristic of the Ionian coast is the presence of spring phenomena (the most important are "Borraco", "Galese" and "Chidro", fig. 2). According to ZORZI & REINA (1957), COTECCHIA *et alii*, (1975) and DAURÙ *et alii* (1990), geophysical researches have shown that these points of preferential ground water flow correspond to the zones where the sediments have a greater degree of permeability, due to fracturing and/or karst and principally corresponding to faults in the calcareous and calcareous–dolomitic mass of the Cretaceous. In these high permeability zones the groundwater under pressure rises, perforating and eroding the clay mantle (fig. 14). Other minor superficial springs are the result of the perforation of impermeable continental layers that occlude shallow aquifer.

A shallow porous aquifer, formed by the Middle–Upper Pleistocene marine calcarenitic and sandy deposits overlying the lower Pleistocene clays, holds a phreatic ground water body. This aquifer is of the phreatic type, with semiconfined conditions where its upper part is overlain with sediments of low permeability (recent continental deposits).

Based on lithostratigraphy, this aquifer can be subdivided into several hydrogeologic units that differ from previous literature (RADINA, 1968; COTECCHIA, 1977; CHERUBINI *et alii*, 1987; RICCHETTI & POLEMIO, 1996). The subapennine Clays (Early Pleistocene) constitute the impermeable base of the aquifer ($3*10^{-7}$m/sec, RICCHETTI & POLEMIO, 1996) in both areas. At least in the Brindisi area, the Pleistocene aquifer system involves two hydrogeologic units and not only one as in the mentioned bibliography. The greatest permeability ($5*10^{-4}$m/sec, CONSORZIO BASI, 2002) is found in the calcarenite deposits (Terraced Deposit hydrogeologic unit, Middle–Late Pleistocene). As the fraction of silt increases, the permeability of the deposit decreases. The lower section of the aquifer, characterized by the presence of silty-sandy sedi-

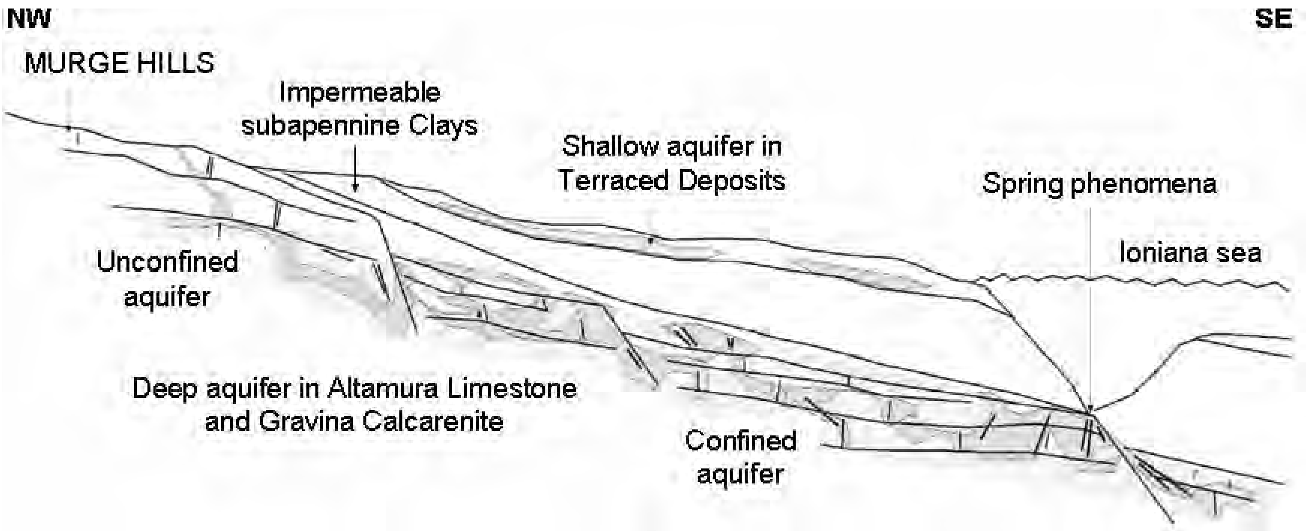

Fig. 14 – Hydrogeologic scheme of the Taranto study area.
– *Schema idrogeologico del Tarantino.*

ments (Brindisi sands hydrogeologic unit, Early-Middle Pleistocene), has low permeability (on average $4*10^{-5}$m/sec, CONSORZIO BASI, 2002). The saturated part of the shallow aquifer has a thickness varying from a few decimetres to over 30 m and flows towards the sea. The lack of homogeneously distributed and temporarily comparable data does not permit the elaboration of a piezometric map.

6. - CONCLUSIONS

The stratigraphic succession of the Brindisi - Taranto plain was reconstructed for hydroegeologic purposes integrating geological and geophysical surveys, which highlighted the heterogeneity of the subsoil. The results of this research, especially about the shallow aquifer, modify the previous geological and hydrogeological models (fig. 14 and fig. 15). The Brindisi sands are here formalized: the type-section near Cerano cliff, where the contact with the overlying and underlying units is exposed, has been described. To this unit are ascribed the sequences studied by DI GERONIMO (1969), GENTILE *et alii* (1996) and COPPA *et alii* (2002). This study points out the necessity to clarify the stratigraphy of Pleistocene sediments of the Taranto area, particularly for the possible identification of the Brindisi sands, probably included also in the western area in subapennine Clays and particularly in its upper sandy interval. In the Taranto area, BELLUOMINI *et alii* (2002) describe a transgressive clayey–sandy unit (about 4 m thick) that is of Middle Pleistocene age overlying the subaapennine Clay Formation but a lack of borehole log data does not permit the determination of the extension in the subsoil of this unit and its real thickness. The Taranto unit could correlate with the Brindisi sands but more studies are necessary. The two formations can be differentiated not only in terms of composition, but also in terms of permeability, that is higher in the Brindisi sands compared to subapennine Clays. These two formations are easily distinguished for their distinct electrical properties. The Brindisi sands have resistivity values that range from 8 to 20ohm*m while subapennine Clays are characterized by values below 5ohm*m. Based on this lithostratigraphy the shallow aquifer can be subdivided into several hydrogeologic units that differ from previous literature.

Brindisi sand hydrogeologic unit (permeability of $4*10^{-5}$ m/sec) constitute the lower section of the aquifer, Terraced Deposit hydogeologic unit (permeability of $5*10^{-4}$ m/sec) the upper part and subapennine Clays the impermeable base (permeability of $3*10^{-7}$ m/sec).

ERT surveys have shown themselves to be a useful tool in the individualization offspring phenomena that are situated at the bottom and along the edges of the natural basins and channels flowing especially into Mar Piccolo with a non-homogeneous distribution along the west coast.

From the paleogeographic point of view, the South Salento sediments of Galatone Formation have been recognized for the first time near Talsano (western coast): this lithostratigraphical attribution indicates an Oligocene lacustrine environment also for the Taranto area. Furthermore, the identification of the existing wells has provided an initial overall picture of the distribution and density of the points of extraction from the deep aquifer, highlighting its possible overexploitation.

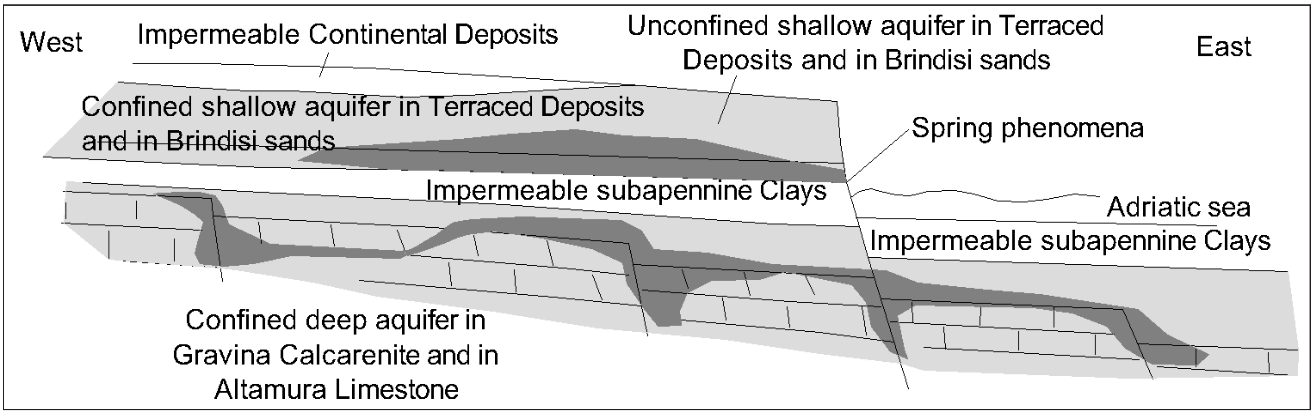

Fig. 15 – Hydrogeologic scheme of the Brindisi study area.
– Schema idrogeologico del Brindisino.

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