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TECTONIC GENESIS OF THE SALT MARSHES ON THE SICILIAN COAST OF THE STRAITS OF MESSINA (SICILY)

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ABSTRACT: Bottari A., Bottari C. & Carveni P., *Tectonic genesis of the salt marshes on the Sicilian coast of the Straits of Messina (Sicily, Southern Italy)*. (IT ISSN 0394-3356, 2005).
Based on historiographical, geophysical and seismological data a detailed geological and geomorphological survey has been carried out to reconstruct the genesis of two Sicilian salt marshes. These salt marshes, called *Pantano Piccolo and Pantano Grande*, are located respectively on the northern and southern seashore of the coastal plain of Peloro Cape. The Peloro Cape is placed at the northern opening of the Straits of Messina and together with the two salt marshes, constitute a complex eco-system of great interest because of the multiple implications of anthropic and naturalistic nature. The result of geological and geophysical surveys shows that the origin of these salt marshes was due to the activity of some normal faults that conform Peloro Cape Peninsula and that control the level of coastal plain. The shallow basin of Pantano Grande (big marsh), has a lengthened shape along the Ionian coastline. It is delimited to N by a normal fault that set the limits to S of the horst of Granatari hill and to S from some small faults that conform the southern shore. The southern coastline of Pantano Grande is composed by a narrow strip of alluvium deposits that separate the salt marsh basin by Ionian Sea; here along the coastline a narrow strip of paleontologically sterile conglomerate outcrops. Otherwise, the atypical morphology of Pantano Piccolo (small marsh) is characterized by a high depth (M = - 28 m) compared with its horizontal dimensions; from the bathymetric analysis results that the facing Tyrrhenian Sea is less deep of the Pantano Piccolo basin till 600 m far from the coastline. The basin of this salt marsh is situated inside a small semi-graben N-S oriented and it is located in the coastal lowland that conforms to E the Peloro Cape peninsula. In short, the analysis of geomorphologic characteristics and the results of geological, geophysical and seismological surveys support a tectonic genesis for both the salt marshes.

RIASSUNTO: Bottari A., Bottari C. & Carveni P., Genesi tettonica degli stagni salmastri ubicati sulla costa siciliana dello Stretto di Messina (Sicilia)*. (IT ISSN 0394-3356, 2005).*
Lo Stretto di Messina è un graben che dall'inizio del Pliocene ha subito un'intensa evoluzione; esso è limitato da un sistema di faglie NNE-SSW lungo la costa siciliana e da un sistema di faglie NE-SW lungo quella calabra. La penisola di Capo Peloro, estrema propaggine nord-orientale della Sicilia, è situata all'imboccatura settentrionale dello Stretto, ed è formata da una zona collinare con sviluppo E-W, corrispondente ad un horst, delimitato a settentrione dalla Faglia di Mortelle ed a meridione dalla Faglia di Ganzirri; nella zona collinare affiora prevalentemente la Formazione di Messina*, un deposito ghiaioso-sabbioso clinostratificato di facies deltizia, discordante su limitati affioramenti di conglomerati tortoniani, su lembi discontinui della Serie Gessoso-Solfifera messiniana e di Trubi infrapliocenici; al disopra della* Formazione di Messina *si trovano limitati affioramenti di sabbie a Ostrea e, sopra di queste, livelli di sabbie a* Strombus bubonius*. La zona collinare è bordata da una pianura costiera di larghezza variabile. Tale pianura, che non supera 4 m di quota, è formata da ghiaie, sabbie e limi; al suo interno si trovano due specchi di acqua salmastra, denominati* Pantano Piccolo e Pantano Grande*, i quali costituiscono un importante e complesso ecosistema, di grande interesse per le molteplici implicazioni di carattere antropico e naturalistico. Sulla base di dati di ricerche storiografiche, geofisiche e sismologiche, cui hanno fatto seguito rilievi geologico-geomorfologici di dettaglio, è stata ricostruita la genesi dei due pantani che è da attribuire all'attività di alcune faglie normali: il bacino del Pantano Grande, poco profondo, con forma a clessidra allungata parallelamente alla linea di costa ionica, è delimitato a settentrione dalla* Faglia di Ganzirri *ed a meridione da una serie di piccole faglie che ne conformano la riva; la linea di costa, che delimita a meridione il sottile cordone di depositi alluvionali che separano il Pantano Grande dal Mare Ionio, è marcata da un affioramento di conglomerato paleontologicamente sterile. Il Pantano Piccolo presenta una morfologia atipica, caratterizzata da una grande profondità (M = - 28 m) paragonata alle dimensioni orizzontali del bacino, da un gradiente batimetrico circa triplo di quello dell'antistante braccio di Mar Tirrenico che risulta essere meno profondo del Pantano Piccolo fino ad oltre 600 m dalla linea di costa. In sintesi, l'analisi delle caratteristiche geomorfologiche e dei risultati di indagini geologiche, geofisiche e sismologiche supportano una genesi tettonica per entrambi i pantani.*

Keywords: Straits of Messina, coastal salt marshes, tectonics, morphologye.

Parole chiave: Stretto di Messina, stagni costieri salmastri, tettonica, morfologia.

1. INTRODUCTION

The Peloro Cape Peninsula, placed on the Sicilian shore of the Straits of Messina, presents peculiar geomorphological characteristics which make it of notable morphotectonic and landscape interest (Fig. 1). It is composed by a hilly zone along an E-W direction, and bounded by a coastal plain of variable width. In particular, the salt marshes of Faro and Ganzirri, called respectively Pantano Piccolo (small marsh) (Fig. 1: **PP**) and Pantano Grande (big marsh) (Fig. 1: **PG**), situated inside the coastal plain, constitute a complex ecosystem of great interest of anthropic and naturalistic nature. Recently, the attention of environmental characteristics of this area was enlarged by proposing of realization of a bridge to connect the two shores of the

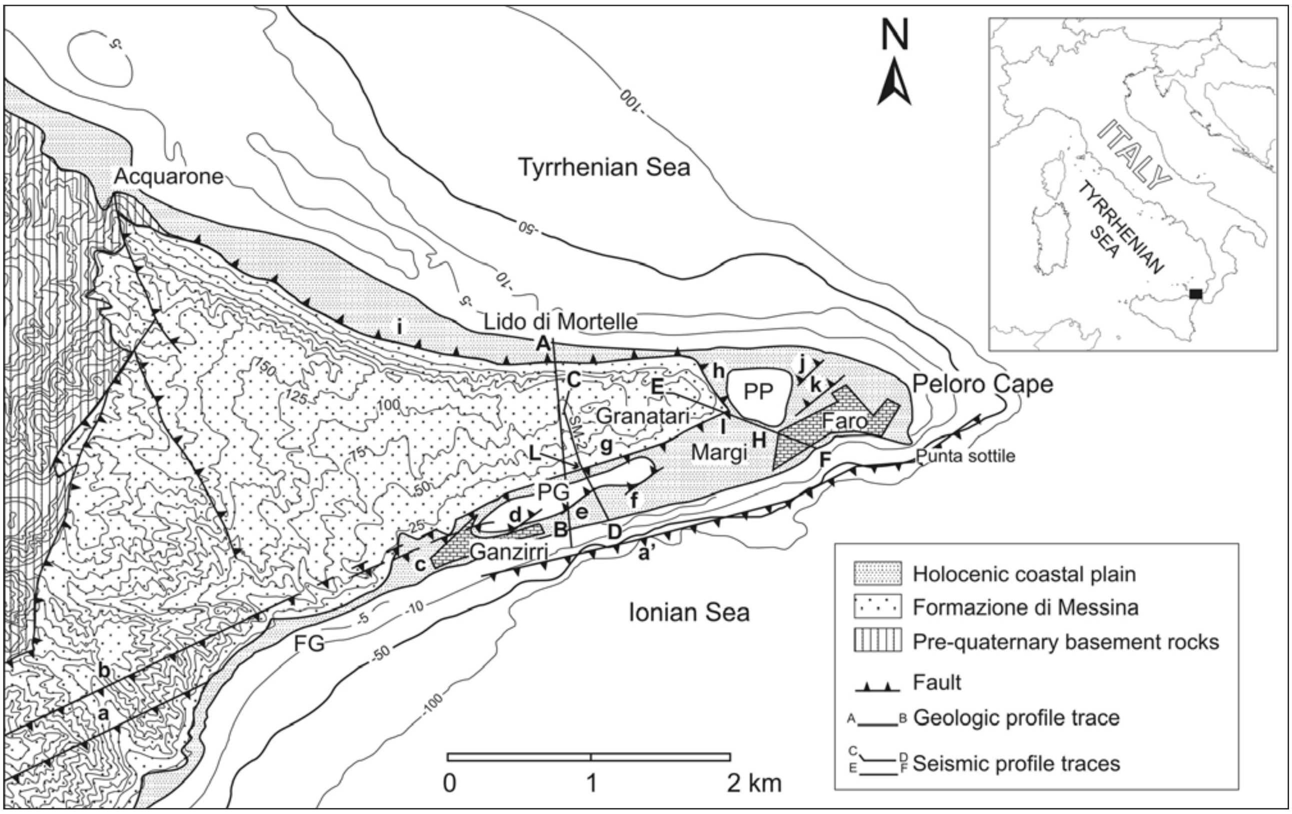

Fig. 1 - Geological sketch of the Peloro Cape peninsula.

Straits of Messina.

Among the unsolved problems of prevailing geological interest detaches that one relative to the genesis and evolutional history of the basins of Pantano Piccolo and Pantano Grande. With this aim, and starting from analysis of historiographical, geophysical and seismological data, some new geological and geomorphologic surveys have been carried out.

2. HISTORIOGRAPHIC OUTLINES

The first known human settlement on the Sicilian shore of the Straits was located in the area between Ganzirri and Faro as shown by the finding of some pieces of pot that were brought to light in the 1960s excavation. The dating of this material between 2200-2000 BC provides a terminus post quem for the prehistoric village (Biddittu *et al*., 1979).

Historical sources of Roman age mention that the legendary town of Risa, placed on Granatari hill, collapsed during an earthquake and its remains fell down in the Pantano Piccolo. The same sources relate that two temples were once in the area between the two salt marshes. The first one was built by Orion and was probably dedicated to Neptune. Remains of this building were brought to light in 1835, during the digging work of a waterflow to connect Pantano Grande to Pantano Piccolo (Fig. 2: C_3). The second temple was built in a third salt marsh, deep only 0.5 m, located between Pantano Grande and Pantano Piccolo. This temple was destroyed in Roman times and the salt marsh was filled in (Fig. 2: **P1**). Indeed, at around AD 1500, only two marsh existed, Pantano Piccolo and Pantano Grande (Maurolico, 1543).

The material deriving either from the digging work of the first canal or from the digging work of a second canal, which was built in the 18th century to connect Pantano Piccolo (Faro) with the Ionian Sea (Fig. 2: $\mathbf{C_1}$), was used to drain a fourth small marsh (Fig. 2: **P2**) which had formed between Pantano Grande and Pantano Piccolo (Abbruzzese & Genovese, 1952).

In conclusion, the whole historiographical data documents that the area between the two salt marshes (Pantano Grande and Pantano Piccolo) was influenced by local subsidence in the last two thousand years which produced in different times another two small basins at least (Fig.1: **P1** and **P2**) that no longer exist as they were filled in by man.

3. GEOLOGICAL AND STRUCTURAL FEATURES OF THE PELORO CAPE PENINSULA

The Peloro Cape Peninsula is the extreme northeastern tip of Sicily, and forms the western shore of the Straits of Messina in a tract where the minimum distance from the Calabrian shore is 3.2 km. The Straits of Messina is a graben which suffered an intense evolution at the beginning of the Pliocene; it is bounded by fault systems in a NNE–SSW direction along the Sicilian shore and NE-SW fault systems along the Calabrian shore; it was partially filled by transgressive Plio–Pleistocene deposits on a crystalline allochthonous basement and Mio-Pliocene deposits (JACOBACCI *et al.*, 1961).

Most authors affirm that the origin of the Straits of Messina can be attributed to lowering movements along normal faults which were active in the Plio–Pleistocene, although different opinions exist about movements along the structures, and for the number of tectonic phases which have resulted in the present day setting of the territory (SELLI, 1978; BOUSQUET *et al*., 1980; GHISETTI, 1981).

The deepest geometrically geological formation in the stratigraphic succession which outcrops in the Straits area is formed by pre-Mesozoic high grade metamorphites, transposed as nappes in the mid Miocene and making up part of the Aspromonte Unit; in particular, it features pegmatoid gneiss for the Sicilian area (ATZORI *et al*., 1974) and high grade monzogabbro, augengneiss, paragneiss and micaschists for the Calabrian shore (PEZZINO & PUGLISI, 1980).

Neogenic quartenary sediments relating to the filling of subsiding basins formed immediately after the mid – Miocene orogenic transport phase, lie in transgression on metamorphic rocks. (BARBANO *et al.*, 1978; LENTINI & VEZZANI, 1978). In particular, the polygenetic sterile base conglomerate evolved as a sandstone – clay alternation of the Tortonian age (JACOBACCI *et al.*, 1961), on which tongues of evaporitic limestone and Messinian gypsum lie in sedimentary continuity; transgressional on these is early–Pliocene white globigerine marl (*Trubi*) (JACOBACCI *et al*., 1961); early–Pleistocene limestone deposits lie transgressive on all the formations described (LOMBARDO, 1980 a; 1980 b) and on which lie the early-Pleistocene Argille di Vito Superiore; yet discordant on all the terms listed lies clinostratigraphic mid Pleistocene gravel and sand from the *Formazione di Messina* (LOMBARDO, 1980 a; 1980 b). Still in discordance, late Pleistocene terraced deposits, both in marine and continental facies, outcrop on this (GHISETTI, 1981): the stratigraphic succession is closed and completed by alluvial fans, recent and present-day alluvial and beach deposits.

The following succession outcrops in the survey area:

1) *The Formazione di Messina*: this consists of clinostratigraphic deposits, mainly delta facies, laterally passing to organogenic sandstone calcarenite, coastal facies sand and gravel; its thickness ranges between 70 and 250 meters; to the west of the study area, the formation lies in discordance on Tortonian rocks, on the Messinian ones of the Serie Gessoso Solfifera and on Trubi; because of faults, it is in contact with the metamorphic rocks of the Aspromonte Unit; the *Formazione di Messina* was recognized to be discordant and transgressive on the substratum (JACOBACCI *et al*., 1961) and was ascribed to the early and/or mid Pleistocene; according to SELLI, (1978) it was formed in a river fed deltaic environment; according to SAURET (1980) and BARRIER (1984), it was a regressive and diachronic

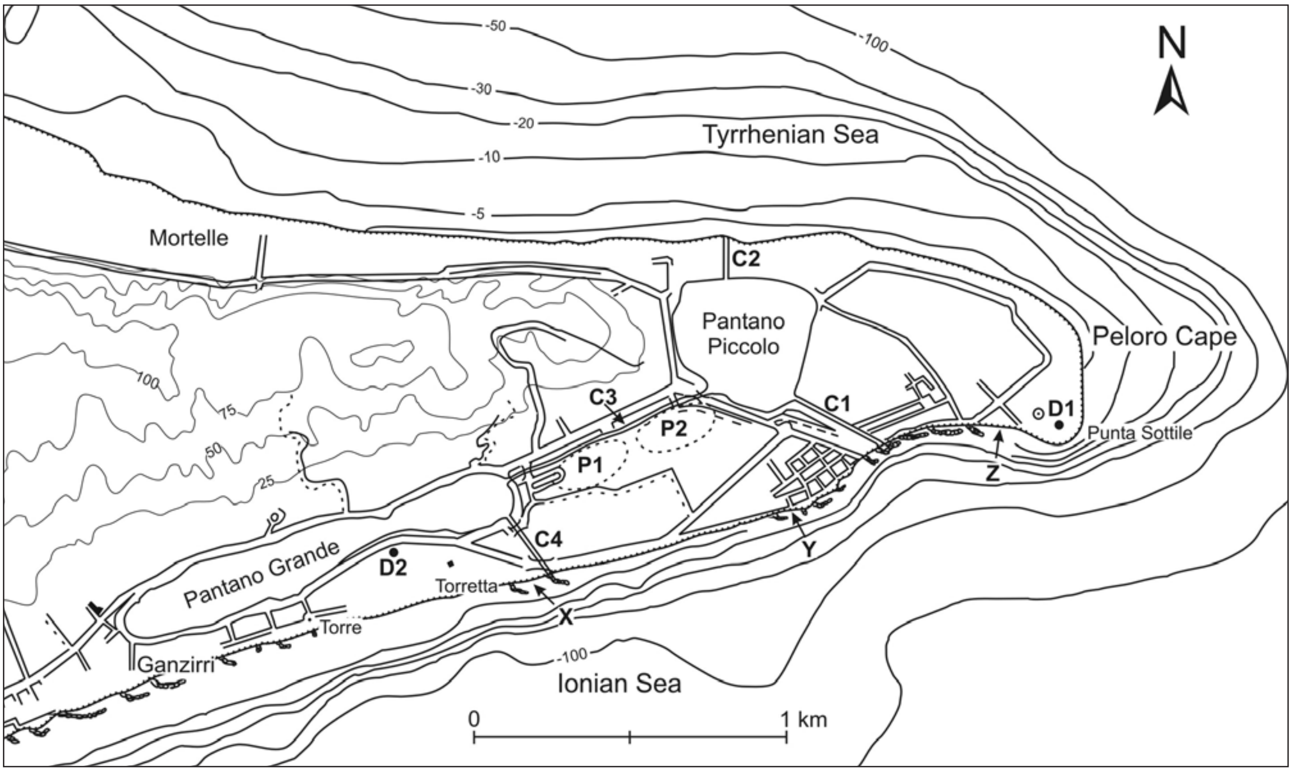

Fig. 2 - Map of the Peloro Cape peninsula with the bathymetry of surrounding seas; C_1, linking canal between Pantano Piccolo and the Ionian Sea, C_2, linking canal between Pantano Piccolo and Tyrrhenian Sea, C_3, linking canal between Pantano Piccolo and Pantano Grande, C_4, linking canal between Pantano Grande and Ionian Sea; P_1 and P_2 , assumed locations of two ancient marshes which are not more existing; X-Y and Y-Z, shares of the sterile conglomerate outcropping along the shoreline of Ganzirri – Punta Sottile; D_1 and D_2, geognostic boring locations (modified from Carta dello Stretto di Messina, I.I.M., scale 1:30000).

facies due to centripetal progradation towards the centre of the Straits, caused by a rapid uplift of the crystalline hinterland;

2) *Gravel and sand with Ostrea*: to the East of the Papardo river, approximately 60 m above sea level, minute gravel lies in discordance and transgression on clinostratigraphic deposits of the *Formazione di Messina,* except for a sub-horizontal surface of marine erosion. This gravel is characterised by the presence of Ostrea shells; higher up, this is followed by sand in which specimens of *Strombus bubonius* and *Glycimeris* have been found and which have been attributed to the Tyrrhenian; the highest altitude of these sediments is about 85 m (BONFIGLIO & VIOLANTI, 1983);

3) *Terraced alluvial deposits*: these are formed by gravel, sand and reddish silt with alluvial facies; Cardium coastal facies are often present at the base; the elements that make up the deposit derive mainly from crystalline rock erosion from the Aspromonte Unit and secondarily by their sedimentary covering. They were related to Tyrrhenian (HUGONIE, 1974);

4) *Recent alluvial and coastal plain*s: this term indicates deposits situated on the edges of naturally formed water channels; they are formed from gravel, sand and silt originating from metamorphic rocks and from the previously described conglomerate and gravel formations; their thickness range from one to tens of meters and occupy the edges of main rivers and the strip of coast that forms the extreme tip of the Peloro Cape, which enclose the two salt marshes in Ganzirri and Faro; inside coastal deposits there are lens of sterile conglomerate, about 1m thick, strongly cemented (BONFIGLIO & VIOLANTI, 1983);

5) *Eluvial and colluvial sheets*: this is a strip which extends from the foot of the hilly area for several tens of kilometres and is made up of a brown-reddish, gravelly-sandy deposit, sometimes in the form of alluvial cones; its litho–structural characteristics and area distribution make it relative to the superimposition of successive accumulations of the slope declivity deriving from the weathering of previous territories; states of various inclinations can be seen along the man made trench, as a consequence of the trend of the sub-stratum;

6) *Present day alluviums and beaches*: present day alluviums are found along the river beds; they originate from the erosion of previous terms and present a variable size; current beaches are formed by gravel fashioned by wave movement and currents.

4. GEOMORPHOLOGICAL CHARACTERISTICS

The Peloro Cape Peninsula presents a smooth morphology, related more to the outcropping lithologies than the tectonic structures. It is characterized by a hilly range and a coastal plain which houses two salt marshes (Fig. 1).

The hilly range is formed by a series of small rises with flat peaks; the watershed descends gradually from the West to the East, separating the northern slope from the southern one. The northern slope is characterised by an average slope of 25% and a series of small streams. The southern slope is less sloping (17%) of the previous one, with numerous small and less pronounced streams. The width of the coastal plain varies from a minimum of 75 m in Lido di Mortelle on the northern coast, to a maximum of 1,750 m between Granatari and Peloro Cape; the isobaths form a cusp on the extension of this alignment (Fig. 1). The different trend of bathymetric gradient along the northern shore of Peloro Cape Peninsula (Tyrrhenian Sea side) compared with that of southern shore (Ionian Sea side) is evident (Fig.2).

The Ionian coast from Messina to Peloro Cape is bordered by a coastal plain which is characterized by different morphological features: from Messina to the outlet of the Guardia River (Fig. 1: **FG**), it lies in a roughly NNE-SSW direction, with an approximately straight trend, modelled by small recesses and protrusions and is several tens of meters wide; at the outlet of the Guardia River, the coastline diverts clearly towards ENE and assumes a straight trend as far as Peloro Cape. In this last stretch, the width of the coastal plain is still several tens of meters wide as far as Ganzirri, and from Ganzirri beach to Pantano Grande it sharply widens reaching approximately 500 m (Figs. 1, 2). Along this coast the tidal currents which can reaches 7 knots have a strongly erosional influence on the shore (MONTENAT *et al*., 1987; AMORE *et al*., 1988).

The active tectonic from Upper Pleistocene until today carry an important rule in conditioning the geomorphological conformation of this area as pointed out by analysis of the paleoseismicity (VALENSISE & PANTOSTI, 1993), of the deformation/rupture/dislocation of superficial terrains observed after strong seismic events (LO PERFIDO, 1909; BARATTA, 1910) and of the focal mechanism of earthquakes. The Straits of Messina area is characterized by high values of magnitude (M) of the strongest earthquakes occurred in the last 220 years ($7.0 \leq M \leq 7.2$). The 1908 seismic event (M = 7.2) was the most catastrophic event of the last century, with epicentre in the Straits, focal depth h = 18 km and seismogenetic rupture along the NE-SW direction which was 45 km long and 14 km wide. The focal mechanism was normal with a strike-slip component, consistent with distensive stress condition (BOTTARI *et al.*., 1986; BOTTARI *et al*., 1989). Among the major coseismic effects observed after the 1908 earthquake in the mesoseismic area should be pointed out the lowering of Peloro Cape terrains of about 20 cm, the subsidence/ ruptures along the southern slope of Granatari hill and the underwater landslides along the Ionic coast (LO PERFIDO, 1909; BARATTA, 1910). The lengthening of the isosismal lines in NE-SW direction of the near field of earthquakes with origin in the Straits is consistent with the analysis of focal mechanism and the geo- structural framework of this area (BOTTARI *et al*., 1984).

The most recent earthquakes ($4.0 \leq M \leq 4.7$), which occurred between 1975 and 1995, with hypocentral depth encompassed between 8 and 21 km, show either normal or strike-slip focal mechanism along the NE-SW direction and in some case along E-W direction (CACCAMO *et al*., 1996: NERI *et al.*, 1996; FREPOLI & AMATO, 2000).

Therefore, analysis of intensity distributions and focal mechanisms of earthquakes originating in the area of the Straits shows the actual seismogenetic activity of faults of the NE-SW structural system but also of tectonic structures with E-W trend.

5. THE SALT MARSHES

5.1 Pantano Piccolo

Pantano Piccolo is the deepest natural basin of Sicily. It presents an almost rectangular shape with the major diagonal oriented in a NW-SE direction where it reaches a length of about 650 m (Fig. 3).

The bathymetric trend of this marsh is asymmetrical, as noted also by ABBRUZZESE & GENOVESE (1952): starting from the western shore, the depth increases very little and gradually from 0 until some meters at a distance of 250 m from the coast; the maximum depth **M** = -28 m is found in the central eastern area of the basin (Fig. 3). The same authors put forward the hypothesis that the genesis of the basin was tectonic, due to the collapse of its base. The basin, placed inside the northern sector of the coastal plain is bounded to W by a NW-SE normal fault, with a NE dipping (Fig. 1: **h**) and to E by two small NE-SW normal faults which lower to NW (Fig. 1: **i, l**). These faults were pointed out through seismic surveys (DEL BEN, 1985).

To North the basin of the small marsh is separated from the Tyrrhenian Sea from a strip of beach deposits, primarily gravel-sandy, 150 m wide. The width of the actual beach is of around 70-80 m and the corresponding back beach is characterized by low elevation that locally do not reach 1 m above sea level.

For the protection of such places from the west sea storms in different times banks in masonry and more recently in relief of gravels and sands were realized.

The bathymetric gradient of the Tyrrhenian Sea overlooking the northern shore of the small marsh is 3-4 times smaller of that in relief in the lake basin: the bathymetric line of -10 m, that in the Tyrrhenian Sea is located at around 200 m from the coastline, in the small marsh is placed at around 55 m from the northern shore; the maximum depth M = -28 m, that in the basin it is located at around 240 m from the northern shore, in the sea it usually is located at around 600 m by the line of coast.

Toward the end of the 18th century, the small marsh and the Ionian Sea were connected through the construction of a channel (Fig. 2: C_1) ; in 1962 it was also connected to the Tyrrhenian Sea (Fig. 2: C_2). Both the digging works were realized for favouring the development of the harvest of mussels.

The northern coast of Peloro Cape Peninsula, from Acquarone to the Mortelle Beach, is modelled by a normal fault (Fig. 1: **i**), that lowers to North, that was mapped from JACOBACCI (1961), BONFIGLIO & VIOLANTI (1983) and DEL BEN & FINETTI (1985). Nevertheless the trend of bathymetric lines overlooking the northern coastal lowland seems us compatible with his prolongation to East to Peloro Cape.

The strong asymmetry of the marsh bathymetry, the steep slope of the northern and eastern shores and the maximum depth value, which is the greatest of all natural basins of Sicily, support the hypothesis of a tectonic genesis.

5.2 Pantano Grande

Pantano Grande in Ganzirri is a small and shallow coastal basin (surface, 0.34 km^2, maximum depth, 6.5 m, 1.67 km long, and approximately 0.28 km wide, roughly rectangular in shape, with a rapport to the extension equal to 5.9) and its biggest sides run parallel to the coastline (Figs. 2, 4). It is located to the North of Ganzirri village, where the coastal plain is approximately 500 m wide and it is separated from the sea by a strip of Holocene alluvium deposits formed by silt, sand and gravel (GARGANO, 1994) on which aeolian deposits outcrop (BONFIGLIO & VIOLANTI, 1983).

As regard the genesis of the big marsh we should consider that for the development of a coastal lake we needed: (1) a submerged coastal zone and many inlets; (2) a very shallow sea; (3) fluvial mouths which provide remarkable amount of sands and/or gravels. In this condition, it is possible to get a coastal bar at a short distance from the coast, next to an inlet. The bar develops to a tombolo and the bay become a lagoon or a

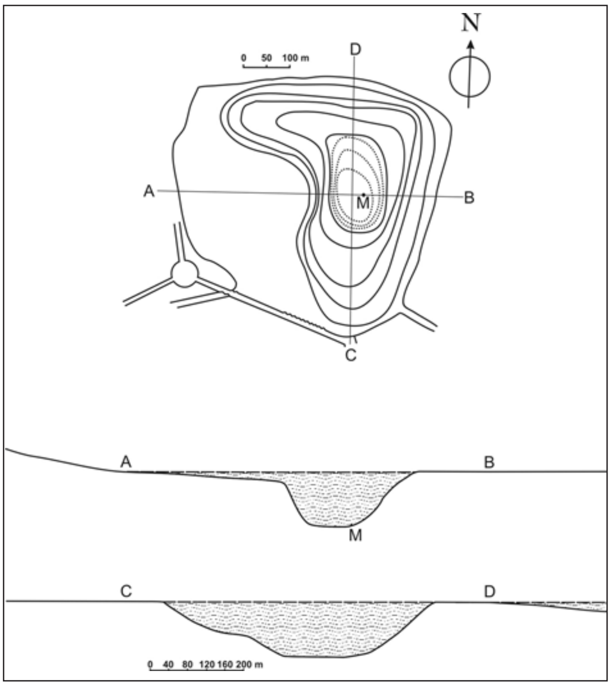

Fig. 3 - Pantano Piccolo salt marsh: above, map of the isobaths (continuous curve distance 5 m and dot curves distance 1 m, maximum depth M = - 28 m); below, altimetric-bathymetric profiles along A-B and C-D shares (derived from ABBRUZZESE & GENOVESE, 1952).

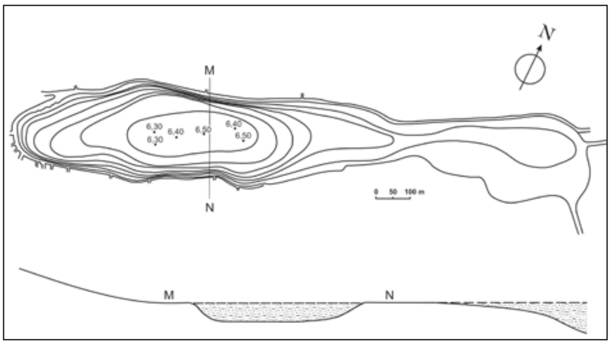

Fig. 4 - Pantano Grande salt marsh: above, map of the isobaths (continuous curve distance 1 m); below, altimetric-bathymetric profile along M-N share.

coastal pond.

The general features of a coastal pond are: low shores and shallow depth and finally a lengthened shape parallel to the coastline. For such morphological characteristics of Pantano Grande basin, and particularly for the shallow depth of its waters could be preliminary supposed that it is a coastal basin (Fig. 4). It could be formed by an amassing of sands and gravels which were carried away and after deposited by the sea currents and wave motion. However the other conditions are not satisfied.

The Straits of Messina results to be uplifting (Westaway, 1993), there are not inlets and there are not water-courses to convey enough amount of sands and gravels. Besides the sea depth along the coasts increases sensibly with the distance from the seashore (Figs. 1, 2).

Consequently a sedimentary genesis for the Pantano Grande cannot be proposed.

Concerning the sediments that form the submerged beach, Colantoni (1987) reports a dimension encompassed between medium size sand and gravel. According to Amore *et al.* (1988) the submerged beach is formed by sands whose medium size is 1.8÷2.0 mm, while the emerged beach is prevalently constitutes by sand.

The portion of the coastal plain where is located Pantano Grande is interested from two faults with direction ENE-WSW, partly already noticed by Gargano (1994) and from Lentini *et al*. (1998; 2000): in the maps of these authors the faults, that are here indicated with the letter **a** and **b**, are interrupted at 2 km to WSW from the Pantano Grande (Fig. 1).

Del Ben (1985) and Del Ben & Finetti (1985) noticed, through investigations of high-resolution seismic surveys, that on prolongation of fault **b** there is a direct fault, with rejection of around 10 m and a lower southern block (Fig. 1: **g**). This fault, that is located to some tens of meters upstream of the northern shore of the Pantano Grande (Fig. 1), will be subsequently indicated as *Faglia di Ganzirri.* It was shown up during two seismic profiles denominated MS2 and MS7 (Figs. 5, 6), and it extends to North till the small marsh. This fault displaces of about 10 m the refractor horizon "A" placed at the top of sub-weathering in the gravels and sands of the *Formazione di Messina*. In addition, the same authors have revealed that some small normal faults NW dipping model the southern shore of the salt marsh (Fig. 1: **d, e, f)**; some direct faults on the prolongation of fault **a**, approximately parallel to the coastline, fault downward the Straits (Fig. 1). The basin is transversally bound by the extension of two direct faults, parallel to each other, and which make up part of an ENE–WSW oriented system (Lentini *et al.*, 1998). The same authors indicated that a doubtful fault (Fig. 1: **c**), with the same direction, which was located adjacently to the greatest axis of Pantano Grande. Gargano (1994) reported the same faults (**a** and **b**), but did not recognize any fault along the Pantano Grande basin.

As observed, and together with an analysis of the geomorphological characteristics of the Peloro Cape area, the coastal plain is bounded by two direct fault plans ENE–WSW oriented. The first one (Fig. 1: **g**) is situated along the NW shore of the Pantano Grande,

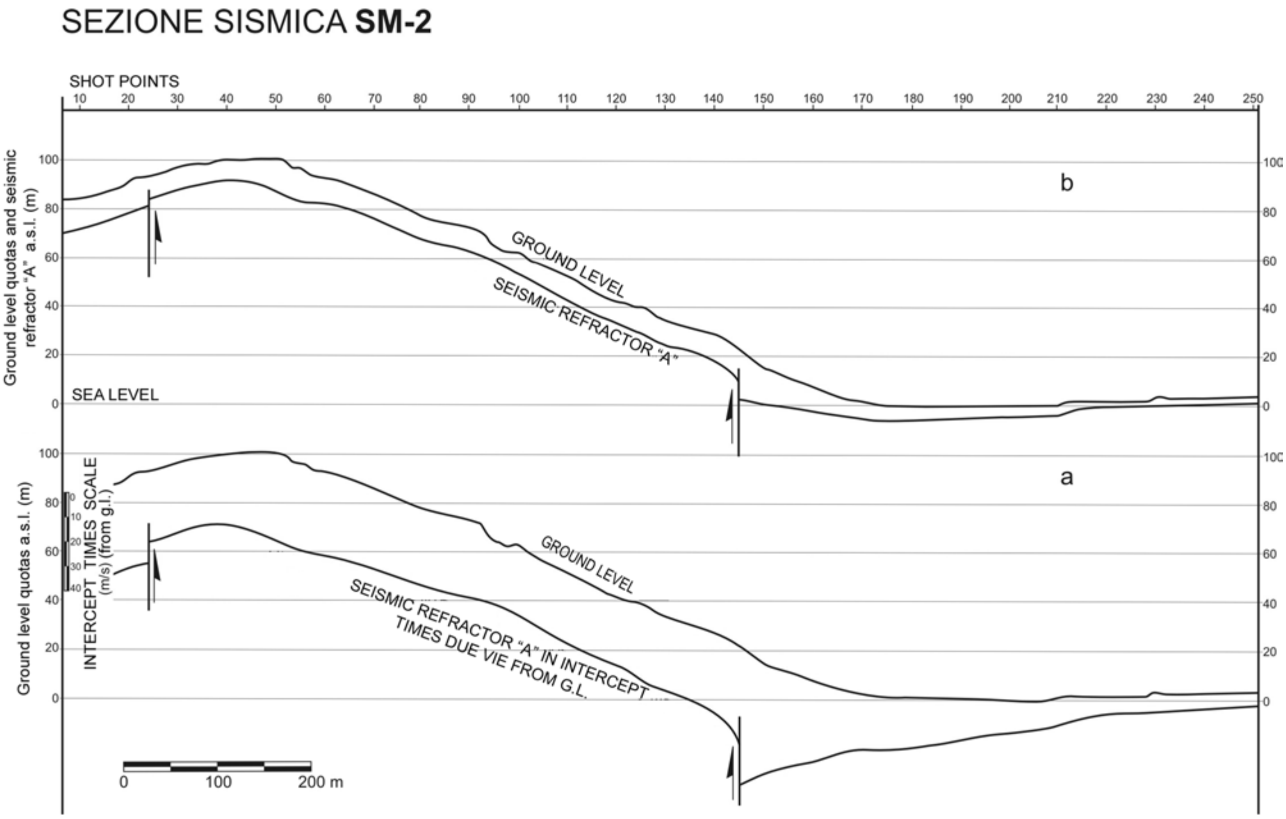

Fig. 5 - SM-2 seismic high resolution profile along C-D share (Fig. 1): a) diagram of the intercept-times; b) seismic section (after Del Ben & Finetti, 1985).

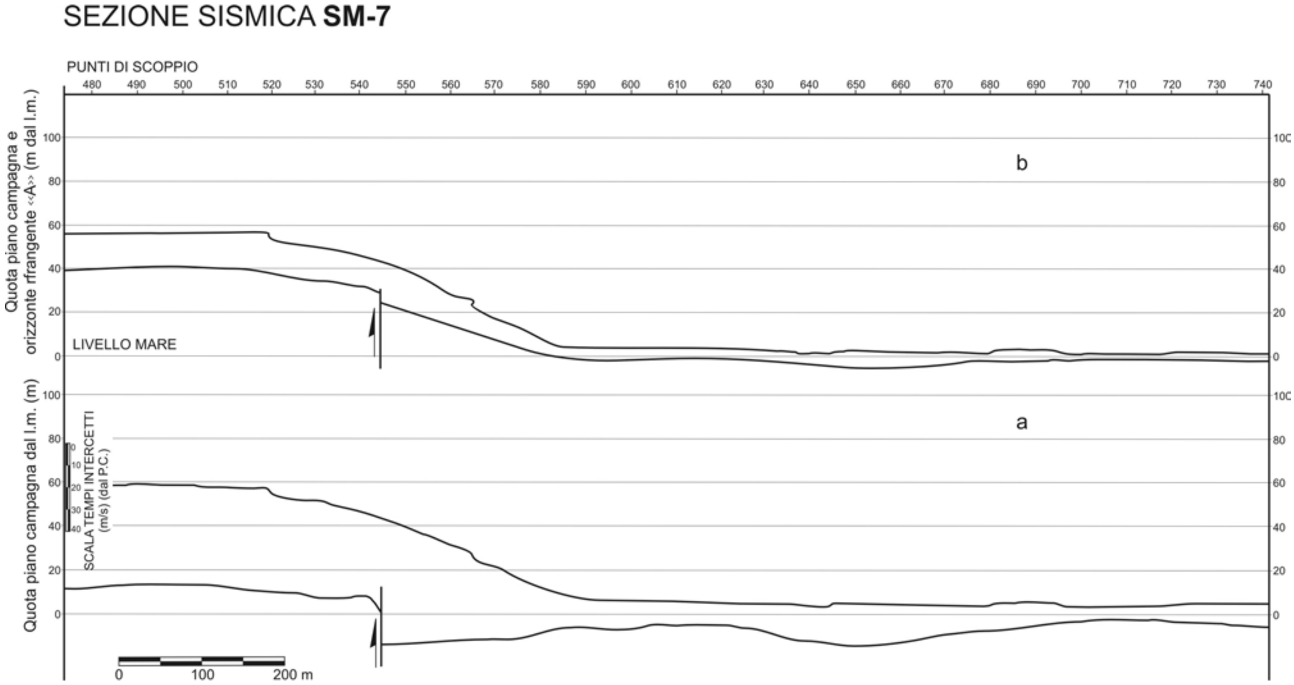

Fig. 6 - SM-7 seismic high resolution profile along E-F share (Fig. 1): a) diagram of the intercept-times; b) seismic section (after Del Ben & Finetti, 1985).

above the mentioned Holocene deposits and in contact with the underlying mid-Pleistocene *Formazione di Messina*. This fault plan is not visible anymore due to the intense urbanisation experienced by the site, to the scarce mechanical characteristics of the formations and to the existence of a colluvium covering. The second fault, on an extension of **a**, situated to the South of the southern shore of the basin and parallel to **b**, conforms the coastline between the outlet of the Guardia river and Peloro Cape (Fig. 1: **a'**).

5. NEW DATA AND SURVEYS

Summarizing, the results of the morphological characteristics, tectonic elements and seismic surveys mentioned above, indicate that the Ionian coastal plain is bound by two direct faults, parallel to each other and ENE–WSW oriented, with the edge that lowers towards the SSE. The basin of Pantano Grande is situated inside such a step: the northernmost of the two faults conforms the northern shore of Pantano Grande, while the southern shore is conformed by some small faults (Del Ben, 1985) which lower towards NW (Fig. 1, **d, e** and **f**).

A wide substratum of sterile conglomerate beneath sea level (Fig. 7) prevalently outcrops along the waterline between Ganzirri and Faro; it has been mapped during an underwater survey. The outcrop (Fig. 8) bound a strip of beach 2.3 km long, from Pantano Grande to Punta Sottile. The average width of the outcrop measures approximately 20 m, with a maximum values around 35 m and thickness up to 3 m. Such a value is greater than that already ascertained from boreholes drilled to the NE, near Punta Sottile (Fig. 2: S_1), where intercalations of coarse pebble conglomerate present a thickness of about 50 cm which were found within the sand and gravel deposits (Bonfiglio & Violanti, 1983).

According to the same authors this deposit is a beach rock. Conversely, this conglomerate is missing in a layer 30 m thick, formed by medium size sand and grey polygenetic gravels with lens of mud in the upper part, investigated during geognostic boring carried out 300 m to West of La Torretta (Servizi Tecnici S.P.A. - Fintecna Gruppo IRI, 1999; Fig. 9).

With its squashed funnel shape, Pantano Piccolo presents a bathymetric trend that can be justified by assuming that the basin was formed by a tectonic pro-

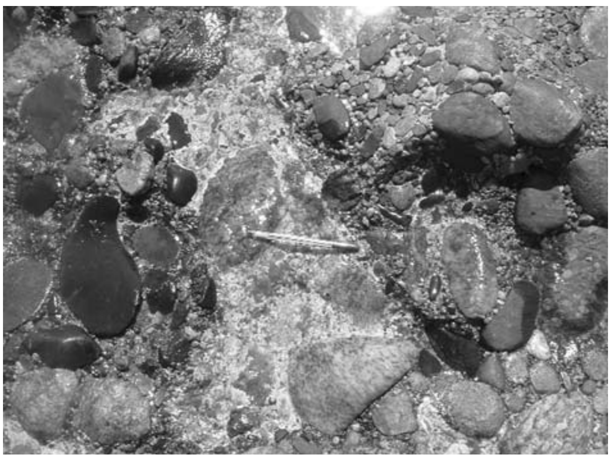

Fig. 7 - Particular of the Mid-Pleistocene sterile pebble conglomerate outcropping along Ganzirri shoreline.

cess connected with the activity of the faults that conform to the Peloro Cape Peninsula. The strong acclivity of the bottom along an E-W direction near the centre of the basin corresponds to a direct fault oriented approximately NNW–SSE, that lowers towards ENE and was reported by DEL BEN (1985) and DEL BEN & FINETTI (1985). Samples taken from the marsh bottom next to bathymetric line of – 5m, on the edge of the scarp that bounds the southwestern sector of the basin, show that they were formed by conglomerate presumably belonging to the *Formazione di Messina*.

As a whole, the data from literature and the results of various tests carried out in the study area allow to define the geological section of the area of study (Fig. 10). The direct fault along the northern shore of Pantano Grande (Fig.1: **g**) is supported by the previously mentioned geophysical surveys such as the small faults (Fig. 1: **d, e** and **f**) which bound it to the South, and are compatible with the evidence of local subsidence derived from historiographical documentation; the existence of the fault which conforms to the coastline (Fig. 1: **a'**) is supported by the morphological analysis and the results of geophysical exploration (DEL BEN, 1985).

6. CONCLUSIVE SUGGESTIONS

The observation reveal that the genesis of the Pantano Piccolo and Pantano Grande basins is markedly tectonic, as supported by the following points:

a) the hilly relief located upstream of Pantano Grande, makes up a small horst bound by faults ENE–WSW oriented; the northern fault constitutes the limit of the Mortelle coastal plain on the Tyrrhenian Sea slope (Fig. 1: **i**); the less evident southern fault (Faglia di Ganzirri; Fig. 1: **g**) delimits the northern shore of Pantano Grande. The lengthened shape of the basin

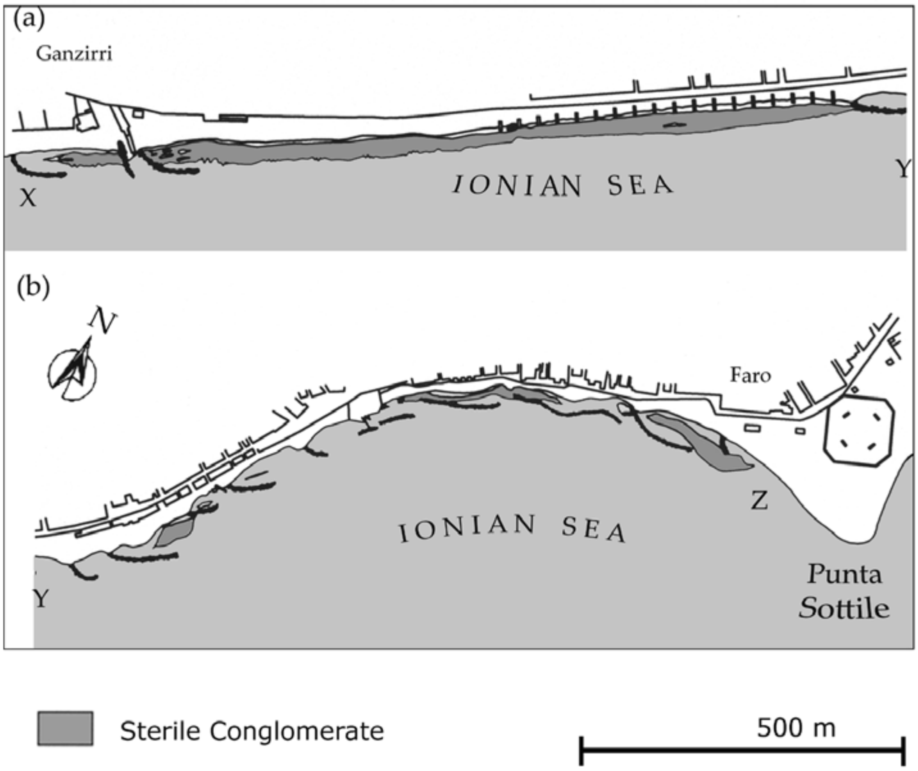

Fig. 8 Map of the Mid-Pleistocene sterile pebble conglomerate outcropping along Ganzirri shoreline (above) and Ganzirri-Punta Sottile shoreline (below).

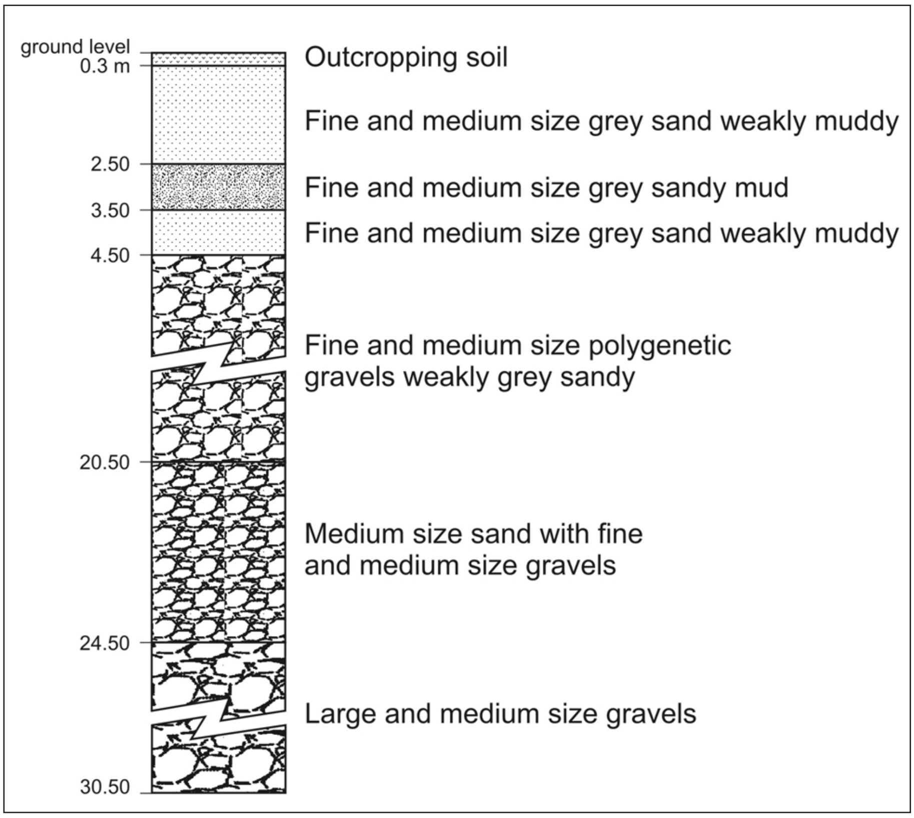

Fig. 9 - Shallow stratigraphy resulting from geognostic boring 300 m at W of La Torretta (D_2 , in Fig. 2).

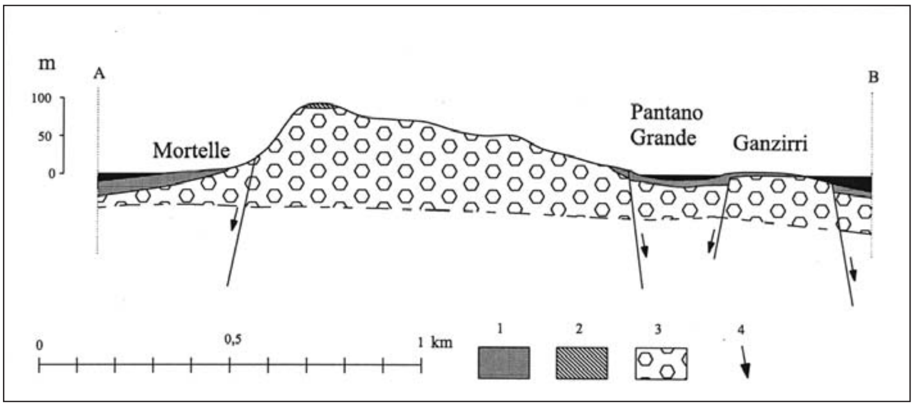

Fig. 10 - A-B geological cross-section of the Peloro Cape peninsula (Fig. 1): *1*, alluvial deposits (Holocene); *2*, terraced deposits (Late Pleistocene); *3*, sand and gravel of the *Formazione di Messina* (Mid-Pleistocene); *4*, normal fault.

parallel to Ganzirri Fault direction and the contiguous location of this fault with the basin are substantial elements which configure the causal nexus about the tectonic genesis of Pantano Grande.

Besides, with reference to the remains of ancient temple uncovered at a few meters depth during the digging work of a canal between Pantano Piccolo and Pantano Grande and of present-day molluscs of brackish environment brought to light during well borings in Margi, show that level was correspondent to the bottom of one or more ancient small marshes which at the present-day are not anymore existing. Such evidence are to be related to local subsidence processes activated by movement of the direct fault of Ganzirri;

(b) the transversal dimension of Pantano Grande is bound to the North by the above mentioned g fault and to the South by some small direct faults which lower towards the NNW (Fig. 1: **d, e, f)**; another normal fault ENE–WSW oriented, and which lowers towards the SSE, model the Ionian coastline from the outlet of the Guardia River to Peloro Cape (Fig. 1: **a'**);

c) the basin of Pantano Piccolo, located in the northern coastal plain, is characterised by a conspicuous depth compared to its horizontal dimensions, by a marked asymmetry of the isobaths and by a steep slope acclivity of northern and eastern shores. In the eastern sector of the basin, where the depth reaches the maximum value, the bathymetric trend along the W-E profile suffers a rough increase and the depth by an initial value of -1.5 reaches -28 m. In this portion the bathymetric trend is three times of that observed along the Tyrrhenian shore. The basin is located in a semi-graben, formed by a direct fault NW-SE oriented and NE dipping (Fig.1: **h**) and by two direct small faults NE-SW oriented and NW dipping (Fig. 1: **i, l**).

In conclusion, the analysis of geomorphological features of Pantano Piccolo correlated to those of the area in which the salt marsh is placed is consistent with a tectonic genesis.

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