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*Research Article*

# Geological, Geomorphological and Archaeological Sites in Pachino and Portopalo di Capo Passero Areas (Syracuse, Southeastern Sicily)

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**Abstract.** The studied area corresponds to the extreme south eastern side of Sicily, characterized by the presence and coexistence of peculiar natural characteristics, connected to some expressions of a "virtuous" anthropic activity. Firstly, the purpose and objectives of the research are described. Characteristics of geological evolution, studied under structural, stratigraphical and geomorphological are later described. Some of the more important sites of geological, geomorphological and archaeological interest are also discussed.

**Keywords:** Geoarchaeology, Geomorphology, Pachino, Portopalo di Capo Passero, Tuna salt factories

## 1 Introduction

The extreme south eastern side of Sicily is characterized by the coexistence of several interesting sites, pertinent to geological, geomorphological and archaeological aspects that deserve greater acknowledgement.

This paper aims to take a census of sites with value of *Cultural Good* and to describe them. The requirement for this arises from the absolute need to protect, and use to its advantage, a rich heritage that is currently exposed to the risk of disappearance. This is due to anthropic foolish interferences and/or conscious and inconscious negligence of citizens and local managers.

Unfortunately, many environmental problems have already arisen, but if communities and local administrations were informed of the scientific, ecological and cultural aspects of this heritage many could have perhaps been prevented. Through the initiation of work that aims to preserve and recover this heritage, it will be possible to enrich and diversify the touristic opportunities the area offers, taking a meaningful step further towards a solid Sustainable Development.

The Geosites and Geomorphosites of Pachino and Portopalo of Capo Passero territories are the "consequence" of a long and complicated palaeogeographic evolution.

More interesting formations are thought to be a product of the effusive processes of the Cretaceous age and to the erosive action of the sea along the coasts. Remains of superficial eruptive structures, lined up along directrices of tectonic weakness, and many dykes with similar orientation, belong to effusive processes. In comparison, slopes, flat spaces of sea abrasion, marine terraces, marine caves, potholes and coastal ponds are connected to the erosive action of the sea. Complex shapes of karstic surfaces, epygeal and hypogeal, carbonatic rocks of the Cretaceous and Eocenic age, are also present.

The rise of sea level during historical ages is proven by the presence of archaeological sites and historical installations that are now partially or entirely submerged.

Morphological characteristics cannot be assigned to one scheme of evolution, due to the lithological variability of the outcropping rocks and their different exposure during geological time to atmospheric agents.

## 2 Geological – Structural frame

The basin of the central Mediterranean Sea, within Sicily, is characterized by the structural domains linked to the collision between the African and European continental plates. These plates have joined, giving rise to the Apenninic–Maghrebid Orogen, a corrugated belt which

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forms the Apenninic Ridge. This belt passes through Sicily and the Straits of Sicily, and continues along the North African coasts of Maghreb.

In the north eastern sector of Sicily, the Apenninic–Maghrebid Orogen is formed by the presence of the Apenninic–Maghrebid Belt (Fig. 1: **cam**) and the Kabilo–Calabride Belt (Fig. 1: **ckc**).

The Apenninic–Maghrebid Belt is made by nappes with southern vergence, corrugation of which implicated sedimentary sequences of Tetide and of joined minor palaeodomains, originally placed between edges of European and African plates. The Kabilo–Calabride Belt is made by nappes of crystalline, with a basement origin involved in hercynic metamorphism, along with some components of primary meso-caenozoic sedimentary sequences (Finetti I, Lentini, Carbone, Catalano & Del Ben, 1996).

Nappes of Apenninic–Maghrebid Orogen overthrust Hyblaean foreland areas are regarded as a stablecomponent of African plate margin (Burollet, Mugnot & Sweeney, 1978). The sequence outcropping in the Hyblaean foreland is prevailingly formed by calcareous rocks. The age extends from Triassic to Middle Pleistocene. Cretaceous, Miocenic and Pleistocenic basic effusive rocks (connected to extensional tectonic phases) are embedded within sedimentary rocks (Cristofolini, 1966; Di Grande, 1967, 1969, 1972; Carbone, Grasso & Lentini, 1987; Amore, Carveni, Scribano & Sturiale, 1988; Carveni, Grasso, Romano & Tricomi, 1991; Carveni, Romano, Capodicasa & Tricomi, 1991; Carveni, Leonardi & Romeo, 1993; Carveni & Sturiale, 1999).

Hyblaean foreland borders on the east with the oceanic crust of the Ionian Basin (Finetti I, 1982) through Hyblaean-Maltese continental slope (Fig. 1: **SIM**), morphological expression of normal step faults system: their extension towards the north intersects the eastern side of Mount Etna (Cristofolini, Lentini, Patane' & Rasa', 1979).

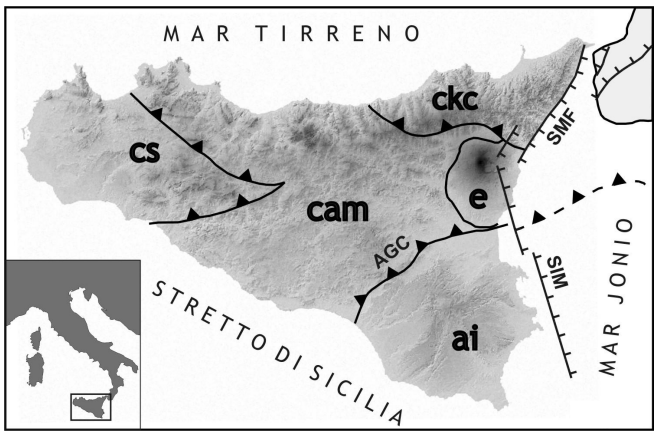


**Figure 1:** Structural scheme of the Sicily - **ai**) Hyblaean Foreland; **cam**) Apennine-Maghrebid Belt; **ckc**) Kabilo-Calabride Belt; **cs**) Sicana Belt; **e**) Etna volcano; **AGC**) Outcropping border of Gela-Catania foredeep; **SIM**) Hyblaean-Maltese continental slope fault system; **MF**) Messina-Fiumefreddo fault system (from Finetti I, Lentini, Carbone, Catalano & Del Ben, 1996).

## 3 Geology of the Pachino and Portopalo area of Capo Passero

The geological area studied coincides with the extreme south eastern part of Sicily and structurally, with Hyblaean foreland, is one of the most important structural elements of eastern Sicily. It is regarded as part of the African continental crust (thick more than 30 km), that would be actual continental shelf, contiguous to Apenninic–Maghbrebid Belt area, characterized by intense tectonic deformation (Barberi et al., 1974; Amodio Morelli et al., 1976).

Iblean foreland is delimited in the north west by the Caltanissetta Basin, an asymmetric trench, wedged between the foreland and the belt. The south eastern part of the formation constitutes the Gela-Catania foredeep. Off the eastern coast, Iblean foreland is cut off by the Iblean–Maltese slope, which separates the thin belt of continental platform and the Malta Channel from the Ionian Bathial plane, making up the western edge of all the Ionian Basin.

The studied area is part of the eastern sector of Hyblaean Cretaceous-Upper Miocenic geological sequence (Carbone, Grasso & Lentini, 1982), and is characterized by a basement of Cretaceous subaerial basic volcanites on which a sequence, prevailingly calcareous, is transgressive. There are many stratigraphic gaps ranging from Maastrichtian to Quaternary (Carveni, Romano et al., 1991).

The outcropping stratigraphic sequence is:

**CRETACEOUS VOLCANITES** (Fig. 2: **Cv**) – Very weathered basic volcanites outcrop widely between inhabited places of Pachino and Portopalo and are well observable along the cliff at northern of Portopalo. Hoffmann (1839) compared volcanites outcropping in the area of Pachino to Palagonitic Tuffs, a term denoting volcanic rocks typical of the Palagonia area, afterwards identified by Rittmann (1958, 1973) as volcanic rocks connected to submarine eruptions and named hyaloclastites. Hoffman's interpretation conditioned many researchers, who ascribed volcanic rocks of Pachino to submarine eruptions.

As a matter of fact, the rocks in question are subaerial lava flows with subordinate pyroclastic products (Carveni, Romano et al., 1991).

The Cretaceous age has been ascertained on the basis of the presence of Cretaceous calcilutites, with *Globotruncanae* discovered during drilling works (Colacicchi, 1963; Patacca, Scandone, Giunta & Liguori, 1979), as bedrock, and of Maastrichtian calcirudites with

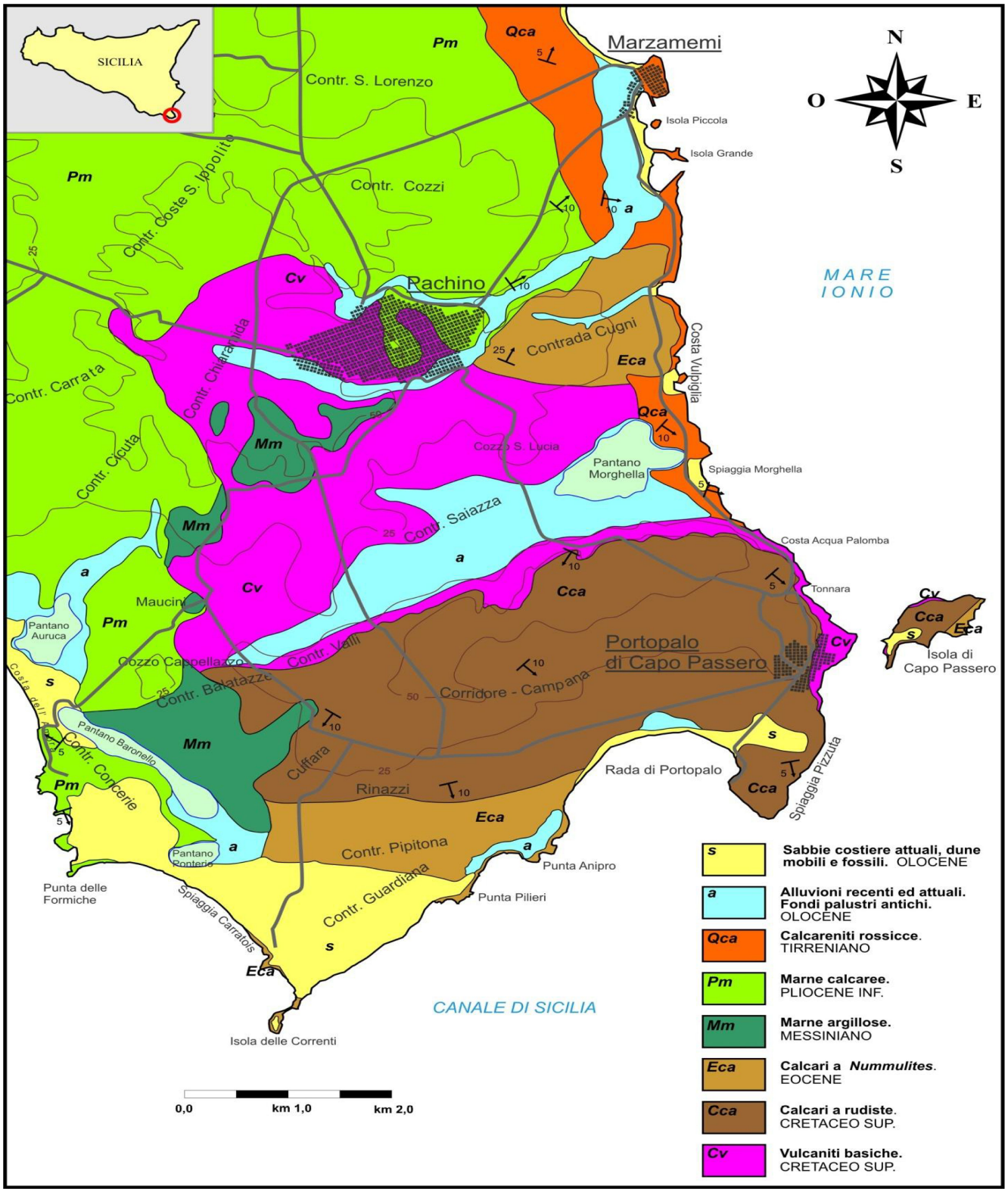


**Figure 2:** Geological map of Pachino and Portopalo area (from Carveni & Capodicasa, 2011). **s**) Present day beaches; dunes (Holocene); **a**) Recent and present day alluvial deposits; deposits of old marshy areas (Holocene); **Qca**) Reddish calcarenites (Tyrrhenian); **Pm**) Calcareous marls (Lower Pliocene); **Mm)** Clayey marls (Messinian); **Eca**) Limestones with Nummulites (Eocene); **Cca**) Calcirudites with Rudistae (Upper Cretaceous); **Cv**) Volcanic rocks (Upper Cretaceous).

*Rudistae* at the top (Colacicchi, 1963) as of radiometric (K/Ar) datations.

Carveni, Romano et al. (1991) identified, from the base to the top, the following formations:

**ACQUA PALOMBA LAVA SERIES** (Fig. 3: **12**) – they are mainly constituted by alkali-basalt lava and are clearly observable along the cliff at the east of Portopalo (Carveni et al., 1991 b). Several members of this series have been distinguished.

At the sea level, Porticciolo megaporphiric lavas outcrop. In the lower levels, they are strongly weathered, jointed and similar to volcanoclastic products if superficially analysed. At contact between a lava flow and an underlying one, there are clearly visible wall rocks, connected to the phenomena of thermometamorphism.

**TONNARA OLIGOPHIRIC LAVAS** – follow a clear surface of contact. They are rough and extremely weathered, with a reddish-purple blue colour. In particular, this aspect is connected with the way of emplacement that is the method of how lava pours into the sea. Lava flows can be very fluid single units of flow, prevailingly formed by spheroidal or long bodies (connected by thin strips, variously lying upon, of lava), modelling themselves on underlying surfaces.

The following effusive episode gave rise to PLAGIOCLASIOPHIRIC LAVA: some dykes of alimentation are recognizable along the Acqua Palomba cliff. These lavas are compact and characterized by a columnar structure and desquamation, like onions, in the upper levels.

**PORPHIRIC LAVAS** – with prevalence of crystals of augite are weathered, joined and outcrop above.

**BASANITIC SUBVOLCANIC BODY** (Carveni, Romano et al., 1991) – approximately 40 metres thick, and are formed by very compact grey rocks with associated pyroclastites of little/medium dimensions. These outcrop at the north of the Acqua Palomba spring. It is very likely to be the filling of an important eruptive joint.

In the areas studied, the census consists of more than 100 dykes. Among them, some have fed outcropping lava flows, whilst many others, which have crossed all the described volcanic series, located at the top, are broken off by erosional boundaries connected to the movement of swells. All of the lava flows, weathering and outcropping in the hinterland of Pachino and Portopalo, have been ascribed to the Acqua Palomba Series due to the impossibility of further subdivisions.

Other volcanites have been recognized and distinguished at the top. They are:

**COZZO FILUA AND CONTRADE SAIAZZA AND TIGANELLO APHIRIC LOWER LAVAS** (Fig. 3: **11**) – Aphiric lava flows with remarkable decimetric columnar structure and planes of flow lamination. They outcrop along the western slope of Cozzo Filua and in the countrysides of Tiganello, Saiazza and Chiusa di Pozzo. The bedrock has been assigned to members of the Acqua Palomba Series, although strong weathering makes it extremely difficult to identify.

**CONTRADA MALTEMPO LAVAS AND PYROCLASTITES** (Fig. 3: **10**) – Pyroclastites are formed by lavic fragments and weldered scoriaceous elements, sometimes cemented by secondary calcite. Outcrops of boulders and fragments of lava (cumulates basalts according to Carveni, Romano et al., 1991) are discontinuous. It is not possible to observe the contact between lavas and pyroclastites. The area of outcropping is at the northern area of Pantano Marghella. K/Ar dating of lavas gave an age of $80.0 \pm 1.3$ Ma (Carveni, Romano et al., 1991).

**CONTRADA TIGANELLO PORPHIRIC LAVAS** (Fig. 3: **9**) – This member of the sequence is composed of a series of little and thick lava outcrops, connected to a supposed area of linear emission, with a strike NE/SW. Lavas are compact with many small crystals of augite. The structure is porphiric. K/Ar dating is $79.9 \pm 1.3$ Ma (Carveni, Romano et al., 1991).

**COZZO PAGLIARO PYROCLASTITES** (Fig. 3: **8**) - These pyroclastites can be related to red-purple blue weldered small scoraceous elements, and assumed connected to the same effusive fracture that gave rise to porphiric lavas of Contrada Tiganello (Carveni, Romano et al., 1991).

**COZZO SANTA LUCIA MEGAPHORPHIRIC LOWER FLOW AND COZZO FILUA UPPER FLOW** (Fig. 3: **7**) – Cumulates basalts (Carveni, Romano et al., 1991), which outcrop around homonimous height, extend towards the south, with a total thickness of approximately 20 metres. An outcrop of similar lavas is present at the top of Cozzo Filua, above the aphiric lava unit.

**COZZO SANTA LUCIA OLIGOPHORPHIRIC UPPER FLOW AND ASSOCIATED PYROCLASTITES** (Fig. 3: **6**) – Porphiric alcali-basaltic lavas (Carveni, Romano et al., 1991), with evident columnar structure and a thickness of approximately 10 metres. Crystals of augite are prevalent, but less represented than those of olivina. A level of pyroclastites consisting of red weldered scoriaceous elements and rare volcanic bombs are also associated. K/Ar dating is $79.7 \pm 1.3$ Ma (Carveni, Romano et al., 1991).

## 4 Sedimentary rocks

At the end of Cretaceous volcanic activity, the area of Pachino and Portopalo was affected by a subsidence that caused a partial ingression of the sea. The Cretaceous, terrigenous and carbonatic deposits, at the top of Acqua Palomba Series volcanites, demonstrate a crucial change

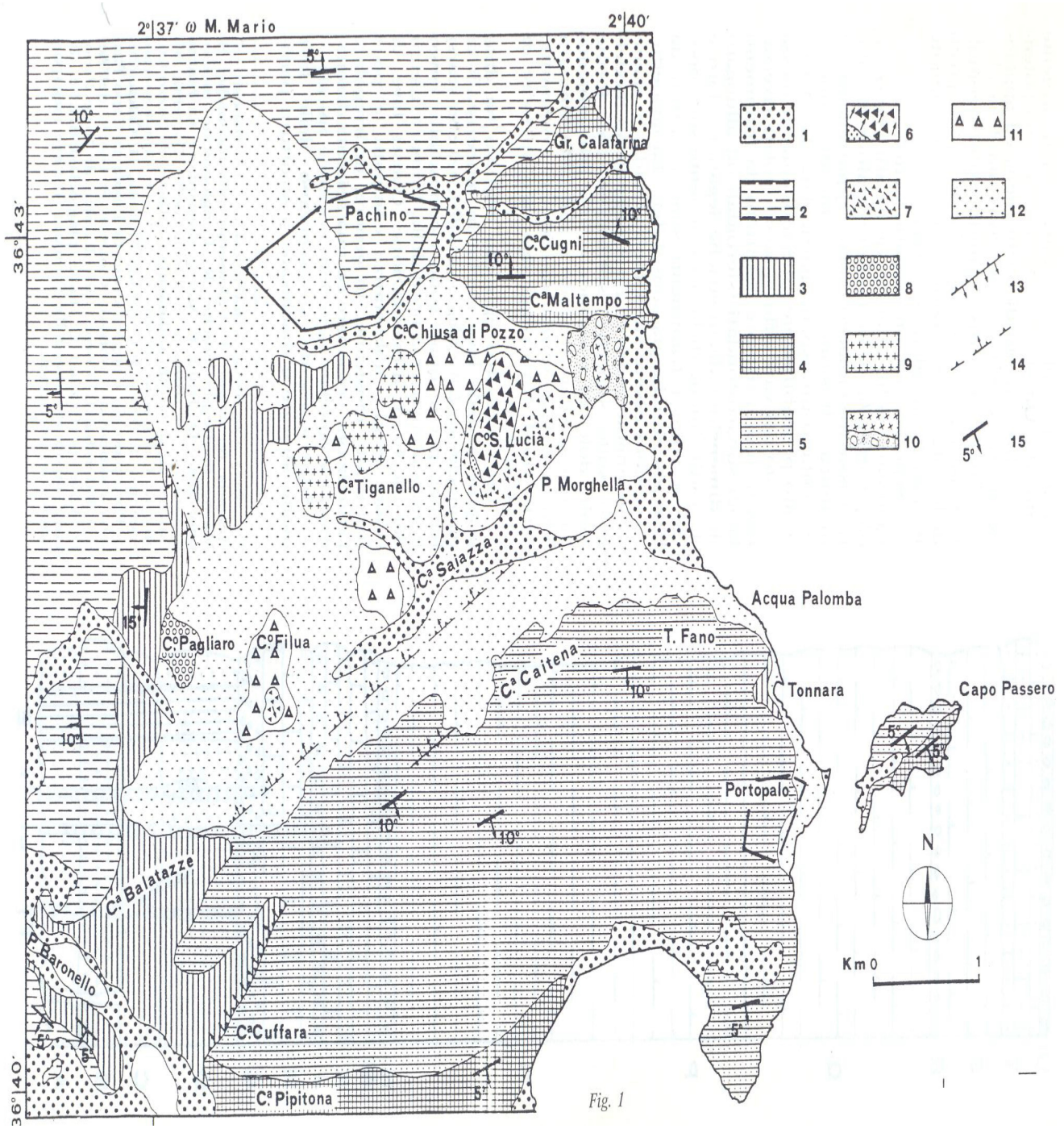


**Figure 3:** Geological scheme of area of Pachino and Portopalo of Capo Passero (Carveni, Romano, Capodicasa & Tricomi, 1991). **1**) Quaternary deposits (Calcarenites; Terraced beaches deposits; Hypogean deposits; Fossil dunes; Deposits of present day beaches); **2**) Pliocenic deposits (Trubi; Middlepliocenic conglomerates; Middlepliocenic marls); **3**) Miocenic deposits (Grotta Calafarina Calcarenites; Isola delle Correnti Breccia; Tortonian marls; Messinian marls); **4**) Eocenic deposits (Eocenic conglomerate; Cozzo Cugni Calcirudites; **5**) Cretaceous deposits (Contrada Càitena Sands; Isola di Capo Passero Conglomerates; Portopalo Calcirudites); **6**) Cozzo Santa Lucia Oligoporphiric upper flow and associated pyroclastites; **7**) Cozzo Santa Lucia Aphiric lower flow and Cozzo Filua upper flow; **8**) Cozzo Pagliara Pyroclastites; **9**) Contrada Tiganello Porphiric lavas; **10**) Contrada Maltempo Lavas and pyroclastites; **11**) Cozzo Filua and Contrade Saiazza and Tiganello Aphiric lower lavas; **12**) Acqua Palomba Lavas Series; **13**) Faults; **14**) Presumed faults; **15**) Dip of the strata.

in the geological evolution of this area.

The base of the Cretaceous sedimentary series is formed by yellow, thin, terrigenous deposits, referred to as the Contrada Caitena Sands (Carveni, Romano et al., 1991). This resulted from the erosion of underlying volcanic rocks. Eastward, sands pass to Isola di Capo Passero Conglomerate (Carveni, Romano et al., 1991), formed by decimetric spherical cobbles originating from the dismantlement of Cretaceous volcanic rocks. Interfingering between sands and conglomerate is not visible, but hypothesized on the basis of stratigraphic considerations, because Maastrichtian CALCIRUDITES WITH RUDISTAE (Colacicchi, 1963; Camoin & Duchafour, 1980; Matteucci, Schiavinotto, Sirna & Russo, 1982) (Fig. 2 **Cca**; Fig. 3: **5**) outcrop in conformity on the top of both lithotypes. Calcirutides are well developed on the top of alkaline basalts outcropping along the northern cliff of Isola di Capo Passero and along the coast at the east of Portopalo. Disconformity with underlying volcanites is emphasized by an erosional surface associated with the motion of the swells, under a low sounding depth. Truncation of many dykes makes this phenomenon even more evident.

Calcirudites are characterized by many and stratigraphically important fossil species: *Hippurites cornucopiae* De France, *Sabinia aff.* aniensis Parona, *Mitrocaprina bulgarica* Tzankov, *Hydnophoraraea spp.*, *Montastraea spp.*, *Actinastraea spp.*, *Columnastraea pachinensis* (De Gregorio), *Orbitoides apiculata* Schlumberger, *Omphalocyclus macroporus* (Lamarck), *Siderolites spp.*, *Simplorbites gensacicus* (Leymerie), *Hellenocyclina beotica* Reichel (Carbone et al., 1987).

**LIMESTONES WITH NUMMULITES** (Fig. 2: **Eca**; Fig. 3: **4**) – At the top of the Calcirudites with Rudistae outcrop, with angular unconformity, there are the limestones present with Nummulites. At the base there is a conglomeratic level: clasts derive from the erosion of aphiric lavas and, subordinately, of calcirudites with Rudistae (Trevisan, 1936; Colacicchi, 1963).

From a lithological point of view, it is a question of calcirudites and calcarenites and, locally, of micrites without fossils. Depositional environments can be referred to as a sea not too deep, with high energy and clear waters. Checchia Rispoli (1905b, 1905a) attributed these limestones to Eocene; Trevisan (1936) and Colacicchi (1963) specified attribution to Lutetian.

The colour is whitish-yellow, and there is generally little evidence of stratification.

There are many vughs and fossils containing internal models of Mollusca, Nummulites, fragments of skeletons of Corals and calcareous Algae (Carveni, Romano et al., 1991).

**CALAFARINA CAVE AQUITANIAN CALCIRUDITES WITH LEPIDOCICLINAE** – Sedimentation of these calcirudites occurred during the Aquitanian, in apparent conformity with Eocenic limestones with Nummulites outcropping at Cozzo Cugni (Fig. 3: **3**) (Colacicchi, 1963). They are assimilable to the member of Siracusa Limestones of Monti Climiti Formation (Lentini et al., 1986).

Limited extension of the outcrop and the noticeable lithological analogy with underlying Eocenic limestones impeded a long time (reinserted) the identification of these limestones, which was made by Colacicchi (1963). An outcrop of smaller dimensions, with reworked fossil fragments of Rudistae and Orbitoides, formed by biosparrudites and biolitites was identified by Amore et al. (1988) along the cliff at the north east of Portopalo.

**TORTONIAN DEPOSITS** – In the Isola delle Correnti, a breccia formed by calcareous fragments outcrop at the top of aquitanian calcirudites. According to Ruggieri (1959) and La Rosa (1974) this would be basal sediment of Tortonian transgression. Tortonian azure marls of the Tellàro Formation outcrop in conformity with breccia. Modest areal extension does not allow the determination of total thickness; however, data deriving from surroundings indicate a thickness of 70 metres (La Rosa, 1974). Microfauna, studied by Colacicchi and Romeo (1960), indicates the Tortonian age.

**MESSINIAN ARGILLACEOUS MARLS** – At the southwest of Pachino, along the northern side of Pantano Baronello, Messinian argillaceous marls (Fig. 2: **Mm**) studied by Colacicchi and Romeo (1960), outcrop in conformity with marls of Tellàro Formation. The contact is clear and underlined by a level of Ostrea coclear, with a thickness of a few centimetres.

The hill, on which the village of Pachino lies, is characterized by direct superposition of Messinian sediments on volcanic terms. On the contrary, at Contrada Balatazza and Contrada Cuffara, they are unconformed on Cretaceous and Eocenic limestones, making a marine transgression that occurred during the Messinian age evident. Strata are centimetric, with the prevalence of calcareous or argillaceous components. Total thickness, obtained from surroundings, is approximately 30 metres. Surroundings made evident even the presence of strata of gypsum, unknown in the studied area but outcropping a little to the north, at the top of marls (La Rosa, 1974).

**TRUBI** – The term Trubi indicates, in Sicily, a sequence characterized by marly limestones and calcareous marls, rich of Foraminifera and closely alternating. The colour is white and the fracture is typically conchoidal.

Trubi outcrop extensively in the north and west of Pachino (Fig. 2: **Pm**), strata are rarely clear and thickness is of 50–70 centimetres. Trubi pass, whether later-

ally or vertically, gradually to calcarenites. At the base, there is a conglomeratic poligenic bank, some metres thick and formed from pebbles, which are either rounded or rich in edges. These originate from the erosion of underlying Cretaceous and Eocenic carbonatic rocks (Piano Casa Nova). Microfaunistic associations are those of zones with Globorotalia margaritae and with Globorotalia puncticulata (Lentini et al., 1984). Among the few macrofossils, there is Liostrea coclear. On the basis of surrounding data, thickness is approximately 50 metres (La Rosa, 1974). The age of sedimentation is lower Pliocene.

**QUATERNARY REDDISH CALCARENITES** – Along the eastern coast of the studied area, reddish calcarenites (Fig. 2: **Qca**), which are well cemented and with granulometry from middle to fine, outcrop (Fig. 3: **9**).

Fossils do not allow certain dating. Trevisan (1936), Ruggieri (1959), Colacicchi (1963) attributed a probable Tirrhenian age on the basis of considerations about height and subhorizontal layering.

The particular importance of calcarenites is attributed to use of that rock as building materials during the Greek-Roman period.

**SCALO MANDRIA CONGLOMERATES** – Near the village of Portopalo, along the coast of Scalo Mandria, there are two little outcrops of beach deposits, resting on Cretaceous lavas and placed at different heights.

The first is made from a small, cemented conglomerate with centimetric pebbles, prevailingly volcanic and subordinately calcareous into a reddish sandy matrix. The height of the base is 2.30 metres above sea level.

The second, outcropping a few metres southward, is made from a well-cemented conglomerate with decimetric pebbles, prevailingly calcareous and subordinately volcanic, into a whitish matrix. The height of the base is 1.20 metres above sea level.

The age of those conglomerates can probably be referred to as Quaternary.

**HYPOGEAN FOSSILIFEROUS DEPOSITS OF ISOLA DI CAPO PASSERO** – Along the northern coast of Isola di Capo Passero, bones of terrestrial mammalia, and blocks of carbonatic rock in yellow ochre mould were found. Deposition of mould occured around stalagmites (Carveni, Romano et al., 1991). It is an important fossiliferous layer, formed into a karstic cavity, where carcasses of entrapped animals accumulated within.

**RECENT BEACH DEPOSITS** – Along the beach before Isola di Capo Passero, there is a beach deposit formed from strata of sand and gravel, rich in fragments of fictile material and bones of tuna.

The outcrop is joined to a very important archaeological site: the height, which is approximately one metre above actual sea level, witnesses a recent relative sinking of the sea level.

**FOSSIL DUNES** – Cemented deposits of aeolian origin are present near the beaches.

**PRESENT DAY BEACH DEPOSITS** – Present along some of the coast, and are prevailingly made up of sands; more extended beach is that in front of Isola delle Correnti.

**MOBILE DUNES** – Mobile dunes are generally associated with sandy coastal deposits, from which originates material of alimentation.

**ACTUAL ALLUVIAL DEPOSITS** - Present along the streams, and are made up from gravels, sands and muds.

## 5 Geomorphological frame

As already accounted, morphological general configuration and morphological characteristics of the analysed territories cannot be related to a single evolutive scheme, due to the lithological variability of outcropping rocks and their different exposure to atmospheric agents during geological time. During geologic eras, many submersions and emersions of the studied area occurred. Consequently, reciprocal actions of sea abrasion and of superficial factors of erosion repeated, sometimes in association with some tectonic displacements. Such phenomena contributed greatly to the determination of different morphoevolutive processes and consequent different aspects of the landforms and landscapes.

The northern sector, characterized prevailingly by marly rocks, is marked by a series of small hilly raisings with a rounded outline, separated by large valleys. Erosional processes, mainly connected to the action of waters of surface run-off, are extremely contained, owing to little extension of drainage basins.

In the central sector, outcrop wide volcanic rocks from which emerge, as little and isolated hills, eruptive volcanic structures of the Cretaceous complex that are deeply eroded. As a whole, that area is a wide valley that, in its terminal part, enlarges to form coastal quagmire of Marghella. Hydrographic net is represented by short torrents, locally named *saie*, where downflowing of which happens only on occasions of particularly abundant and prolonged rains.

The southern sector is characterized by a monocline descending gently towards the south, delimitated at the north and east by retreated fault scarps. In this sector, it is possible to observe typical tabular morphology of calcareous landscapes, characterized by a dip of the strata, relatively uniform, and by a small inclination. Superficial erosive action is moderate, owing to the tenacity of outcropping rocks and their high draining power.

Littoral areas are characterized by low and rocky coasts, high cliffs perpendicularly on the sea and creeks, which are sometimes very narrow and deeply incised, or sometimes large and occupied by sandy deposits.

Behind some beaches there are little dunes not yet destroyed by agricultural training and by interventions of urbanisation, which, in the last period of ten years, changed the natural equilibrium of the coasts without the possibility of being recovered.

Little altimetrical difference between more high height of reliefs and base level (10–15 metres) is the cause of a sudden diminution of the velocity of waters along slopes, determining a phase of sedimentation after a very brief stage of transport.

The coastal inland is bordered by many ponds, representing the emergence of phreatic water tables. These occupy morphological hollows that sandy and/or calcarenitic bars divide from the sea.

The climate is Mediterranean arid, with long periods of nearly fully dry (from May to October), sporadically interrupted by precipitations with characteristics of storm, and months with temperate climate, characterized by brief rainy periods alternating with long periods of insolation.

## 6 Description of sites

**GEOSITES AND GEOMORPHOSITES OF VOLCANIC ORIGIN** – The origin of most important Geosites and Geomorphosites is volcanic. They characterize the Acqua Palomba cliff, where marine erosion made evident the internal structure of Cretaceous volcanic structures.

**TORRE FANO NECK** – A subvolcanic body, outcropping along the cliff in correspondence of ruins of Torre Fano. At petrographic analysis, it resulted to be a basanite (Carveni, Romano et al., 1991). The neck has been partially dismantled by marine erosion, which allowed an important eruptive apparatus to individuate.

**ACQUA PALOMBA CLIFF DYKES** – Along the Acqua Palomba cliff, a census of 111 dykes has been performed. Strike is comprehended between N 5° E and N 90° E, with a prevalence in the interval N 40°–50° E. Some dykes resist meteoric erosion better than walls, putting out on the plane of the field, while others are attacked more easily by marine abrasion, along with the formation of deep caves. Of particular interst is the zigzag pattern of the dykes. Such a phenomenon is attributed to be the wall of a columnar basalt, which determined the form of intruded mass.

**GEOMORPHOSITES OF MARINE ORIGIN** These Geomorphosites are often indicative of variations of the level of the sea. This is one of the reasons why they are so important.

**CAVES EXCAVATED INTO THE DYKES** – Phenomena of marine abrasion, as aforementioned, are particularly evident where dykes of a large thickness outcrop dykes that cross cretaceous volcanites.

**CAVES ALONG NORTHERN CLIFF OF ISOLA DI CAPO PASSERO** – The northern coast of Isola di Capo Passero is also affected by considerable erosive phenomena, giving rise to a cliff approximately 20 metres high. Action of the swells and local structural and lithological characteristics determined the morphological evolution of classic wave-cut notches into caves of remarkable dimensions.

**CAVES UNDER CASTELLO TAFURI** – At the north of the countryside of Portopalo, under Castello Tafuri, there are two caves connected to marine abrasion. Both develop into Cretaceous limestones, forming a rocky slope on which lies the castle, in correspondence to a small plane at the height of 15 metres above sea level. Research carried out does not supply useful elements for the determination of the age of their formation. Still, their height suggests a correlation with marine terraces of upper Pleistocene which, in the south eastern Iblean area, according to Carbone, Di Geronimo, Grasso, Iozzia and Lentini (1982), are present at the height of approximately 15 metres above sea level.

**CORRUGGI CAVE** – At the northeast of Pantano Marghella, there is a marine abrasion cave, known as the Corruggi Cave, before which, at a height of about 4 metres, is a plane. The cave, which comprises Eocenic limestones, is observed in archaeological literature, due to the discovery of manufactureted goods of final phase of upper Palaeolitic (Bernabo' Brea, 1949).

**POTHOLES ON ISOLA DI CAPO PASSERO** In the south eastern sector of Isola di Capo Passero, at the height of about 6 metres above sea level, there are several potholes near the border of the cliff. These caves concern Eocenic limestones. One of them, in particular, preserves inside rounded big calcareous blocks. Their vortical movement, connected to the breakers, excavated the rock. It is not possible to determine the age of formation of these morphosculptures. Their ubication, however, is testimony to the relative lowering of sea level.

**POTHOLES OF SPIAGGIA CARRATOIS** – At the north west of Isola delle Correnti, along the low rocky coast and at a height between 1.20 metres and sea level, there are many potholes comprising of algal Eocenic limestones. The caves of various dimensions are cylindrical. Walls are vertical and deep until 1.50 metres and the bottom is flat. Often, there are many caves blended to form big basins arriving at 7–8 square metres. Other potholes are present under sea level and are still active.

**ABRASION PLANE OF SPIAGGIA PIZZUTA** – At the south of the countryside of

Portopalo di Capo Passero, along the rocky coast denominated Spiaggia Pizzuta, it is possible to observe a marine abrasion plane comprising of Cretaceous calcarenites. The plane, which declines from a height of about 6 metres to sea level and cuts very evidently calcareous strata, witnesses a recent lowering of sea level.

## 7 Archaeological witnesses of sea level variations

**NEOLITHIC SETTLEMENT OF SPIAGGIA MORGHELLA** – Close to the eastern part of Pantano Morghella, archaeological excavations carried out at the beginning of '90s by Soprintendenza of Siracusa individuated rests of a wide coasting village of the neolithic age (Guzzardi & Basile, 1996). The southern sector of the installation is partially under sea level, but there are no studies useful in determining the rate of heightening of sea level.

**OLD CANAL OF ALIMENTATION OF SALTERN OF MORGHELLA** - A rectangular canal, deep at 2.90 metres and cut into Quaternary Reddish Calcarenites. Its function was to allow seawater to enter into Pantano Morghella, and was perhaps used as a saltern during the Greek-Roman period (Lena, Basile & Di Stefano, 1988). The canal is nearly entirely full of sand and is visible only in proximity of the area where sea waves break, it can be followed along some tens of metres towards the open sea. The upper border of the canal reaches a depth of only 1.40 metres at the point furthest from the coast. Calcarenitic level crossed by old excavation preserves tracks of old quarries of stones ("Latomie") of Ellenistic period, most of them submerged.

**OLD MARZAMEMI QUARRIES OF STONES ("LATOMIE")** – Wide old quarries ("Latomie") of the Greek period consist of Quaternary Reddish Calcarenites outcropping along the rocky coast of Marzamemi. From those quarries, probably going back to the fifth century before Christ (Guzzardi & Basile, 1996), blocks of calcarenite were extracted, many of which are still in place. "Latomie" are developed at various levels, with many of them totally submerged. Other little quarries of calcarenite, probably of the same period and partially submerged, are present on Isola Grande, Isola Piccola and the south of Spiaggia Morghella.

At Marzamemi, measurements carried out through subaqueous immersions pointed out that the lowest level of extraction is actually at 1.40 metres below sea level.

**INDUSTRY FOR THE CONSERVATIONS OF THE TUNA OF SCALO MANDRIA** – In front of Isola di Capo Passero outcrop rests an installation, of the Ellenistic-Roman period, where the manufacture of fish can be found. It is composed of basins excavated into lavic rock and utilized for the salting of tunnies from the fifth century before Christ to fourth century after Christ (Guzzardi & Basile, 1996). Basins were identified by a strong heavy sea during the 1981 winter (Bacci, 1983), and some of them, buried by the sand, are actually in correspondence of the area where sea waves break.

Unfortunately, available data does not allow the measurement of the amplitude of the phenomenon of submersion of archaeological sites. In spite of this, the presence of manufactured goods under sea level and disguised by the sand is clearly indicative of a sensible rise of sea level.

Recent deposits of bones of tunnies are to be regarded as discarded matter of manufacture of that industry.

**BASINS OF CONTRADA CONCERIE** – Along the coast at the north of Punta delle Formiche, there is a site of archaeological interest. There are some basins of Greek-Roman period, excavated into infrapliocenic calcareous marls, which are assumed to have been utilized for breeding fish. The basins are rectangular and are partially submerged. Measurements revealed the greatest depths of approximately 1 metre below actual sea level. Practical considerations allow us to presume that rising of sea level could have reached two metres.

## 8 Conclusion

Multiform peculiarities, characteristic of area of Pachino and Portopalo di Capo Passero, make the importance and value of that Cultural Heritage extremely evident.

These peculiarities identifiable in geological history are very fascinating. This area shows an element of specific importance in the sphere of evolution of the Mediterranean area; with the presence of palaeovolcanic phenomena. Indeed, deep explorations carried out to research petroleum and natural gas revealed the presence of underground volcanic rocks of Triassic age. Moreover, this area was particularly active during Cretaceous times; as the "interference" with coeval marine sedimentation; with a stratigraphic sequence of marine deposits getting untied until to the Tyrrhenian clearly show.

Geomorphological characteristics have the same interest. Morphotypes are specific and expressive answers manifold geological events and to characteristics of lithotypes.

In conclusion, the described sites have been the result of a peculiar geological history, of geomorphological evolution, and human activities.

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