

The Geological Heritage of Salento Leccese Area (Apulia, southern Italy)

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Abstract The Salento peninsula is a well-known Apulian tourist area. Its peculiar geological and geomorphological features also have attracted numerous researchers during the last 150 years. The importance of the Salento geological heritage and identification of key sites was determined by literature review, assessment of the records of field trips in and around the Salento area during scientific geological meetings, and conferences over the last 30 years, using a geographical information system. Furthermore, these sites identified are the Otranto-Castro and Gallipoli-Porto Selvaggio coastal areas, the area of Leuca as well as the area between Cursi and Melpignano. The Otranto-Castro area contains Late Cretaceous Rudist reefs and Ammonites, an Upper Oligocene reef complex, as well as Lower Pleistocene calcarenites containing slumps and erosional features. The coastal landscape is marked by boulder accumulations produced by a historical tsunami. The Gallipoli-Porto Selvaggio area is noted for its abundant remains of *Strombus bubonius* Lamarck. In Porto Selvaggio, there is a rich fossiliferous association with abundant taxa of fish found in Cretaceous dolomitic and calcareous layers, with the rocks showing thin chert layers and spectacular slump features that had been triggered by tectonic activity. The Leuca area is the location for the stratotype of the Leuca Formation and by the occurrence of Grotta del Diavolo, a coastal cave that exhibits polycyclic evolution in the Middle Pleistocene. Finally, the Cursi-Melpignano area is important for its numerous quarries of Pietra Leccese Formation that have yielded numerous fossils of Miocene marine vertebrates. The results from the

analysis point to the valuable geological heritage of the Salento area which is still completely unexploited by the local tourist industry. Data reported in this paper could be usefully integrated in plans aiming to build a cultural tourist attraction in Salento area.

Keywords Geosites · GIS · Salento · Apulia region

Introduction

The Salento peninsula is the southernmost part of the Apulian region in southern Italy (Fig. 1). This peninsula contains numerous sites of environmental importance (SIC—Site of Community Importance as defined in the European Commission Habitats Directive 93/43/EEC and ZPS—Special Protection Areas, as defined by the European Directive 79/409/CEE), regional and natural reserves and regional parks. Its beaches and coasts attract increasing numbers of tourists each year (Fig. 2).

The geological heritage of the Apulian region has strongly been supported by the promulgation of Puglia Regional Law n. 33/2009 “*Tutela e valorizzazione del patrimonio geologico e speleologico*” (conservation and promotion of geological and speleological heritage) which promotes compiling of inventories of sites of geological interest (*geosites*), allocates economic support and provides for a number of measures for their valorization and protection. These sites may constitute, in fact, the basis for the building of a cultural attraction for attracting tourists to the region during off-season periods.

The aim of this paper is to identify the most important geological sites in the Salento area following the review of the scientific literature and records of field trips associated with geological conferences held during the last 30 years in this region. A description of the sites is provided. A comparison of the geological sites of Salento with other Italian or

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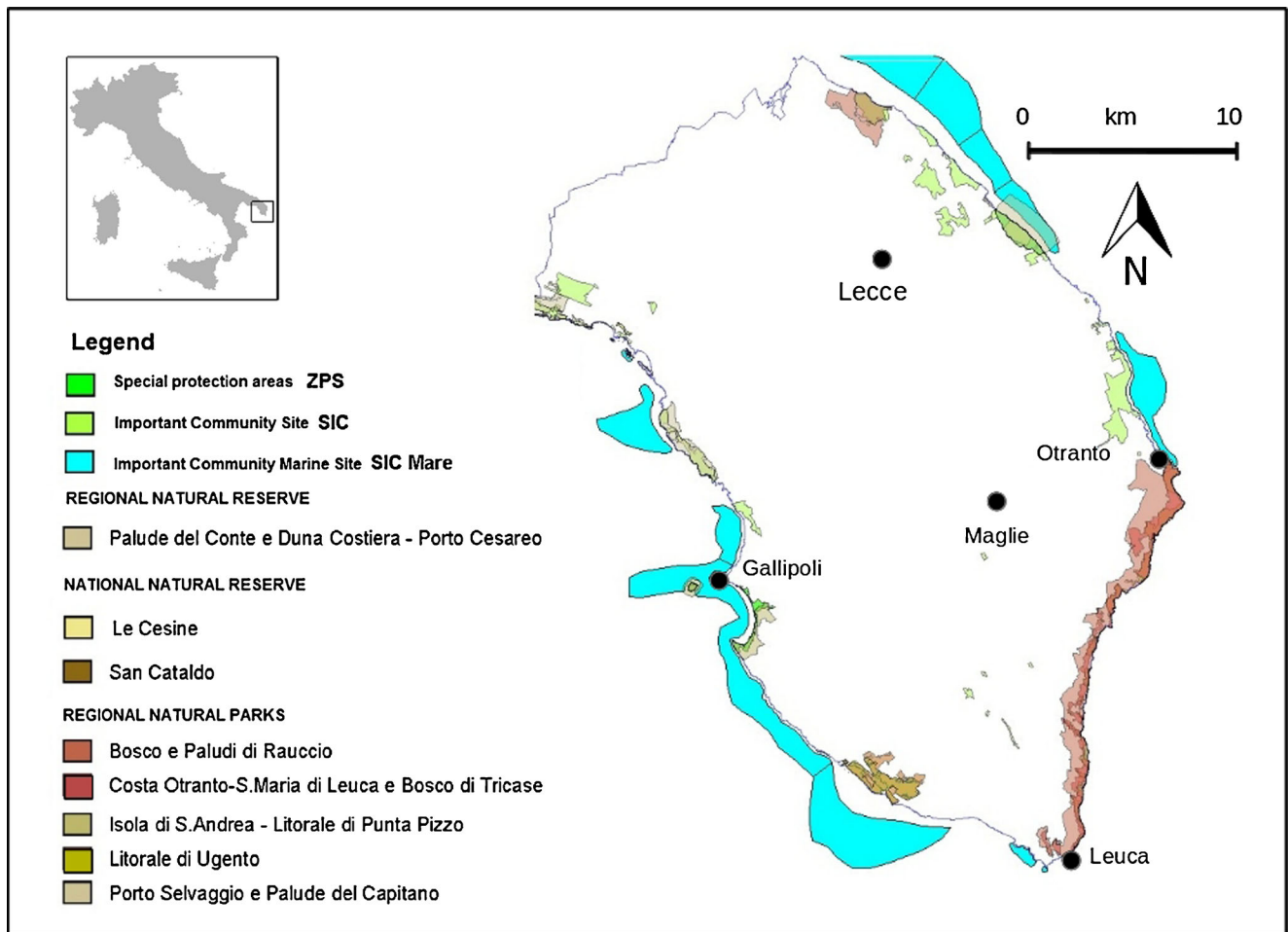
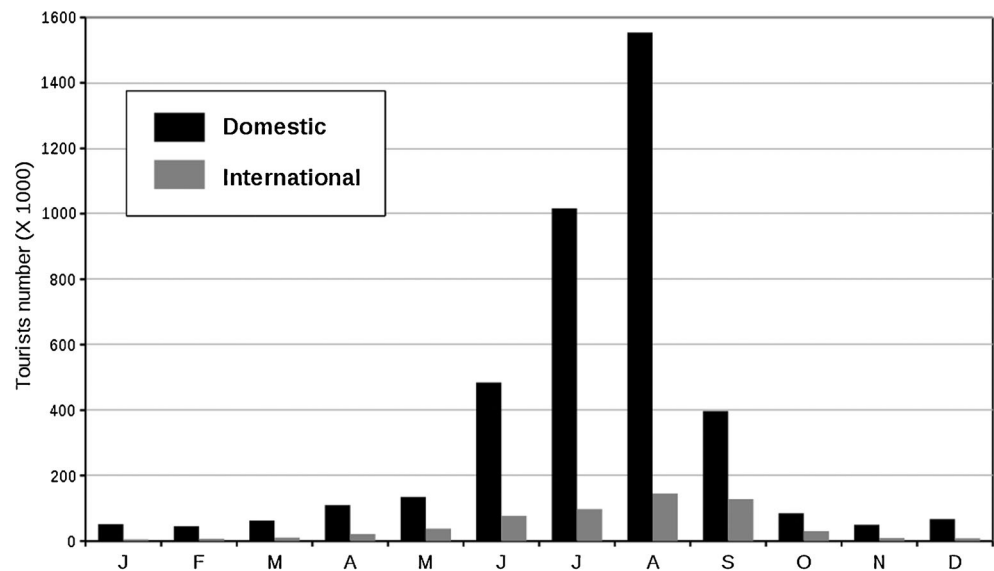


Fig. 1 Natural protected areas in the Salento leccese region. SIC site of Community Importance as defined in the European Commission Habitats Directive 93/43/EEC, ZPS Special Protection Areas, as defined by the European Directive 79/409/CEE

European geosites was not undertaken. While this would place the Salento area in a National or European context, such

an exercise was beyond the scope of our research, and a further paper would be needed to accomplish this task.

Fig. 2 Annual distribution of tourists number in the Salento leccese in 2011 (data from Puglia Promozione–Regione Puglia). Domestic and international tourists cluster during the summer. The promotion of geotourism in the Salento leccese is an opportunity to increase the number of visitors during low season



Geological Outline of the Salento Peninsula

The Salento peninsula is the southernmost emerged part of Adria Plate which constitutes the foreland of both Apenninic and Dinaric orogens. It comprises a Variscan basement covered by a 3–5-km thick Mesozoic carbonate sequence (the Calcari delle Murge unit) overlain by thin deposits from the Tertiary and Quaternary age (Ricchetti et al. 1988) (Fig. 3).

The most ancient rocks of this cover have been produced by transgressions after the definitive emersion of the Apulian carbonate platform occurred between the end of the Cretaceous and the beginning of Paleogene periods (Fig. 4). In some cases, bauxitic deposits can be found between Mesozoic limestones and Paleogene units that have been studied in detail by numerous authors (Bosellini et al. 1999; Bossio et al. 1999; 2006a, b, 2007; 2009; Esu et al. 1994, 2005; Esu and Girotti 2010; Luperto 1962; Margiotta 1999; Margiotta and Negri 2008; Margiotta and Ricchetti 2002; Parente 1994).

Four sedimentary cycles have been recognized from Neogene to Lower Pleistocene periods (Bossio et al. 2001, 2005, 2006b) (Fig. 4). The first cycle comprises the Pietra Leccese Formation and the overlying Calcarenite di Andrano Formation. The Miocene sedimentary cycle was interrupted because of the emersion of Salento which prevented the formation of evaporites. The total thickness of Miocene formations is greater than 150 m on the eastern side of the peninsula (Giudici et al. 2012; Margiotta and Negri 2005; Mazzei et al. 2009).

The second cycle is represented by breccias and conglomerates of the Leuca Formation that was deposited during the Lower Pliocene period, reaching a maximum thickness of 30 m. The third sedimentary cycle involved the Uggiano la Chiesa Formation, of Upper Pliocene age, and composed of well-stratified and fossiliferous biodetritical limestones and yellowish calcareous sands with a maximum thickness of about 80 m (Giudici et al. 2012).

The fourth sedimentary cycle involved the Calcareniti del Salento Formation (Calcarenite di Gravina Formation according to Ciaranfi et al. 1992), a very fossiliferous biodetritical calcareous sediment with *Artica islandica* Linneo. The Calcareniti del Salento Formation formed in the Lower Pleistocene reaching a maximum thickness of about 60 m (Giudici et al. 2012).

A number of Middle-Upper Pleistocene deposits can be also found on the Salento peninsula (Coppa et al. 2002; D'Alessandro et al. 1994, 2004; D'Alessandro and Palmentola 1978). At the base of the sedimentary succession are massive yellow-greenish clayey sands, very rich in glauconite, and marked by the presence of *Terebratula scillae* Seguenza. The sands are overlain by blue-grey clayey-silts (Argille subappennine of Ciaranfi et al. 1992), that are rich in fossils (*A. islandica* Linneo, *Pecten jacobaeus* Linneo,

Aequipecten opercularis Linneo, *Dentalium rectum* Gmelin, *Mya truncata* Linneo) (Margiotta and Varola 2007), and by sandy and silty clays (Margiotta et al. 2010).

The most recent units are the Marine Terraced Deposits from the Middle-Upper Pleistocene period that were deposited all around the Salento peninsula up to an elevation of 160 m (Ciaranfi et al. 1992). Marine sediments were deposited during repeated marine transgressions and frequently associated with well-cemented aeolian deposits, arranged in continuous dune belts. The best known among the Marine Terraced Deposits are those along the coast stretching from Taranto to Gallipoli. These are referred to the Middle Pleistocene and/or the Last Interglacial Period (e.g., Hearty and Dai Pra 1992; Belluomini et al. 2002 and references therein). Other deposits belonging to the Middle-Upper Pleistocene succession are recognized between Gallipoli and Leuca (D'Alessandro et al. 2004), though several outcrops in other parts of Salento have yet to be studied.

The main tectonic events in this area occurred during the Eo-Oligocene, the Middle Pliocene, and the Middle Pleistocene periods. During this last period, the uplift of the Apulia foreland started, after the general subsidence took place in the early Miocene period. On the Salento peninsula the uplift rate strongly decreased at Marine Isotope Stages (MIS) 9.3, about 330 ka BP (Mastronuzzi et al. 2007b); since then, maximum uplift rates have been recorded only in the Taranto area (0.25 mm/a according to Ferranti et al. 2006), whereas they decrease to zero in the southernmost part of the region (Dai Pra and Hearty 1988; Hearty and Dai Pra 1992; Belluomini et al. 2002). Finally, a slow subsidence at present seems to characterize the Adriatic side of the Apulia region (Mastronuzzi and Sansò 2002; Marsico et al. 2003).

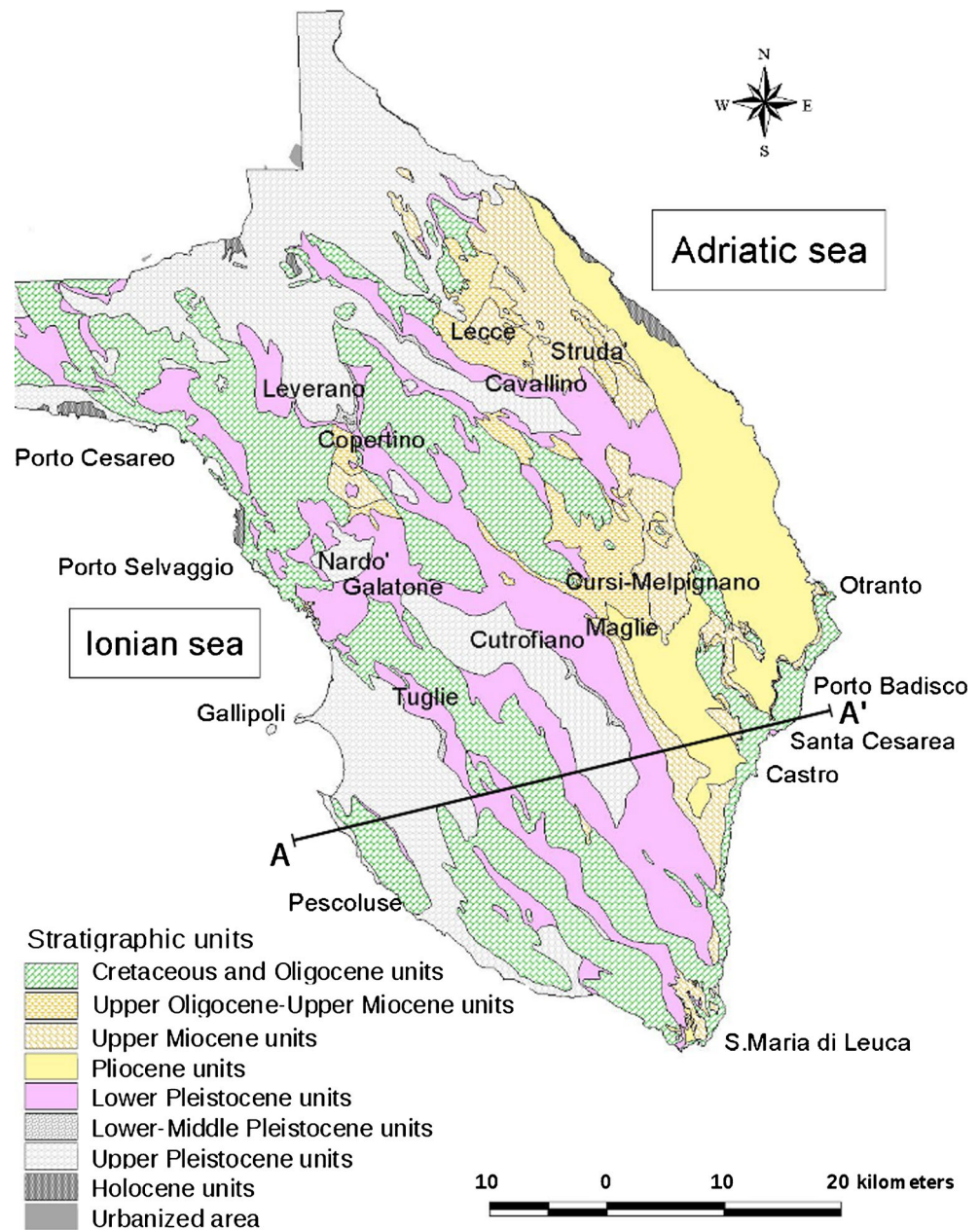
An Outline of the Geomorphology of the Salento Peninsula

The Salento peninsula is a low-elevated landscape composed of a number of Pleistocene plains situated at several levels between sea level and 160 m elevation. They are bordered by geomorphically degraded fault scarps, mostly in the NW-SE and NNW-SSE orientation, by differential erosion scarps, and by relict cliffs (Fig. 5).

The coastal landscape of the Salento peninsula is generally characterized by a number of marine terraces produced by the superimposition of the regional uplift and glacio-eustatic sea level changes that occurred since the Middle Pleistocene period. The terraces are arranged in a staircase morphology; some of them are overlain by a thin sedimentary deposit composed of calcareous sandstones (*panchina*), associated in some places with dune deposits, whereas elsewhere they are only abrasion platforms.

The last interglacial marine terraces are marked by deposits containing a rich Senegalese fauna. In particular, the occurrence of *Strombus bubonius* signals the oldest deposits of the

Fig. 3 Geological map of Salento leccese peninsula. A–A' is the position of the schematic geomorphological section reported in Fig. 5



Last Interglacial age, which were accumulated only locally during the Marine Isotope Substage 5.5, about 125 ka (i.e., Ferranti et al. 2006). However, along the western and eastern coasts of the Adriatic Sea marine terraces with *Senegalensis* fauna deposits are lacking, due probably to the cold marine current pattern in the eastern Mediterranean Sea, which prevented the spreading of *S. bubonius* in the Adriatic Sea (Malatesta 1985).

Finally, boulder accumulations produced by historical tsunamis can be recognized in different places of the Salento coast (Mastronuzzi et al. 2006).

The inner part of the Salento peninsula shows two different landscapes. The eastern area emerged most likely at the

beginning of the Pleistocene period and was developed on Miocene and Pliocene carbonatic rocks. Peculiar landforms have been detected: a Paleogene tropical karstic surface on the top of the morphostructural ridges (Capo d'Otranto, Serra di Montevergine, Serra di Poggiardo and Serra di Martignano), and tectonic depressions stretching from Casamassella to Roca, the widest of which hosts the Alimini Lakes.

The landscape of western Salento is marked by three geomorphological units: a relict karstic landscape (developed at the end of the Lower Pleistocene period) which has recently been partly re-exhumed and re-activated, Middle-Upper Pleistocene sediplains and marine terraces, and the “Serre”, that are NW-SE trending morphostructural limestone ridges.

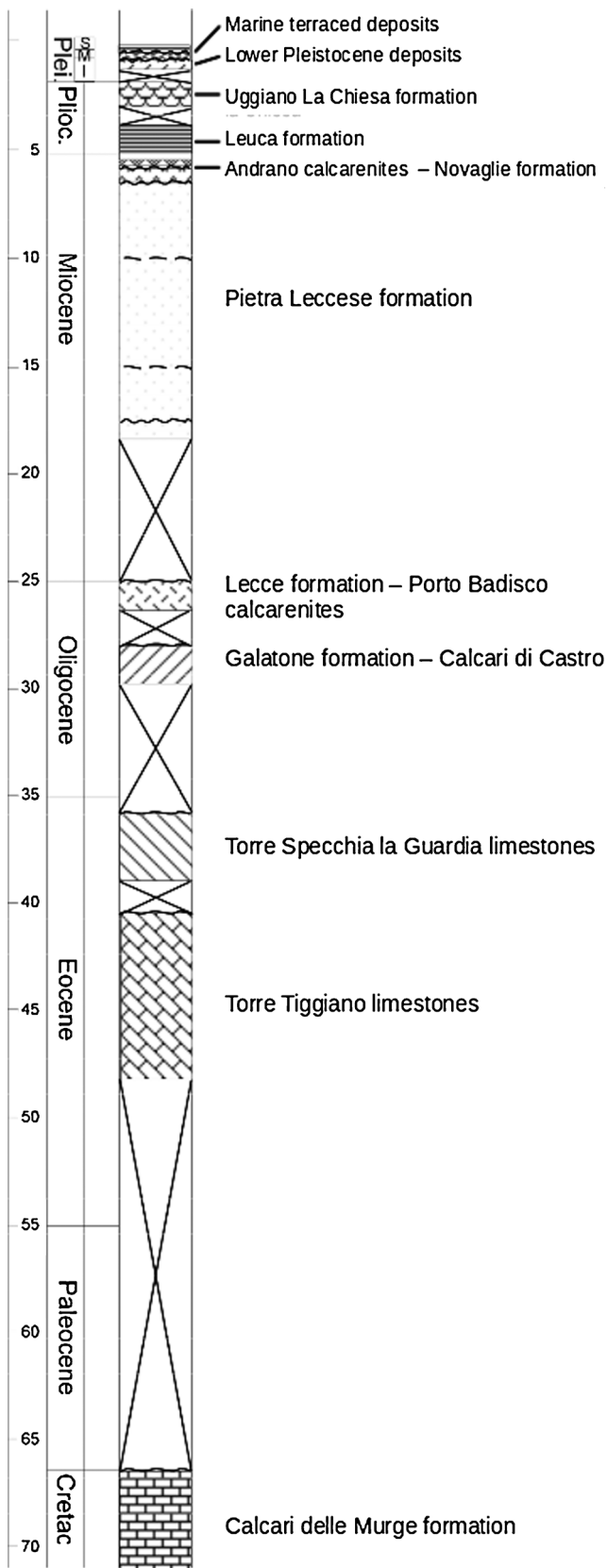


Fig. 4 Stratigraphical scheme of main units cropping out in Salento leccese peninsula

A contact karst has developed in this area, underpinned by the geomorphological characteristics of the region and has contributed to the development of a drainage network flowing northward. This brings allogenic waters to marginal depressions whose floors are studded by cave collapse sinkholes (Selleri et al. 2002).

Material and Methods

The inventory of sites of special interest for their geological features was compiled by a review of research papers. In this way, it is possible to constrain the research of geosites to a few selected areas on the basis of their scientific relevance.

The particular geological structure and geomorphological features of Salento peninsula has made it very attractive for geological research. More than 1,000 research papers were published until 1984 (Battista et al. 1986) and more than 230 papers in the period between 1987 and 2008 (Fig. 6). The average value is of about ten papers per year; the maximum numbers were reached in 1905, 1959, and 2003 (about 40 papers) whereas very low numbers mark the First and Second World War periods. The most important studies are mainly related to the field work carried out for the realization of the first (about 1901–1906 years) and the second (about 1965–1970 years) editions of the Geological Map of Italy.

The First Scientific Papers on the Geology of the Salento Peninsula

A large number of papers focusing on different aspect of Salento’s geology were produced in the period spanning from the birth of Italy as modern nation (1861) to the end of World War I (1918). The geological features of the Salento peninsula attracted, in fact, the most prominent Italian geologists of that period so that this small region played an active role in the development of the nation’s geological knowledge.

Giovanni Battista Brocchi (1772–1827), one of the fathers of Italian geology, reached the Salento during his travels through southern Italy in 1818. Data collected during his field work were reported in an article in *Giornale delle Due Sicilie* (Brocchi 1821).

The first important studies on geology of Salento were carried out by Oronzo Gabriele Costa (1787–1867), who was born in Alessano, a village south of Lecce. He was professor of zoology at Naples University and the author of the very important “*Paleontologia del Regno di Napoli*” (Palaeontology of the Kingdom of Naples). He dedicated a part of this work to the fossil fauna content of Pietra Leccese Formation.

Geological knowledge regarding the Salento peninsula significantly increased thanks to the passion of some local

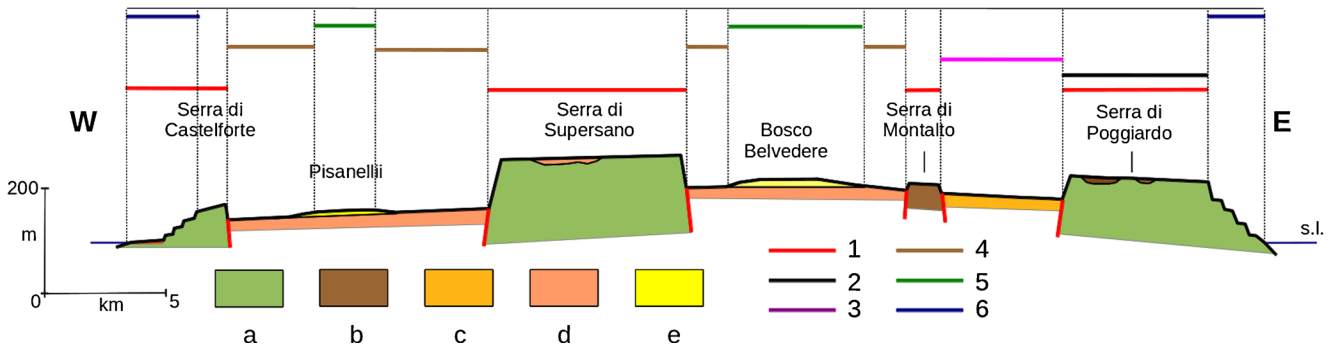


Fig. 5 Schematic geomorphological section of Salento leccese peninsula from the western to the eastern coast. *a* pre-Neogene units, *b* Miocene units, *c* Pliocene units, *d* Lower Pleistocene units, *e* Middle-Upper Pleistocene units, *1* morphostructural ridge, *2* Paleogene tropical karstic

surface, *3* denudation surface shaped on Pliocene units, *4* Lower Pleistocene karstic surface, *5* Middle-Upper Pleistocene sediplain, *6* Marine terraces

scientists like Ulderigo Botti (1822–1906) and Cosimo De Giorgi (1842–1922). The former published a paper about an ichthyolite found in the Pietra Leccese Formation and some studies on Quaternary vertebrate remains found in caves and slope deposits.

Cosimo De Giorgi, born in Lizzanello (a small village near Lecce), was the author of several hundred articles on different topics from meteorology to agriculture. In particular, he produced more than 180 scientific papers dedicated to the geological, palaeontological, geomorphological, and seismological features of the Salento peninsula.

Moreover, the Salento was repeatedly visited by the most important Italian geologists of this period. Among them, Giovanni Capellini (1833–1922), professor of geology at Bologna University, was the first to start the realization of the “*Carta Geologica d’Italia*” (Geological Map of Italy). He visited the Santa Maria di Leuca area in 1869, accompanied

by Botti and described the phosphatic layer occurring at the base of Pliocene calcarenites. He also produced a number of papers about fossil cetaceans from Pietra Leccese Formation. Some other valuable papers about the ichthyofauna and cetaceans found in this formation were later produced by Francesco Bassani (1853–1916), professor of geology at Naples University, a great specialist in fish fossils.

The Eocene rocks of the Salento peninsula were the focus of researches by Giovanni Di Stefano (1856–1918), professor of geology at Palermo University. Carlo Fornasini (1854–1931), who in 1895 founded the *Rivista Italiana di Paleontologia* (Italian Review of Palaeontology), revisited the foraminifers from the Salento peninsula already described by Costa.

Ettore Regalia (1842–1914), palaeontologist at Florence University, carried out very important studies on the Quaternary continental fauna from Grotta Romanelli, a palaeo sea-cave placed along the eastern coast of the Salento peninsula.

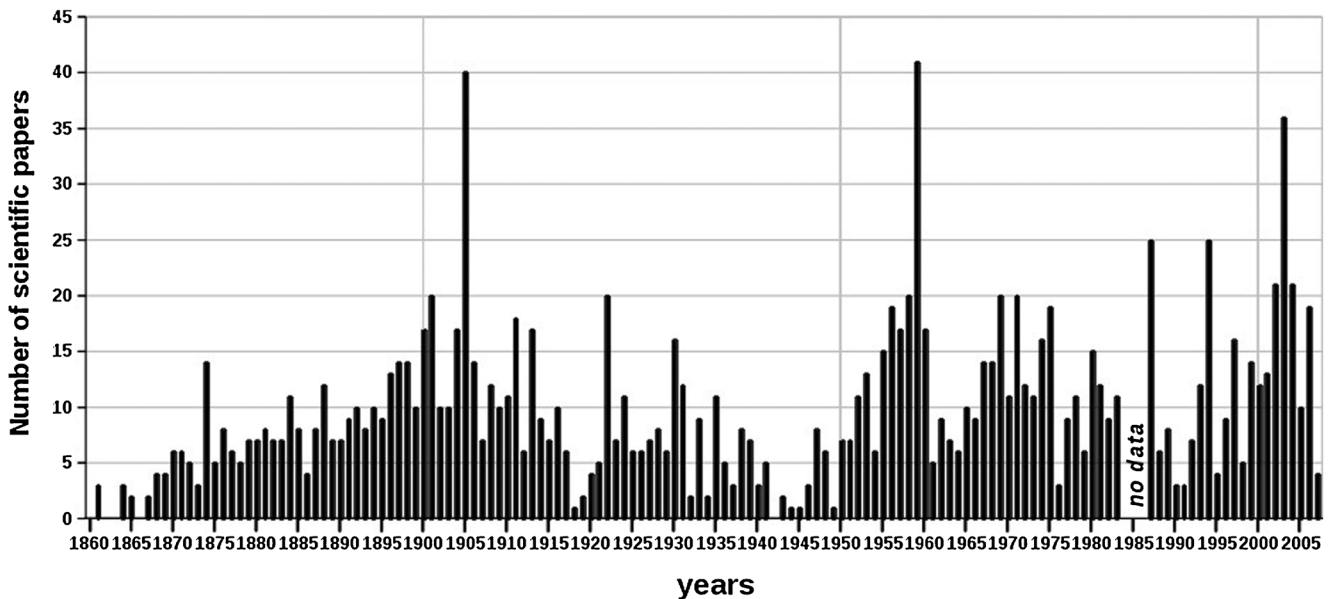


Fig. 6 Time distribution of geological papers number produced on Salento leccese area during last 150 years

Finally, among the numerous geological studies produced for the construction of the Apulian Acqueduct, those carried out Torquato Taramelli (1845–1922), professor of geology at Pavia University, regarding the Salento area must be noted.

The Most Recent Scientific Production

The analysis of scientific papers published since 1987 shows that they were mostly stratigraphical (28 %), geomorphological (27 %), and palaeontological (17 %; Fig. 7a). Stratigraphical and palaeontological research focused on the analysis of sedimentary sequences of the Salento peninsula and its geological heritage as well as on the resolving of geological and environmental problems. The landscape of the Salento peninsula strongly influenced geomorphological studies which mainly involve coastal geomorphology (47 %), karst (27 %), and coastal caves (19 %; Fig. 7b).

The most valuable geosites of the Salento peninsula in the Salento area were identified using a geographical information system (GIS), which helped highlighted areas that were more frequently the object of research and compared them with sites visited during conference’s field trips.

The first step was the analysis of the 125 most representative scientific papers produced on the geology of Salento in the period spanning 1980 to 2003. This choice was made to exploit a collection of already available papers. Representative papers are the ones published in national and international reviews or in proceedings of geological congresses held in Salento area.

The collated data have been organized in a geodatabase. Each scientific paper is marked by an identifying number (ID) and a number of descriptive fields related to bibliographic and scientific properties. Descriptive fields are the following: “author”, “title”, “review”, “pages”, “type of site”, “language”, “locality”, and “key words”. Each paper is linked to a polygon which represents the studied area of that particular research paper.

A simple GIS procedure has allowed areas of major geological relevance to be identified. These sites, in fact, have been the object of numerous papers and can easily be identified by the analysis of density distribution of scientific papers across the Salento peninsula. Then, the area of interest has been subdivided into elementary square cells of 500×500 m size and the number of scientific papers involving each cell automatically calculated.

Maps produced according to this method clearly show areas of major scientific interest as they were the subject of research for the highest number of scientific papers. A simple geographical query allowed us to obtain the list of scientific papers that are related to these particular areas.

Taking into account the palaeontological papers, it is possible to identify a number of areas that were particularly studied (Fig. 8). High-density values mark the quarry districts

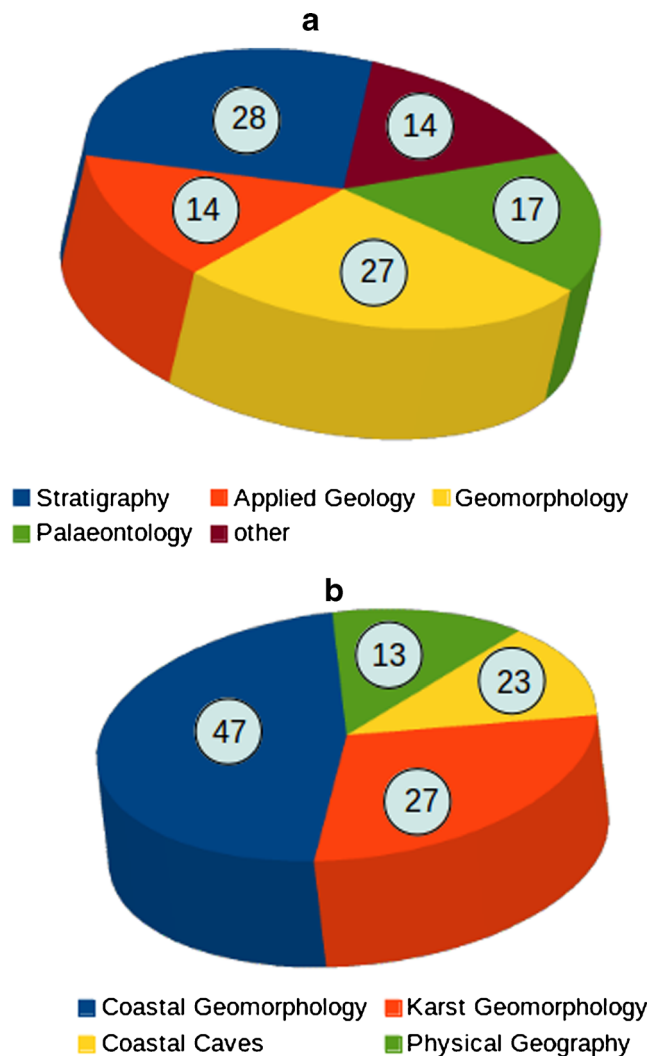


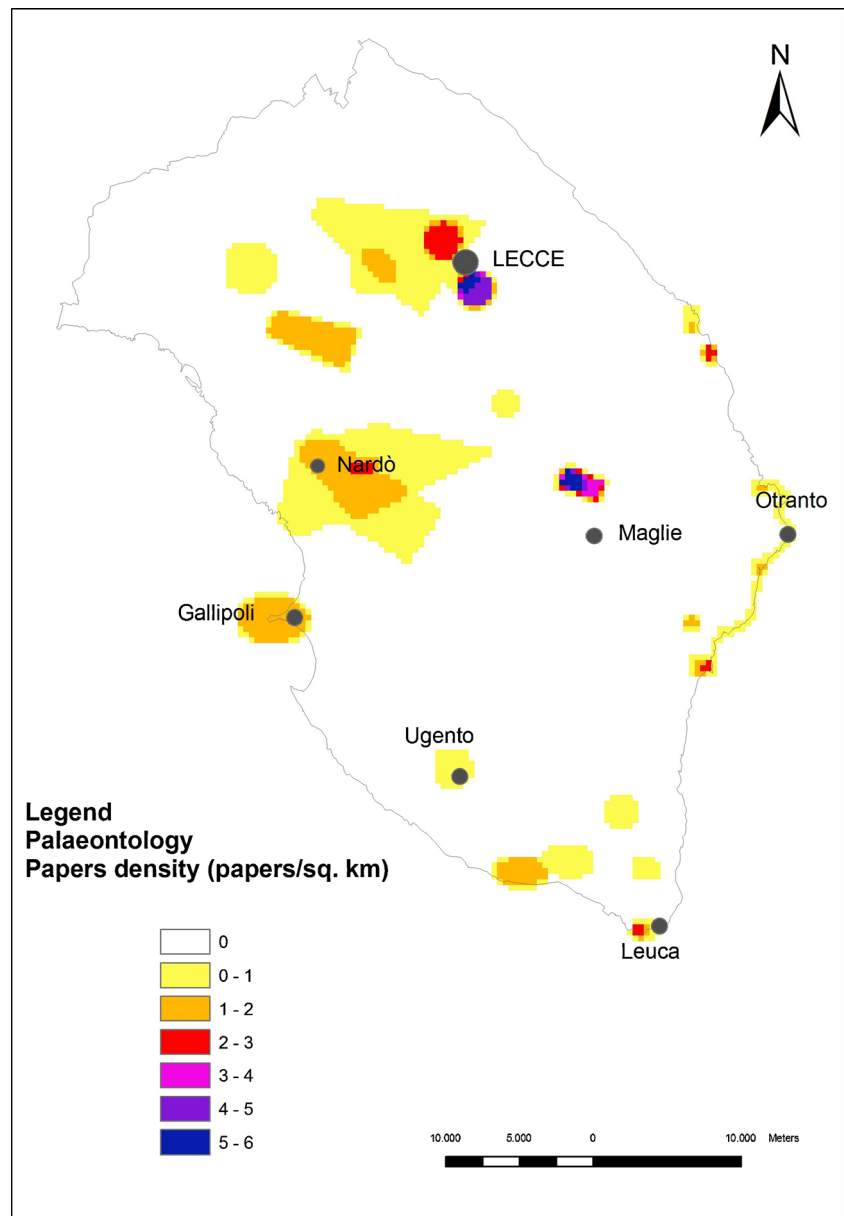
Fig. 7 Distribution (%) of scientific papers in function of geological (a) and geomorphological (b) topics published in the period 1987–2008

of the Pietra Leccese Formation, located in the Melpignano-Cursi area, north of Maglie, and Lecce-Cavallino areas. Lower values can be found near the Nardò, Gallipoli, Copertino-Leverano areas, and in a number of spots along the coastline (Torre Sant’Andrea, Porto Miggiano, and Leuca).

Stratigraphical studies concentrated along the eastern coast of Salento, from Porto Badisco to Santa Maria di Leuca, the coastal area north of Gallipoli, in the area north of Lecce (Fig. 9).

Morphological studies (Fig. 10) focus mainly on the coastline even if some studies concern the Alimini Lakes depressions and the area of Cutrofiano and Presicce villages. Geomorphological research focused on coastal morphology and landscape evolution in response to the Pleistocene sea level change and historical tsunamis. The most studied areas are those north of Otranto and areas in Leuca, Gallipoli, Porto Selvaggio, and Porto Cesareo. Also, a few papers have been produced on karstic features and geomorphological evolution of inner areas.

Fig. 8 Geographical distribution of palaeontological papers density (period 1980–2003) in the Salento leccese



Taking into account all the research papers it is possible to see that the numerous spots along the coastline are marked by having produced a high volume of scientific papers (Fig. 11). In particular, Otranto, Porto Badisco, S. Cesarea Terme, Castro and Leuca on the eastern side, and Pescoluse, Gallipoli, Porto Selvaggio, and Porto Cesareo on the west. Inland, the most valuable area is Cursi-Melpignano. Areas of minor importance are the ones around Lecce, Cavallino, Copertino-Leverano, Nardò-Galatone, Cutrofiano, and Tuglie villages.

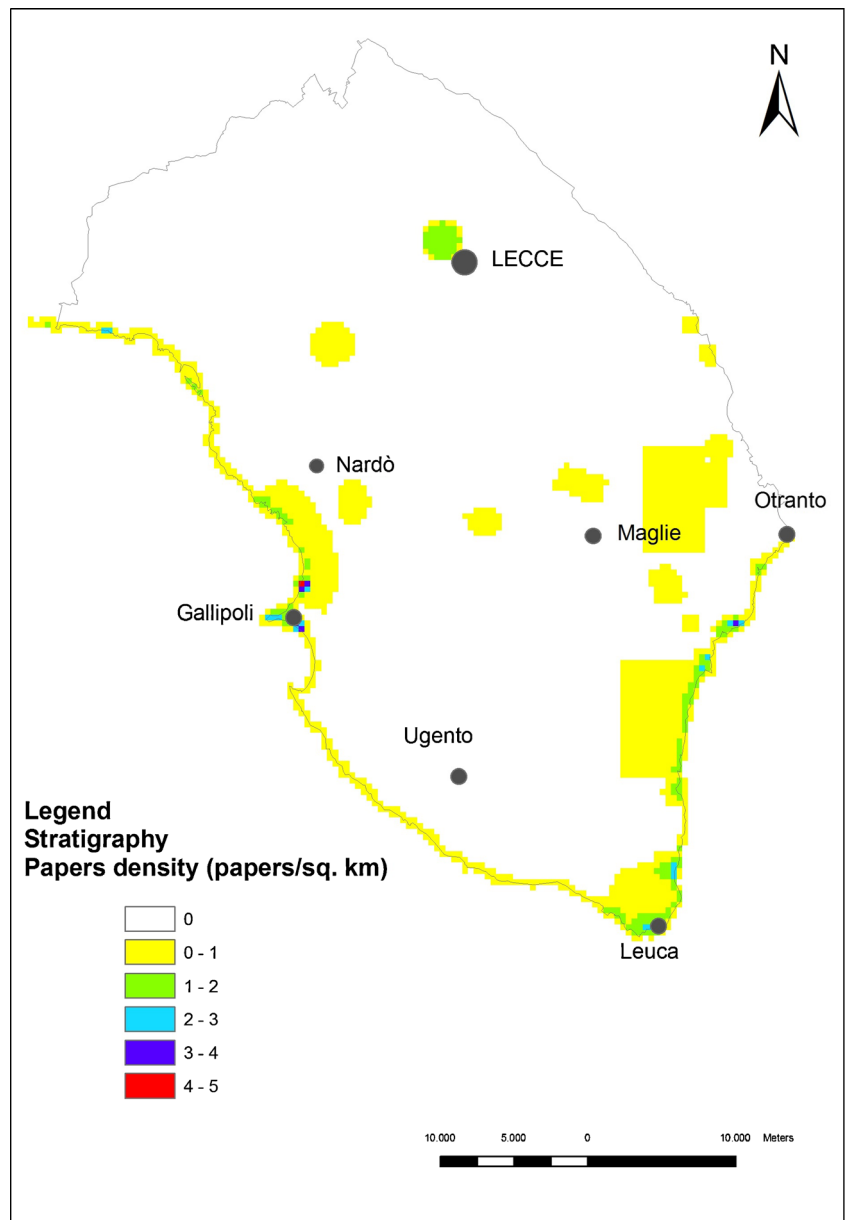
Further indications about the most valuable sites can be obtained by the examination of field trip guides produced for international or national conferences, symposia, or scientific meetings. In particular, the Salento area was visited during the last 30 years by convenors of the Annual Meeting of Gruppo Nazionale di Geografia Fisica e Geomorfologia (1985), the

12th National Conference of the Italian Palaeontological Society (1993), the Final Conference of IGCP Project 437 (2003), and the 2nd International Tsunami Field Symposium—IGCP Project 495 (2008). Finally, some very important geosites have been described in the volume “Il Patrimonio Geologico della Puglia. Territorio e Geositi” edited by SIGEA (2010).

This information is valuable since these sites for excursions were accurately selected to be very interesting from a scientific standpoint but also easily accessible by a tour bus, and accessed by a large number of people (about 55) under safety conditions without any particular skill or equipment.

Sites visited during field trips were mainly along the coastline, clustering along the coastal tracts that stretch from Otranto to Tricase, in the area of Gallipoli and, subordinately, of Leuca (Fig. 12). A few sites have been identified in the

Fig. 9 Geographical distribution of stratigraphical papers density (period 1980–2003) in the Salento leccese



inner part of Salento peninsula, most of them located in the area of Maglie. Some sites have been visited repeatedly during different field trips.

Results

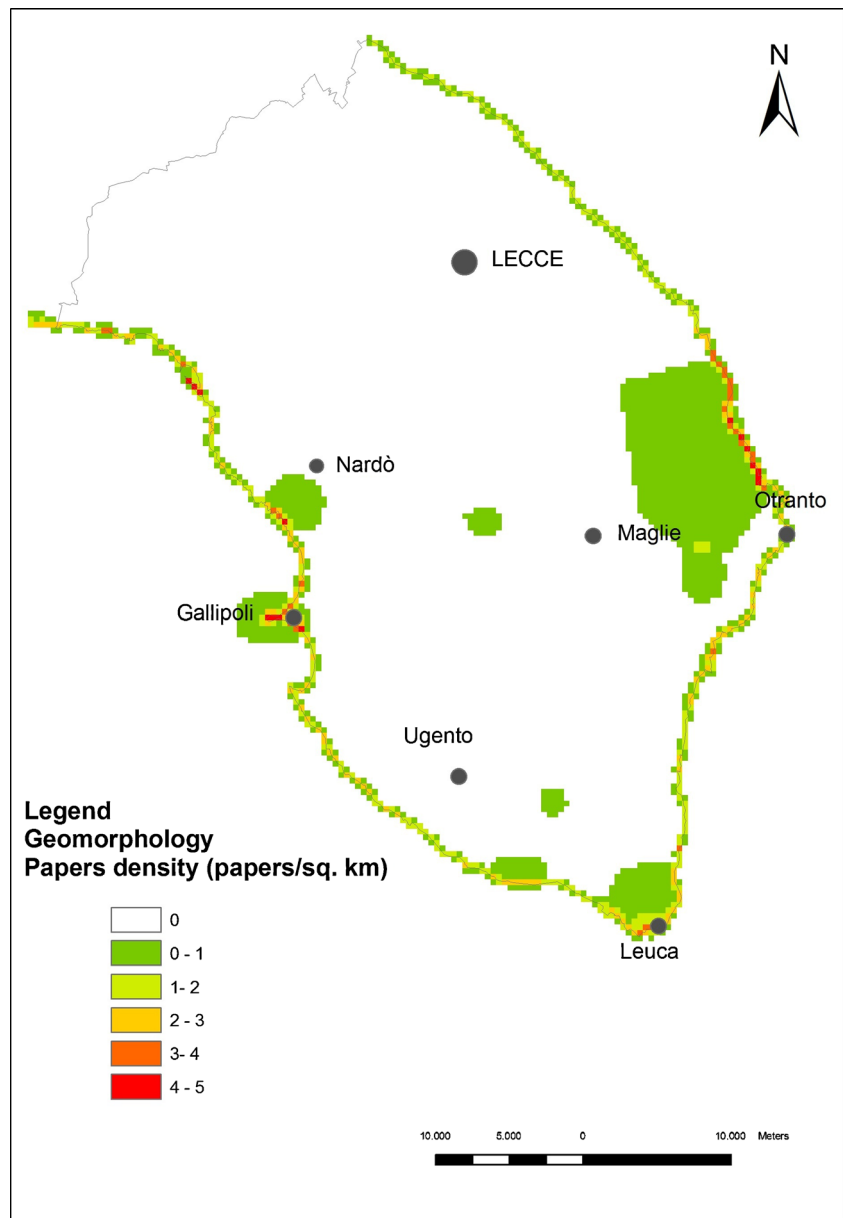
The comparison between areas which attracted a significant number of scientific papers and the distribution of field trip stops during the main geological conferences held in the Salento allows us to identify the sites of major geological interest, as follows: the Otranto-Castro and Gallipoli-Porto Selvaggio coastal areas, the Leuca locality as well as the area between Cursi-Melpignano as the most studied and visited areas of the Salento peninsula.

The Otranto-Castro Coastal Area

This area shows a number of very interesting geological, palaeontological, and geomorphological features. Unique outcrops of rudist reef and ammonites have been found on the late Cretaceous limestone basement (Giudici et al. 1994). This is the youngest record of ammonites in Italy and allows for a correlation with faunas of other Mediterranean areas like those in Israel. The assemblage is interpreted as a storm layer, which accumulated by wave transport, and consists of unoriented rests.

Moreover, it is possible to recognize an Upper Oligocene reef complex with a good exposure of back-reef, reef flat, reef front, and fore-reef facies. Spectacular outcrops, clearly showing stratigraphic features (geometry, clinofolds, and strata attitude), sedimentological characters (sedimentary structures,

Fig. 10 Geographical distribution of morphological papers density (period 1980–2003) in the Salento leccese



textures, cavity infillings, and so on) and above all, palaeontological characteristics (distribution and composition of the coral fauna, structure of the reef framework, colonies, and growth form) allowed for the reconstruction and the proposition of a quite complete reef facies model (Bosellini and Russo 1992).

Finally, Lower Pleistocene calcarenites crop out discontinuously in different localities between Santa Cesarea and Castro (Bosellini et al. 1999; Bossio et al. 1989). The successions consist of long clinobeds cut by slump scars passing downward to gullies; backsets, slumps, and chaotic deposits filling these erosional features (Tropeano et al. 2004) (Fig. 13).

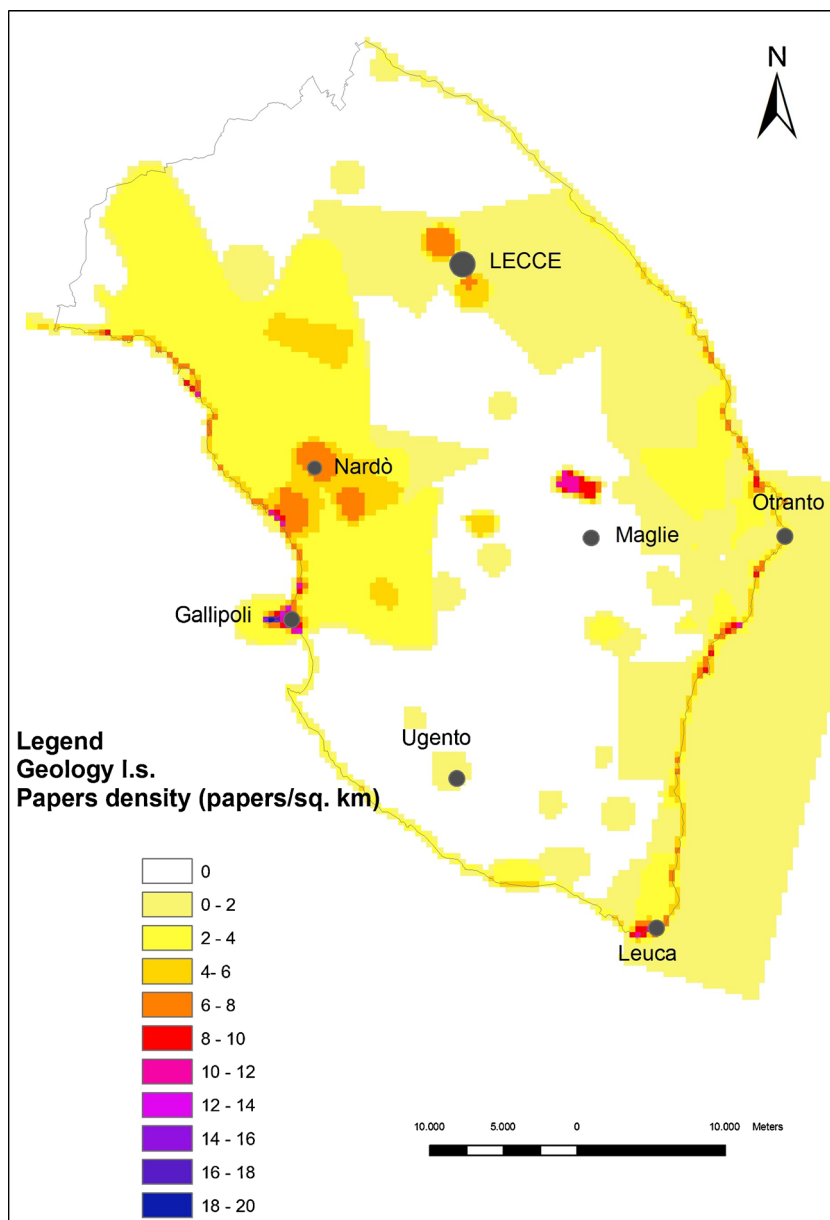
The coastal landscape is marked by four levels of marine terraces, formed during the Middle-Upper Pleistocene period as a consequence of regional uplift and sea level changes. For

a short tract the coastline is a fast retreating cliff cut into the Lower Pleistocene calcarenites. In this area a spectacular boulder accumulation occurs along the coast in the surrounding of Torre S.Emiliano. It was formed by the devastating impact of the tsunami produced by the earthquake of February 20th, 1743 (Mastronuzzi et al. 2007a).

The Otranto-Castro coastal tract is included in the Otranto-Leuca regional park and is visited each year by thousands of tourists, especially during the summer, attracted by the coastal landscape and the clearness of the sea. This tract of coast is also well known for the occurrence of sulfur coastal springs in Santa Cesarea Terme (Calò and Tinelli 1994).

The valuable geological heritage of this coastal area could be exploited to make the coastal path, which should be planned as one of the most valuable infrastructure of the park,

Fig. 11 Geographical distribution of density related to the entire geological scientific production (geology *I.s.*) regarding the Salento leccese in the period 1980–2003



more interesting. Hikers would easily be entertained by the occurrence of numerous points of geological interest which increase the attractiveness of the path.

The Gallipoli-Porto Selvaggio Coastal Area

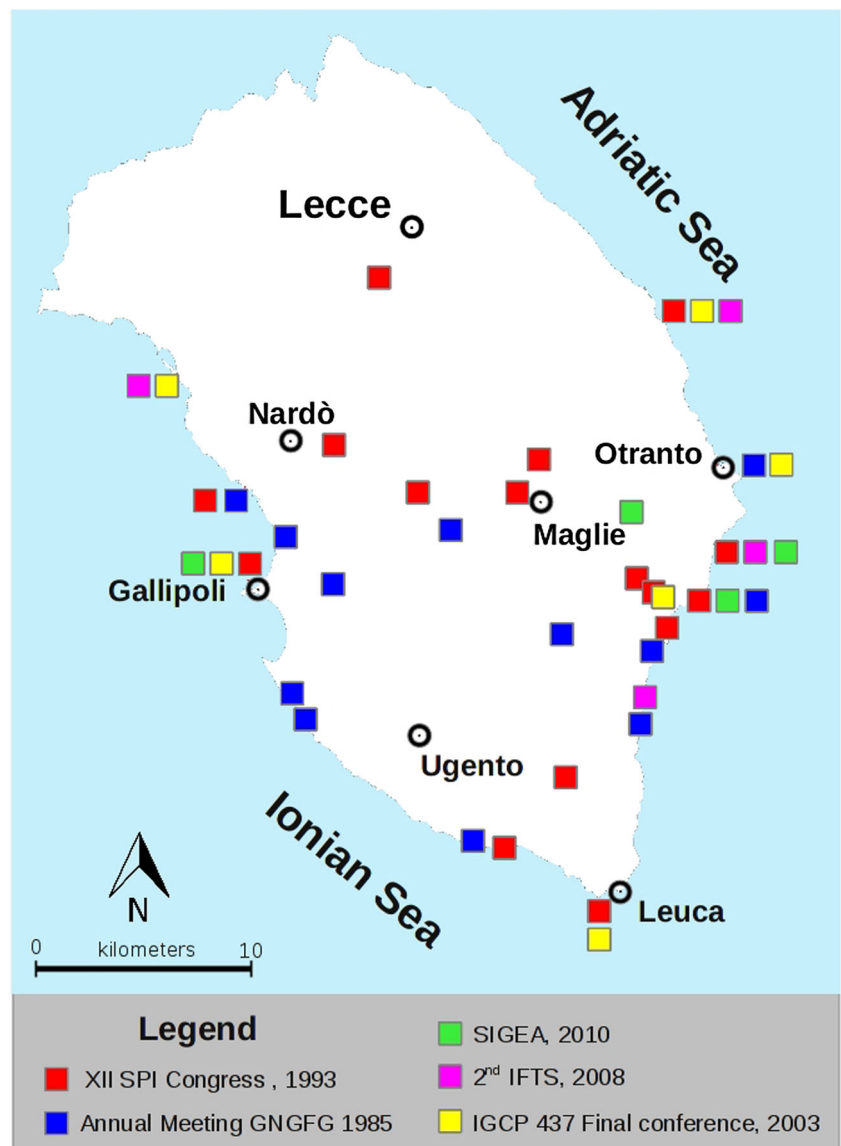
This area is marked by the presence of a site where abundant remains of *S. bubonius* can be found; it has attracted Quaternary geologists and palaeontologists throughout the last century (Fig. 14). *S. bubonius* is an element of an assemblage consisting of warm species that moved from the tropical coast of the Atlantic Ocean to the Mediterranean Basin during the last interglacial period, between 125 and 80 ka B.P. It is correlated with Oxygen Isotope Stage 5 (or more recent

Marine Isotope Stage 5) of Shackleton and Opdyke (1973) and Chappel and Shackleton (1986) eustatic sea-level curves.

In particular, deposits marked by *S. bubonius* are thought to indicate only the substage 5e, spanning between 132 and 116 ka (Shackleton et al. 2003). The last interglacial deposits and associated shorelines are frequently used to calculate uplift rates (Cosentino and Gliozzi 1988; Westaway 1993; Bordoni and Valensise 1998; Ferranti et al. 2006) since the global sea-level was higher than the present one (Shackleton 2000; Waelbroeck et al. 2002; Siddall et al. 2003). Along the Mediterranean coasts, the average sea-level attained during the MIS 5.5 is interpreted to be 6 ± 3 m (Lambeck et al. 2004).

In the central Mediterranean area, along the coasts of the Italian peninsula and its islands, the variability in altitude of the last interglacial sea-level markers was attributed to tectonic

Fig. 12 Geographical distribution of sites visited during the Conference field trips organized in the Salento leccese area during the last 30 years. *SPI Società Paleontologica Italiana* (Palaeontological Italian Society), *GNFGF Gruppo Nazionale Geografia Fisica e Geomorfologia* (National Group of Physical Geography and Geomorphology), *SIGEA Società Italiana di Geologia Ambientale* (Italian Society of Environmental Geology), *IFTTS International Field Tsunami Symposium*, *IGCP International Geological Correlation Program*



processes, which resulted in differential displacements relative to the predicted eustatism. In particular, the Salento peninsula shows uplift rates ranging from 0 m/ka at Santa Maria di Leuca to 0.31 m/ka in the area west of Taranto (Mastronuzzi and Sansò 2002).

The palaeontological importance of this coastal area (Guidotti et al. 1993) is underlined by the finding that Cretaceous dolomitic and limestone layers in the Porto Selvaggio locality show a spectacular fossil ichthyofauna. In this site, Sansò et al. (2011) and Mastrogiacomo et al. (2012) have recently identified thin chert layers and spectacular slump sheets triggered by tectonic movement from the Upper Cretaceous carbonate succession (Fig. 15).

Each year both sites host a great number of visitors who are fortunately unaware of their geological importance. Thus, it would be necessary to protect the most significant sites and



Fig. 13 Porto Miggiano locality. The Lower Pleistocene calcarenites are marked by slump structures



Fig. 14 Gallipoli. This site marked by abundant remains of *S. bubonius* attracted Quaternary geologists and palaeontologists throughout the last century. This warm species came from the tropical coast of Atlantic Ocean and moved into the Mediterranean Basin during the last interglacial period about 125 ka B.P

those outcrops most subject to deterioration (*S. bubonius* deposits, chert, and fossiliferous layers) before planning for cultural tourism in this area.

The Leuca Area

This area is marked by a scenic outcrop of the Leuca Formation so that the section of Punta Ristola (the southernmost tip of the Apulian region occurring at the Leuca locality) has been proposed as a stratotype of this stratigraphic unit (Bossio et al. 2001). It is composed mainly of breccias and conglomerates in a chaotic mass. In some places thin layers of marl and glauconitic biomicrite, both of them rich in planktonic foraminifers, occur above the clastic deposits. The unit is capped by a conglomerate with phosphatized pebbles which marks the transgression of the Uggiano La Chiesa Formation.

The area is also very interesting since in this locality there is the Grotta del Diavolo. This is a coastal cave showing



Fig. 15 Porto Selvaggio locality. The Late Cretaceous carbonate succession shows thin chert layers and spectacular slump sheets triggered by tectonic



Fig. 16 Punta Ristola, the southernmost point of Apulia region. Along a scenic cliff the proposed stratotype of Formazione di Leuca can be observed. At the photo's left corner the entrance of the polycyclic cave Grotta del Diavolo is visible

polycyclic evolution in response to climate and sea level change during the Middle-Upper Pleistocene in a context of tectonic stability (Mastronuzzi et al. 2007b) (Fig. 16).

Inside the cave, mostly filled by breccia deposits, three beach levels have been detected at about 3.0, 3.5, and 5.9 m above MSL. They are either covered or overlain by speleothems that yield an U/Th age of 340, 78 ka, and between 170.3 and 146.5 ka, respectively. The sedimentary fills of sea caves were formed during Middle-Late Pleistocene glacial stages, when arid or semiarid conditions promoted the removal of regolith and the development of thick breccia deposits. During Marine Isotope Stages 9.3, 5.5, and 5.1, cave sediments were partially eroded by sea waves, and concomitantly beach sediments and speleothems accumulated and developed. These deposits, in fact, are the only marine isotope stages marked by a sea level position which in this Mediterranean region was either close to, or slightly higher than, the present one.



Fig. 17 Spectacular fossil remains of Middle-Late Miocene marine vertebrates have been found inside the Pietra leccese Formation at Cursi-Melpignano area (courtesy of Prof. Angelo Varola)

Fig. 18 The singular karst residual landform named “Masso della Vecchia” near Giuggianello village in a drawing of Cosimo De Giorgi (1882). This site has received little attention by researchers so far and it has been never visited by conference field-trips



At present Punta Ristola attracts very few visitors. Cliffs and the opening of the Grotta del Diavolo cave are closed for public safety. However, the cave could be easily visited by small groups of people. Sunlight enters through an opening in the ceiling due to a rockfall, and a corridor connects the cave to the sea which floods its lower part.

The cave could be an excellent site to explain Quaternary and future sea level and climate changes as well as the tectonic behavior of the Salento peninsula in recent times.

The Cursi-Melpignano area

This area along with the one near Lecce has been historically regarded as the type area of Pietra Leccese Formation. The scientific interest of this rests on the presence of numerous quarries that allow good exposures of the stratigraphy. Pietra Leccese has been used since ancient times in Apulia because of its load bearing and decorative function in buildings historically and today. For this reason, the petrophysical and mechanical properties of this soft and porous building rock have been object of numerous specific studies (e.g., Andriani and Walsh 2010; Margiotta 1994). Biostratigraphical and palaeontological studies have also been carried out. The planktonic assemblages of foraminifera (Foresi et al. 2002) and calcareous nannofossils (Mazzei 1994) point to an age ranging from upper Burdigalian to lower Messinian. The formation has a thickness of few tens of meters, despite its wide stratigraphical distribution and the detrital facies. This relatively small thickness is due to at least three gaps in sedimentary accumulation perhaps produced by erosive/dispersive currents which affected the depositional basin and that varied in intensity in time and space.

Pietra Leccese Formation retains a highly interesting fauna marked by the presence of marine vertebrates. In particular, remains of cetaceans, sirenids, pinnipeds, chelonids, crocodiles, and fish have been found (Bianucci et al. 1994) (Fig. 17).

The geological, archaeological, and historical heritage linked to the Pietra Leccese is still completely unexploited despite the high commercial value of Pietra Leccese

Formation. In this area a number of inactive quarries are present. These could be used to show not only the main geological and palaeontological features of the Pietra Leccese Formation but also the evolution of quarry works over the last centuries.

Conclusion

The Salento peninsula attracted numerous researchers over the last 150 years because of its peculiar geological and geomorphological features. The review of scientific literature using GIS allowed the most studied areas of the Salento peninsula to be identified. They correspond to Otranto, Porto Badisco, S. Cesarea Terme, Castro, and Santa Maria di Leuca localities on the eastern side of the peninsula, and Pescoluse, Gallipoli, Porto Selvaggio, and Porto Cesareo on the western side. Inland the area of Cursi-Melpignano is the most valuable one.

Furthermore, review of field trips that took place on the Salento peninsula during scientific geological meetings and conferences held over the last 30 years show various sites of particular interest and scientific value that can easily be visited by a large group of people under safety conditions. These sites are mainly placed along the coastline, clustering along the coastal tracts stretching from Otranto to Tricase, in the area of Gallipoli and, subordinately, of Santa Maria di Leuca. A few sites have been detected in the inner part of the Salento peninsula.

The comparison between most studied area and field trip stops has allowed the most interesting sites of Salento to be identified—the Otranto-Castro and Gallipoli-Porto Selvaggio coastal areas, the Leuca locality as well as the area between Cursi-Melpignano.

The Otranto-Castro area is marked by the occurrence of Late Cretaceous rudist reefs and ammonites, by an Upper Oligocene reef complex as well as Lower Pleistocene calcarenites marked by slumps and erosional features. The coastal landscape is marked by four levels of marine terraces and by a tsunami boulder accumulation.

The Gallipoli-Porto Selvaggio area is marked by the presence of a very famous site marked by abundant remains of *S. bubonius*. At Porto Selvaggio, a rich fossiliferous association with frequent taxa of fish has been found in Cretaceous dolomitic and limestone layers. These rocks also show thin chert layers and spectacular slump sheets triggered by tectonic activity.

The Leuca area is marked by the stratotype of Leuca Formation and by the occurrence of Grotta del Diavolo, a coastal cave showing polycyclic evolution in the Middle-Upper Pleistocene period.

Finally, the Cursi-Melpignano area is important for its quarries of Pietra Leccese which supplied numerous fossil remains of Upper Miocene marine vertebrates.

The reviews allowed us to highlight the most important geological sites in the Salento area. However, it is also possible to identify some very spectacular sites not yet studied or very difficult to reach. This is the case, for example, of “Masso della Vecchia”, a small residual karst landform which is reported to be among the most valuable geosites of the Salento peninsula by SIGEA (2010) but no scientific paper has been produced so far. This landform is a 3-km hike that can be easily walked by a large group of people (Fig. 18).

The reviews point to the valuable geological heritage occurring in the Salento area which is still completely unexploited by the local tourist industry.

Some identified sites are very important for their scientific values since they have been repeatedly studied and visited over the last 150 years (i.e., the site with *S. bubonius* near Gallipoli).

The proposed sites also feature a large educational value since they can help explain the geological evolution of the Salento peninsula, illustrate worldwide geological events (climate and sea level change, mass migrations, and extinctions), catastrophic phenomena (earthquakes and tsunamis), and also illustrate relationships between anthropogenic activities and geological processes (geological hazards and risks). Thus, the geological heritage of the Salento peninsula could be used as a field laboratory for students of primary and secondary schools.

In addition, most of the proposed sites are already targeted by important touristic organizations attracted by the high quality of the coastal environment and are often placed inside natural protected areas, so that their protection and valorization could be easily enclosed in the park's management plans.

The numerous sites of geological interest can significantly improve what the Salento peninsula can offer to cultural tourism. The realization and the promotion of a network of “geological paths” along the most scenic areas of Salento can link numerous protected natural areas in Salento.

Measures for the conservation of geological heritage and the promotion of geotourism can be one of the strategies able to significantly increase the number of Italian and foreign tourists during low-season periods.

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