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Depositional architecture, paleogeographic setting and sequence stratigraphy of the Salento Peninsula from Paleogene to Pleistocene: an integration among field data, well logs and seismic lines

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ABSTRACT - The Salento Peninsula constitutes an outcropping portion of the Apulia Carbonate Platform that was investigated through field analysis and a database of 350 wells and 90 seismic lines that was calibrated with 3 exploration wells in order to construct correlation panels and define paleogeographic schemes of this area during the Paleogene and Neogene. While the Adriatic and Ionic offshore sectors were investigated through 90 seismic lines and 3 exploration wells in order to connect data on land with those at sea to better define the stratigraphic architecture of the area. The Salento Peninsula constitutes the foreland sector of two chain belts migrating in opposite directions (the Dinarides-Albanides-Hellenides chain, moving from NE to SW, and the southern Apennines chain, moving from SW to NE), whose movements influenced the carbonate sedimentation and paleogeographic evolution of this area during the Cenozoic. The analyzed stratigraphic succession is constituted by a shallow-water carbonate sediments that were essentially deposited along reef complexes and variously articulated homoclinal ramps. These environments developed mainly along the eastern margin of the Peninsula and under the influence of the tectonic uplift/subsidence and eustatic sea level changes. This thesis proposes several paleogeographic schemes of the area and discusses how the interference between the two migrating chains, together with the eustatic sea-level changes, influenced the Cenozoic stratigraphic organization of the Salento Peninsula.

Starting from the end of the Cretaceous, the Salento area experienced uplift and erosion, related to the flexural bending of the subducting lithosphere under the Dinarides-Albanides- Ellenides and southern Apennines belts respectively. This process produced an initial extensional fracturing and faulting in the uppermost part of the lithosphere during the Paleocene-early Eocene and an interruption of the shallow-water carbonate deposition; the latter was re-established starting from the middle-late Eocene up to the Pleistocene, with the onset of flexural subsidence, that became more accentuated during the Miocene. This process, together with the eustatic sea-level variations induced by the Cenozoic climatic changes, conditioned the carbonate sedimentation that is characterized by formal and informal lithostratigraphic units bounded by several unconformity surfaces constituting the expression of complete and incomplete simple and composite low- and high-rank depositional sequences.

In this light, this thesis contributes to better define the stratigraphic architecture, the depositional, and paleogeographic setting of the Salento Peninsula for the last 60 Myrs.

Keywords: Depositional setting; paleogeography; sequence stratigraphy; Salento Peninsula; Apulia; Italy.

1. INTRODUCTION

In the last 50 years the several studies conducted on carbonate platforms (CPs) have allowed to classify them utilizing different criteria. On the one hand some Authors considered the basinal and tectonic setting as the main factors controlling the morphology and the physical stratigraphy of the CPs (Bosence, 2005), while other Authors have used the geometry of depositional profile to distinguish two main end members: the flat-topped platforms (FTPs), with a pronounced slope break and steep margin, and the ramps (Rs), both homoclinal with low-gradient profile and distally steepened with a slope break offshore (Ahr, 1973; Wilson, 1975; Read, 1982; 1985; 1998; Eberli and Ginsburg, 1989; Tucker and Wright, 1990; Burchette and Wright, 1992; Handford and Loucks, 1993; Wright and Burchette, 1996). A genetic approach to classify the CPs was proposed by Pomar (2001, 2020), which considered the variability of the CP depositional profiles as a function of a series of factors such as sediment types, locus of sediment production, hydraulic energy, and types of biota based on their dependence upon light. On this basis, the Author recognized two main platform types: the rimmed platforms, that fundamentally coincide with the flat-topped platforms and the nonrimmed shelves or physical accommodation-predominant platforms (e.g., ramps; see Pomar, 2020). In a previous paper, Williams et al. (2011) pointed out that the classification of CPs based on their deposition profile constitutes an oversimplification, because facies and environments distribution, as well as sequence stratigraphic organization, varied significantly between the endmembers of the FTPs and the Rs. The same Authors also highlighted that the euphotic versus oligophotic is not a significant control on carbonate production profile and suggested, based on field and modeling observations, that sediment production, diffusional sediment transport, antecedent topography, tectonic subsidence, and relative sea-level changes are the main factors whose interaction control the depositional profile of the CPs. This would suggest a continuum of platform types, ranging from low gradient and transport-dominated CPs (see ramps) to in situ accumulation-dominated CPs (e.g., rimmed and non-rimmed FTs) (Williams et al., 2011). The same concepts could be applied both to isolated platforms and to isolated platforms.

What has been said previously suggests that all the different types of CPs are closely related to each other both temporally and spatially and that the same platform can develop, on the opposite margins, different depositional profiles that reflect the close interaction among the processes above mentioned.

With this in mind, it was analyzed the stratigraphic setting of the Cenozoic deposits of the Salento Peninsula (i.e., the southern portion of the Apulian foreland), a sector essentially characterized by carbonate sedimentation, that constitutes the foreland of two chains migrating in opposite directions: the Dinarides-Albanides-Hellenides chain that moves from NE to SW and the southern Apennines chain that moves from SW to NE. This thesis will propose several paleogeographic schemes for the area and discuss how the interference of these two chains, and the eustatic sea-level changes have influenced the sedimentation and stratigraphic organization of the Cenozoic succession of the Salento Peninsula in which high and low rank simple and composite depositional sequences were recognized.

2. GEOLOGICAL AND STRATIGRAPHIC SETTING

2.1. GEODYNAMIC AND GEOLOGICAL STRUCTURAL SETTING

The Salento Peninsula constitutes an outcropping portion of the Apulia Carbonate Platform, which represents one of the carbonate platforms developed along the southern margin of the Tethys Ocean since the Triassic (Eberli et al., 1993; Zappaterra, 1994; Bosellini, 2004; Morsilli et al., 2017) (Fig. 1a). This NW-SE oriented platform, is about 650 km long and 180 wide and consist of a 5 to 7 km thick Meso-Cenozoic slightly deformed carbonate succession that develops in emerging and submerged areas (D'Argenio et al., 1973; Rossi and Borsetti, 1974); the eastern margin of the Apulian Platform crops out in the Maiella and Gargano peninsula (Bosellini, 1989; Eberli et al., 1993; Borgomano, 2000), while the western margin is largely incorporated in the southern Apennines thrust belt (Shiner et Al.,2004).
The Apulian Platform occupies the southern end of the Adria microplate (Fig. 1b) which is considered by some authors to be the northern promontory of the African plate (Channel et al., 1979; Muttoni et al., 2001; Schettino and Turco 2011; see also the most recent interpretation of Adria in Mediterranean paleogeography by Channel et al., 2022), and by

others Authors an independent plate, placed between the African and European plates, whose movements would be strongly influenced by the relative movement of the two bigger plates (Doglioni, 1991; Catalano et al., 2001; Guerrera et al., 2005; Carminati et al., 2012a).

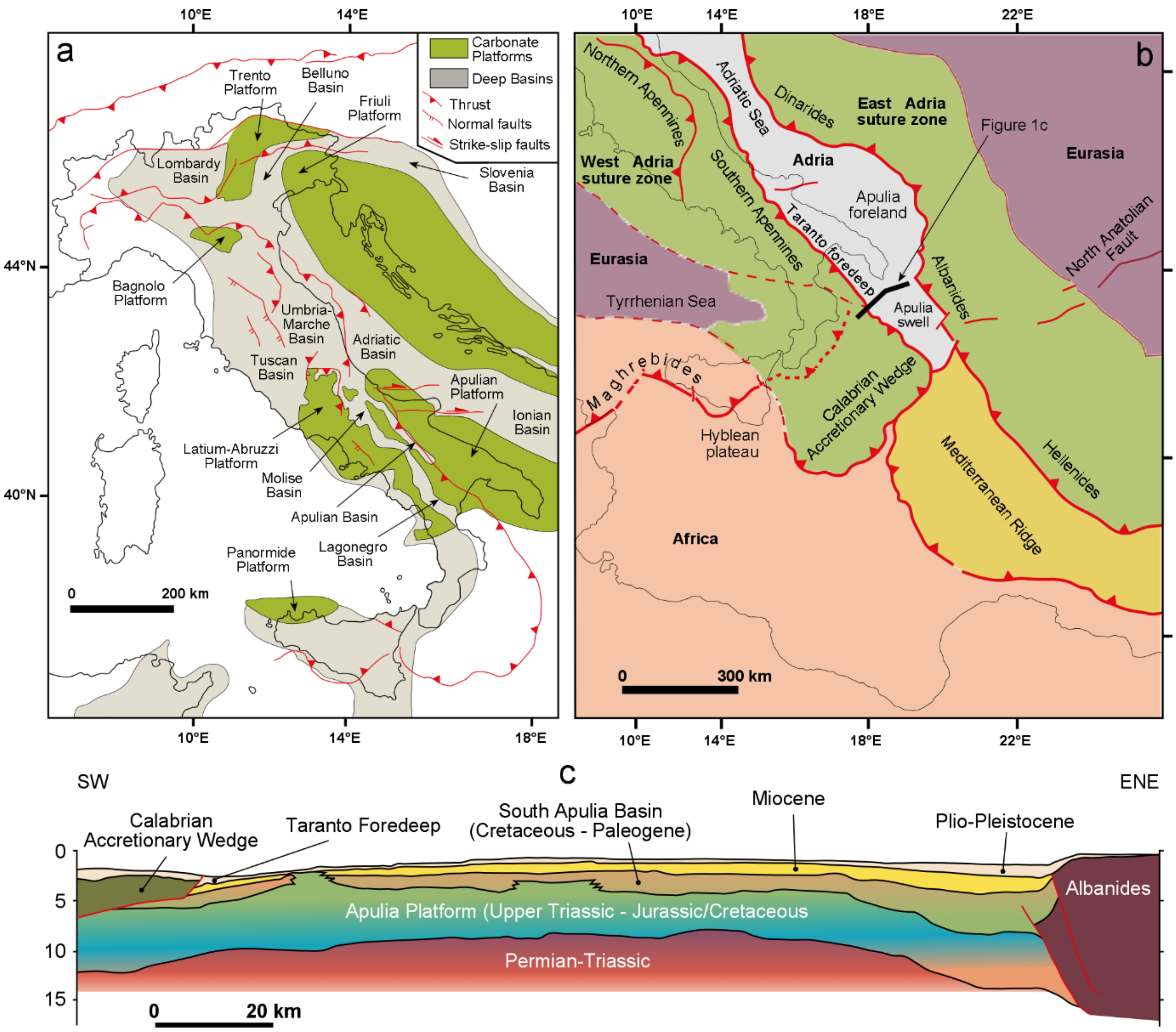


Fig. 1 - a) Early Giurassic- Early Cretaceous paleogeographic map of the Italian peninsula (redrawn from Zappaterra (1994; Carminati and Doglioni, 2012b); b) Simplified geodynamic framework and plates of the Mediterranean area (redrawn and modified from Basso et al., 2021); c) Crustal scale geological section across the submerged lowermost sector of the Salento peninsula (redrawn and modified from Maesano et al., 2020).

The Salento peninsula constitutes, together with its submerged portion in the offshore of the Ionian Sea (Apulian swell), the culmination of a lithospheric anticline, about 100 km wide, whose genesis is linked to the subduction of the Adria plate below two chains with opposite vergence: the Dinarides-Albanides-Hellenides, verging SW, and the Southern Apennines, verging NE (Channel et al., 1979; Ricchetti et al., 1988; Doglioni et al., 1994, 1996;

de Alteris, 1995; Argnani et al., 2001; Bernoulli, 2001; Maesano et al., 2020; Cicala et al., 2021; Fig. 1c). Consequently, the Salento Peninsula and the Apulia Swell constitute the Cenozoic foreland (i.e., the Apulian Foreland) of both the chains and as such is considered to be the peripheral bulge formed as the result of the external flexural bending induced by the loading of the two previously mentioned chains (Moretti and Royden, 1988).

The result of this structural setting of the Apulian Foreland is 1) the presence of E-W strike-slip faults in the northern sector and a NW-SE oriented extensional faults in the Salento Peninsula (Fig. 2) and Apulia swell, giving rise to a horst an graben systems (Martinis, 1962; Tozzi, 1993) whose genesis and age has been discussed in several paper, and 2) the presence of two foredeep basins showing opposite polarity (Doglioni et al., 1994, 1999; Gambini and Tozzi, 1996; Argnani et al., 2001; Butler, 2009; Del Ben et al., 2010, 2015; Volpi et al., 2017; Maesano et al., 2020; Cicala et al., 2021). Most Authors consider the migration of the two chains responsible for the extensional tectonic regime developed during the Pliocene and Quaternary (Ciaranfi et al., 1988; Doglioni et al., 1994; Argnani et al., 2001; Finetti and Del Ben, 2005) as well as for the significant block rotations as recognized in the Salento Peninsula area (Gambini and Tozzi, 1996). According to Di Bucci et al. (2011), a radial extension after the Late Pleistocene may be envisaged, indicating a bulge of the foreland area in place of the Middle Pleistocene SW-NE extension. The bulge should be the consequence of the coexistence of SW-NE contraction caused by the advancing of the Apennines and Dinarides-Albanides-Helledines and the concomitant northward movement of the African plate (see also Argnani et al., 2001). Consequently, the Middle-Upper Pleistocene deposits cropping out on both the Ionian and Adriatic sides of the Salento Peninsula show a deformation characterized by NW-SE, SW-NE, and SSW-NNE oriented extensional faults with small displacement. These structures are strictly related to the uplift of the Apulia region, which began during the Middle Pleistocene according to Doglioni et al. (1994, 1996). This tectonic uplift occurred contextually with the Quaternary eustatic sea-level changes and together determined a complex Quaternary evolution of the area, which was marked by relative sea level rise, and fall. The latter are considered responsible for the formation of the coastal terraces developed along the Ionian and the Adriatic margin of the

Salento peninsula (see Ciaranfi et al., 1988; Ricchetti et al., 1988; Di Bucci et al., 2011; Mastronuzzi et al., 2011; Ricchetti and Ciaranfi, 2013 with references therein).

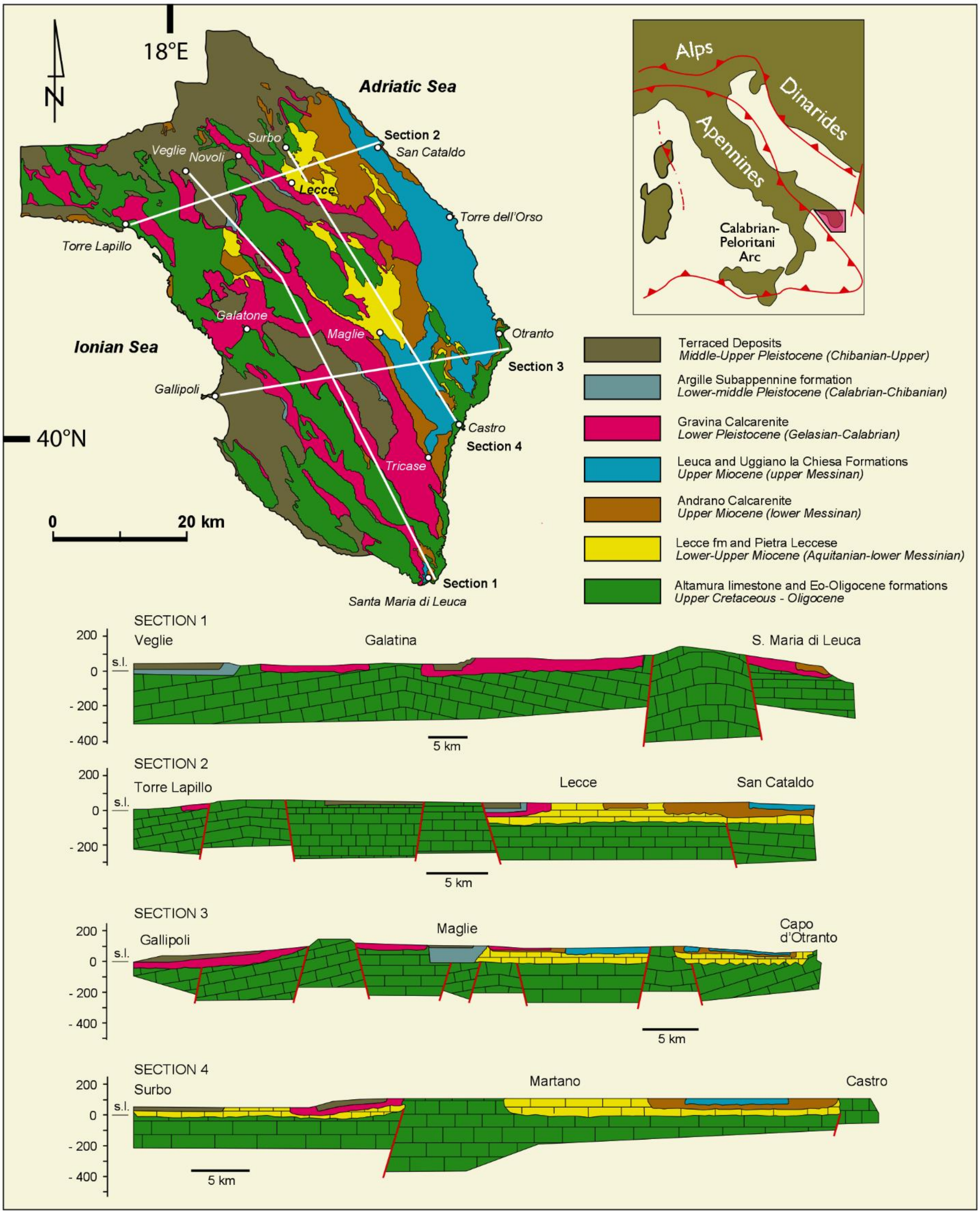


Fig. 2 - Simplified geological map and profiles of the Salento Peninsula (from Tancredi et al., 2022).

2.2. LITHOSTRATIGRAPHIC UNITS

The stratigraphic succession of both the Apulia region and the Salento Peninsula shows a basement constituted by a continental crust on which a thick sedimentary cover, essentially represented by Meso-Cenozoic carbonate rocks, is present (Mostardini and Merlini, 1986 with references therein). In particular, the sedimentary cover, about 7000 m thick, consists of a basal portion characterized by fluvio-deltaic deposits of Permo-Triassic age, passing upward to an anhydritic-dolomitic succession of Triassic age (Puglia 1 well). Above, a thick shallow-water Bahamian-type carbonate platform with associated slope and basinal facies of Jurassic-Cretaceous age (Apulian Platform) developed (D'Argenio, 1974; Ricchetti et al., 1988; Eberli et al., 1993; Bosellini, 2004; Morsilli et al., 2017), which is unconformably covered by thin and discontinuous Eocene to Quaternary deposits on the Adriatic side and by Pliocene and Pleistocene deposits on the Ionian side (Ciaranfi et al., 1988). A similar stratigraphic succession occurs in the Salento offshore sector. The eastern side is occupied by the Dinarides-Albanides-Hellenides foreland basin, whose filling is characterized by an Oligocene-Miocene carbonate and terrigenous succession, Messinian evaporites, and Plio-Quaternary marls and clays (Monopolis and Bruneton, 1982; Robertson and Shallo, 2000; Zelilidis et al., 2003; Del Ben et al., 2010; Karakitsios, 2013); the western side is instead occupied by the Southern Apennines foreland basin whose filling is mainly constituted by terrigenous Plio-Quaternary deposits (Rossi et al., 1983; Merlini et al., 2000; Butler, 2009; Basso et al., 2021).

The outcropping succession in the Salento peninsula is constituted by Upper Cretaceous to Quaternary deposits subdivided into lithostratigraphic units bounded by unconformities (Ciaranfi et al., 1988; Bosellini et al, 1999) (Fig. 3).

The Paleogene and the Neogene sediments crop out discontinuously in the area and were essentially deposited in several structural depressions originated as a result of the horst and graben structural setting occurring in the Salento Peninsula (Martinis, 1962; Tozzi, 1993). On the contrary, the Eocene to Miocene deposits cropping out along the southeast margin of the peninsula shows a different evolution, being characterized by carbonate units with well-developed depositional clinoforms indicating that these sediments were deposited along and at the base of steep rocky slopes that should correspond to the margin of the Mesozoic Apulia Platform (Bosellini and Parente, 1994; Bosellini et al., 1999; Bosellini, 2006; Pomar et al., 2014; Del Ben et al., 2015). A similar depositional context was also described by Tropeano et al. (2022) for the Lower Pleistocene carbonate deposits occurring along the south-east Salento, between Otranto and Santa Maria di Leuca.

Pleistocene	Chibanian-*Upper*	Marine terraced deposits	
	Calabrian-Chibanian?	Argille subappennine	
	Calabrian (Sicilian)	Gravina Calcarenite	
	Gelasian	Uggiano la Chiesa formation	
Pliocene	Piacenzian		
	middle Zanclean	Trubi	Leuca Formation
Miocene	upper Messinian	Leuca Breccia	
	lower Messinian	Andrano Calcarenite - Novaglie fm.	
	upper Burdigalian-lower Messinian	Pietra leccese	
	Aquitanian	Lecce formation	
Oligocene	upper Chattian	Galatone Fm.	Porto Badisco calcarenite
	middle-upper Chattian		Castro limestone
Eocene	upper Priabonian	Torre Specchia la Guardia limestone	
	lower Lutetian-upper Bartonian	Torre Tiggiano limestone	
Upper Cretaceous	Campanian-Maastrichtian	Altamura limestone	

Fig. 3 - Lithostratigraphic units cropping out on the Salento Peninsula. This scheme is modified from Bosellini et al.,1999, 2021, Bossio et al.,2006 a,b; Richetti e Ciaranfi, 2013; Parente and Less, 2019 and incorporate the indications derived from stratigraphic analysis of the investigated sedimentary succession).

The Torre Tiggiano limestone and Specchia la Guardia limestone are the only units of Eocene age (Boselini and Russo, 1992; Parente, 1994a; Bosellini et al., 1999; Russo, 2006). Ricchetti and Ciaranfi (2013) include both these two units in a single formation called Torre Tiggiano limestone. We considered separately these units as they are represented by different facies types: clinostratified bioclastic sediments (Torre Tiggiano limestone) and reef slope deposits (Specchia la Guardia limestone). Such informal formations have no wide distribution, and the few outcrops are only localized along the eastern coast of the Salento

Peninsula. The Oligocene deposits are represented by the Castro limestone and Porto Badisco calcarenite that crops out on the eastern Salento coast, whereas in the internal part of the peninsula the coeval unit is represented by the Galatone Formation. The Miocene deposits are represented by the Lecce formation, Pietra leccese and the Andrano Calcarenite. These units crop out essentially in the peninsula's internal sectors, whereas along the eastern coast the Andrano Calcarenites are replaced by the Novaglie formation. The Pliocene deposits of the Salento Peninsula are represented by the Leuca and Uggiano la Chiesa formations that crop out prevalently on the eastern sector of the peninsula. About the Quaternary deposits, the more developed units are represented by the Gravina Calcarenites and the Argille Subappennine that crop out extensively on the entire region. The more recent Quaternary units are instead represented by the marine terraced deposits that crop out extensively or in limbs along the coastal sector of the Salento peninsula. A brief description of these lithostratigraphic units from literature data and field observations is reported below.

2.2.1. Altamura limestone

This unit (Valduga 1965, Azzaroli, 1967), about 1000 m thick considering wells data, is the oldest outcropping formation of the Salento Peninsula (Campanian-Maastrichtian) and constitutes the substrate together with other lithostratigraphic units of upper Cretaceous in age that is described in Cestari and Sirna, 1987; Pons and Sirna, 1994; Bosellini and Parente 1994; Parente 1994a, b; 1997; Reina and Luperto Sinni , 1994; Laviano, 1996). This substrate is disconformably covered by the different Paleogene, Neogene, and Quaternary deposits (Ciaranfi et al., 1988; Ricchetti and Ciaranfi, 2013). This formation is exclusively made up of shallow-water facies, referable to the internal part and to the high-energy margin of a platform, as have not been identified in the area slope or basinal facies.

Overall, this unit is characterized by numerous meter-thick peritidal cycles of the internal platform showing locally the presence of stromatolites. Furthermore, discontinuous strata with high concentrations of rudist fragments occur, which give rise to bioclastic grainstones, interpreted as storm layers. In the most marginal areas of the platform, coarse bioclastic calcirudites and calcarenites prevail with fragments of rudists, orbitoids, macroforaminifers, corals, bryozoans, and calcareous algae. The rudist faunas indicate a late Campanian-Maastrichtian age (see detailed descriptions of this unit in Cestari and Sirna, 1987; Pons and Sirna, 1994; Bosellini and Parente 1994; Parente 1994a, b; 1997; Reina and Luperto Sinni, 1994; Laviano, 1996).

The top of this unit is locally characterized by karst structures and by the presence of thick residual soils with bauxite and pisoids, suggesting a long-periods of emersion at the end of the Cretaceous following the collision between the African and the European blocks and the westward migration of the Dinarides-Albanides-Hellenides chain (Bosellini et al., 1999; Ricchetti and Ciaranfi, 2013; Maesano et al., 2020; Cicala et al., 2021 and references therein).

2.2.2. Torre Tiggiano limestone

This formation constitutes the first unit of Eocene age deposited along the margin of the Apulian Platform when its internal sector was in subaerial conditions. It discontinuously crops out along the eastern coast of the Salento Peninsula having a thickness of 10-15 meters and lies on the Upper Cretaceous deposits through an erosional unconformity (Bosellini and Russo, 1992; Parente, 1994a; Bosellini et al., 1999).

The deposits of this formation are constituted by parallel- and cross-laminated grainstone/packstone forming units 1-2 m thick with lenticular geometry. The biogenic component is represented by abundant smaller and larger benthic foraminifers (miliodids, alveolinids and nummulitids) at which are associated encrusting foraminifera, coralline red algae and subordinate echinoids and green algae. Other less frequent bioclastic fragments are attributable to bivalves and bryozoans (Bosellini and Russo, 1992; Parente 1994a; Bosellini et al., 1999; Tomassetti et al., 2016). Based on this biota assemblage, and considering bodies geometry, and sedimentary structure, Tomassetti et al. (2016) interpreted these deposits as the product of deposition in a high-energy and wave-influenced shallow-water environment developed in a tropical to subtropical vegetated context (seagrass) and in oligotrophic conditions (Fig. 4).

Although Bosellini et al. (1999) not indicate a particular depositional context, their stratigraphic analysis suggests that this unit, dated lower Lutetian-lower Bartonian (Middle Eocene), was probably thicker and continuous and constituted by two depositional sequences separated by an erosional unconformity. The more recent biostratigraphic analysis of Tomassetti et al. (2016) assigned to this unit an early Lutetian-late Bartonian age.

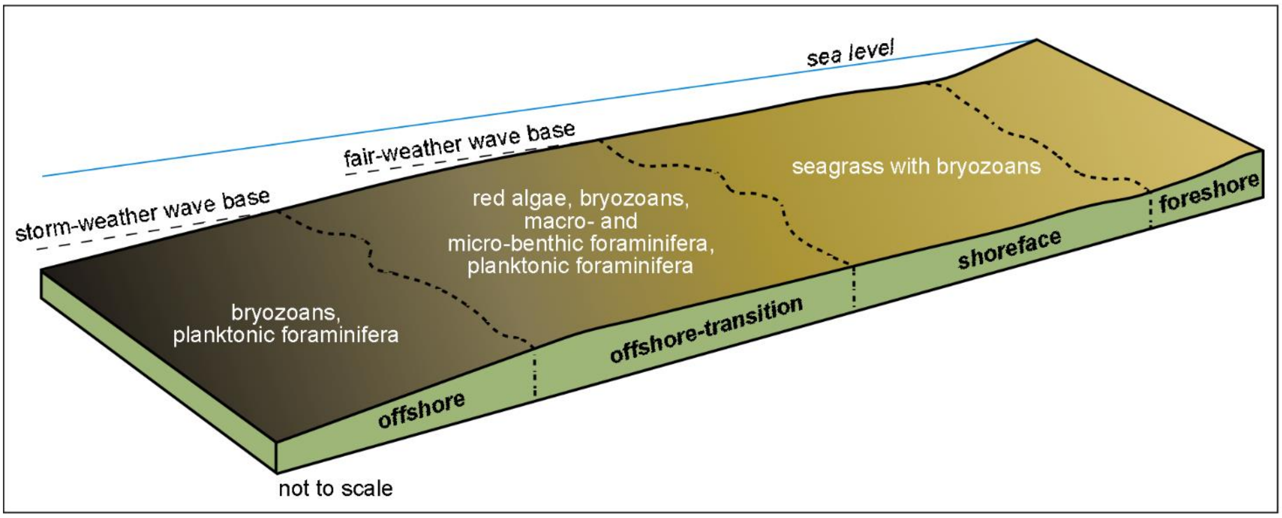


Fig. 4 - Depositional model of the Middle Eocene Torre Tiggiano limestone (redrawn and modified from Tomassetti et al., 2016).

2.2.3. Torre Specchia la Guardia limestone

This unit is the second formation of Eocene age that crops out fragmentarily along the Salento eastern coast. It is a reef slope deposit constituted by breccias and bioclastic sediments onlapping onto the Cretaceous substrate and/or on the middle Eocene deposits through an angular unconformity. The bioclastic component is constituted by corals fragments, calcareous algae (Corallinaceous, Dasycladales, and Halimeda), and benthic foraminifers whose assemblage, characterized by the presence of *Asterociclyna priabonensis* and *Heterostegina gracilis*, allow to attribute at these deposits a late Priabonian age (Bosellini and Russo, 1992; Parente, 1994a; Bosellini et al., 1999; Russo, 2006).

2.2.4. Castro limestone

This Upper Oligocene formation, (Bosellini and Russo, 1992; Parente, 1994a), crops out along the eastern coast of the Salento Peninsula from Capo d’Otranto to S. Maria di Leuca and lies discordantly onto the underlying Upper Cretaceous and Eocene formations. Such unit, whose thickness ranges from 5 to 80-100 m, was initially described by Rossi (1969) and successively studied by Bosellini and Russo (1992, 1994), Bosellini and Perrin (1994), Bosellini et al. (1999), Bosellini (2006) who interpreted these deposits as a fringing reef complex having recognized the subenvironments of back reef, reef flat, reef crest, reef front and reef slope. Successively, Pomar et al., (2014) interpreted the Castro limestone as the product of deposition along a meso-oligophotic distally steepened ramp with a distal talus resting on a paleo-escarpment of the Cretaceous substratum. The Authors highlighted that the production of bioclastic sediments is attributed to the presence, in the inner ramp (shallow water euphotic zone), of a seagrass meadow where epiphytic biota and sediment dweller organism proliferated. Coral fauna was considered confined to the mesophotic zone with no wave influence, where it formed scattered mounds above an escarpment 25°-30° inclined, at the bottom of which a talus constituted by bioclasts (essentially coral fragments) occurred.

More recently, the original interpretation of the Castro limestone as a fringing reef complex has been confirmed by Bosellini et al. (2021) (Fig. 5) that reconstructed the palaeobathymetric profile of this depositional system, highlighting how these deposits show homogeneity of reef-building biota, being characterized by a high diversity and abundant coral fauna associated with a moderate presence of coral, algae (essentially Corallinacee) and by the presence of benthic and planktic foraminifers and calcareous algae. This study has also refined the age of these deposits that have been reassigned to the middle-late Chattian (Pomar et al., 2014 attributed the Castro limestone to the lower Chattian), a period of time coincident with the Late Oligocene Warming Event (LOWE) (Zachos et al., 2001).

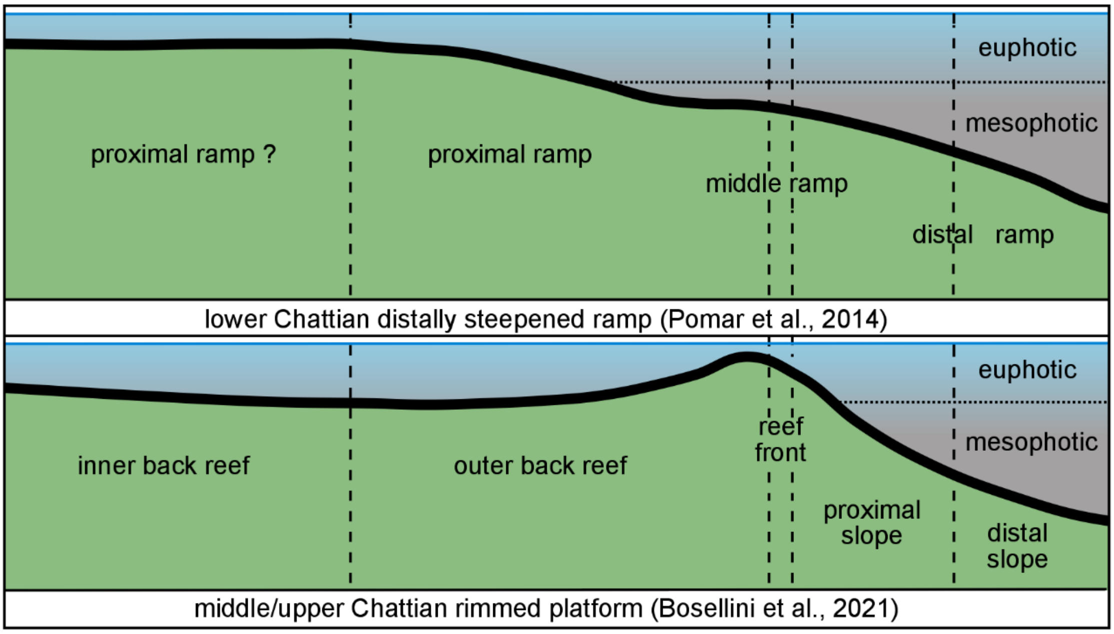


Fig. 5 - Comparison between the depositional models and ages of the Castro limestone proposed by Pomar et al. (2014) and Bosellini et al. (2021).

2.2.5. Porto Badisco calcarenite

This informal unit crops out along the eastern coast of the Salento peninsula from Capo d'Otranto to Cala Ciolo; it is constituted by a poorly cemented bioclastic calcarenite that reaches 50-60 meters of thickness in the locality of Porto Badisco, where it seems to fill a paleo-depression (Nardin and Rossi, 1966; Bosellini and Russo, 1992; Brandano et al., 2010).

Such formation lies disconformably on the Upper Cretaceous, Eocene and Upper Oligocene formations, having always an erosional base on which, locally, a rhodolith horizon 1-2 m thick occurs. On top of the Porto Badisco calcarenites a Miocene (Serravallian-Tortonian) phosphate-glauconite horizon, 5-30 cm thick, known in literature as "*Aturia* level" (Bosellini and Russo, 1992; Parente, 1994a; Föllmi et al., 2015; Vescogni et al., 2018) occurs. The significance of this level in the sequence-stratigraphic context of the area will be discussed in a following paragraph.

Recently, the Porto Badisco calcarenite has been investigated by Pomar et al. (2014), that subdivided this unit into six main lithofacies considered the product of sedimentation on a homoclinal ramp (Fig. 6). Packstones are the dominant textures having a skeletal component constituted by larger benthic foraminifera at which are associated red algae. The Authors described also in this units the presence of corals, forming distinct mounds a few meters to tens of meters in diameter, and scattered colonies. They evidenced that sedimentation of Porto Badisco calcarenites occurred in a euphotic zone characterized by skeletal component in a productive seagrass meadow, and an oligophotic zone where small and discontinuous coral mounds, larger to smaller benthic foraminifers, rhodoliths, and red-algae fragments accumulated. Based on the presence of *Miogypsinoides* Pomar et al. (2014) attributed the Porto Badisco calcarenite to the late Chattian.

More recently Parente and Less (2019) analyzed in detail the larger benthic foraminifera assemblage of this unit, which is mainly constituted by *Eulepidina*, *Heterostegina* and *Spiroclypeus* and subordinately by *Nummulites*, *Operculina* and *Nephrolepidina*. They also analyzed this formation through the Sr isotope stratigraphy and attributed an age of 23.6 ± 0.5 Ma to the lower portion of this formation which corresponds with the latest part of Chattian, almost at the boundary between Oligocene and Miocene. This study together with that of Bosellini et al. (2021) shows that both the Castro limestone and the Porto Badisco calcarenite belong to the same biozone (Shallow Benthic Zone 23, Cahuzac and Poignant, 1997) although stratigraphically the latter is superimposed on the former.

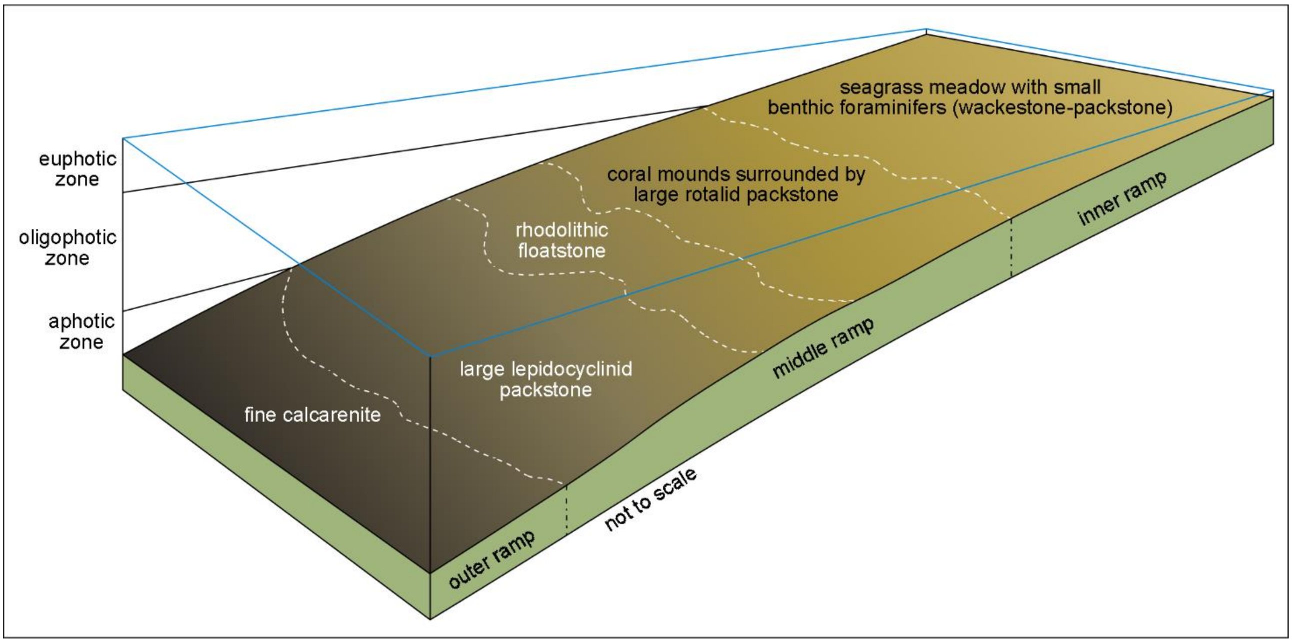


Fig. 6 - Carbonate ramp depositional model of the Porto Badisco calcarenite (redrawn and modified from Pomar et al., 2014).

2.2.6. Galatone Formation

The Galatone Formation, whose maximum thickness is about 100 m in correspondence with graben areas and in the nucleus of small synclines (Bossio et al., 2006a; Giudici et al., 2012), lies unconformably on the Cretaceous substrate, directly or through the interposition of residual deposits rich in pisolites and bauxitic nodules (Bossio et al., 1998). In recent years the stratigraphy of this unit has been described in detail by Esu et al. (1994, 2005), Bossio et al. (1998; 2006a, b, 2007, 2009), Margiotta and Ricchetti (2002), Margiotta and Negri (2008). It is constituted by whitish greyish micritic limestones that are interbedded with centimeter-scale layers of whitish limestone and laminated yellowish calcareous marls, silt, and clays. Paleosols and lignite layers, from a few centimeters to several decimeters thick, occur at different levels in this unit thus suggesting a sedimentary cyclicity and frequent subaerial exposures. Bivalves, gastropods, and ostracods of different environments (freshwater, brackish and marine) are the most common fossils occurring in this formation, and together with the assemblages of benthic foraminifers living in a seagrass environment (planktonic foraminifera are absent), indicate a lacustrine to marshy/swampy restricted lagoonal environment, locally open to the sea. These environments characterize the thickest portion of this unit which only in its terminal part records the presence of mesohaline and marine carbonate facies (Margiotta and Ricchetti, 2002; Esu et al., 2005) indicating a major marine influence related to progressive marine ingression in the Salento hinterland.

The bio-chronostratigraphic framework of the Galatone Formation, based on the ostracofauna, allows attributing the entire unit to the Chattian (Upper Oligocene) (Bossio et al., 1998, 2006a, b, 2009). Based on what was suggested by Bosellini et al. (1999), and Bossio et al. (2006a, b; 2007; 2009) and considering the most recent studies of Bosellini et al. (2021) and Parente and Less (2019) on Castro limestone and Porto Badisco calcarenite respectively, as well as our field observations and correlations, we retain that the Galatone Formation is heteropic of both the two formations whose age, as previously mentioned, covers the time interval of the middle-late Chattian. The Galatone Formation represented the product of deposition in the internal parts of the Salento Peninsula, where a lacustrine-lagoonal environment occurred, passing seaward to the carbonate facies of the Castro limestone and the Porto Badisco calcarenite (Fig. 7). This topic will be further discussed in the following paragraph where the sequence-stratigraphic framework of the entire Paleogene-Quaternary succession of the Salento Peninsula will be analyzed.

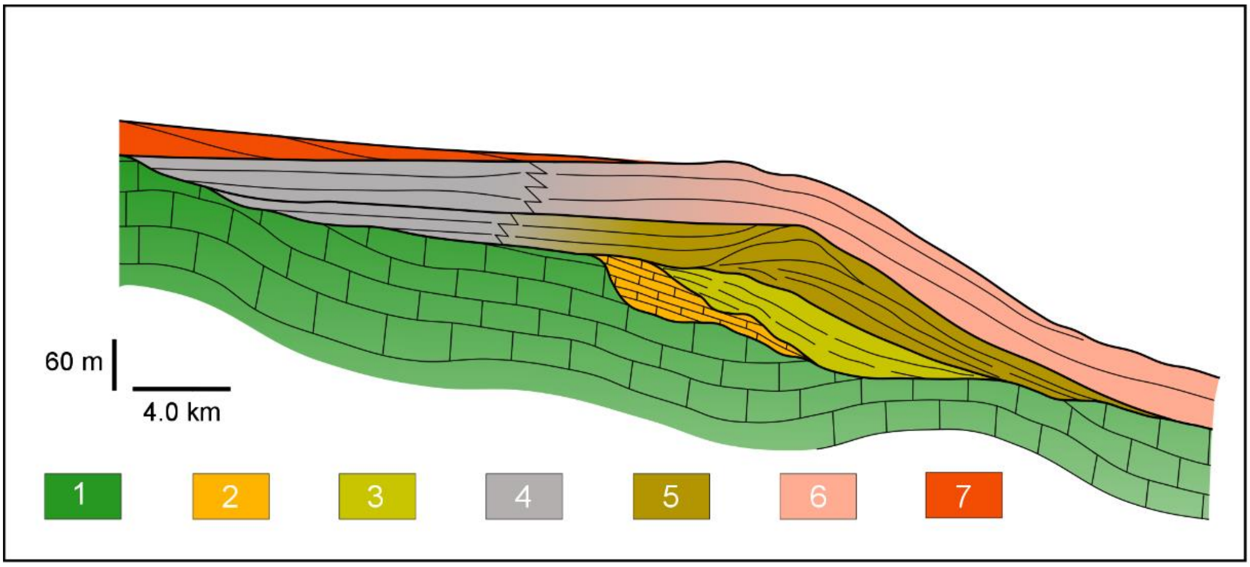


Fig. 7 – Schematic profile showing the stratigraphic relationships among the Castro limestone, the Porto Badisco calcarenite, and the coeval Galatone Fm. Note the transgressive character of the Lecce fm. respect to the underlying lithostratigraphic units. 1: Altamura limestone; 2: Torre Tiggiano limestone; 3: Torre Specchia la Guardia limestone; 4: Galatone Fm.; 5: Castro limestone; 6: Porto Badisco calcarenite; 7: Lecce fm.

2.2.7. Lecce formation

The Lecce formation (Margiotta, 1999; Margiotta and Ricchetti, 2002; Bossio et al., 2006a; 2007, 2009; Margiotta, 2015) crops out to the south-west of the town of Lecce and lies unconformably on the Galatone Formation, through the interposition of a paleosol from a few tens of centimeters to about 2 m thick (Figs 7 and 8). This unit, about 60 meters thick, is constituted by whitish massive calcarenites with gray marly and micritic limestone intercalations which show extensive bioturbation (Fig. 9a). Faunal assemblage is characterized by rare bivalves (especially *Cardium*), echinoids (*Scutella*), gastropods, and macroforaminifers (*Operculina*) (Fig. 9b). The microfauna is represented by microforaminifers and calcareous nannofossils. All these features indicate a deposition of these sediments in a shallow water marine environment where the good preservation of macroforaminifers and the presence of *Scutella* suggest reduced transport and low-energy hydrodynamic conditions.

From a chronostratigraphic and biostratigraphic point of view, the assemblages of planktonic foraminifers and calcareous nannofossils allowed Bossio et al.,(2006a) to assign the upper portion of this formation to the basal Aquitanian (Early Miocene), while the lower portion was doubtfully attributed to the late Chattian. However, considering the recent age attributed to the underlying Porto Badisco calcarenite by Parente and Less (2019) (latest portion of the Chattian) we suggest attributing to Aquitanian the age of the Lecce formation. The marine character of this unit highlights the transgressive trend characterizing the Neogene deposits with respect to the underlying lacustrine-lagoonal Galatone Formation, although this last formation records in the uppermost portion a major marine influence. This transgressive trend will culminate with the deposition of the subsequent stratigraphic unit, represented by the Pietra leccese formation.

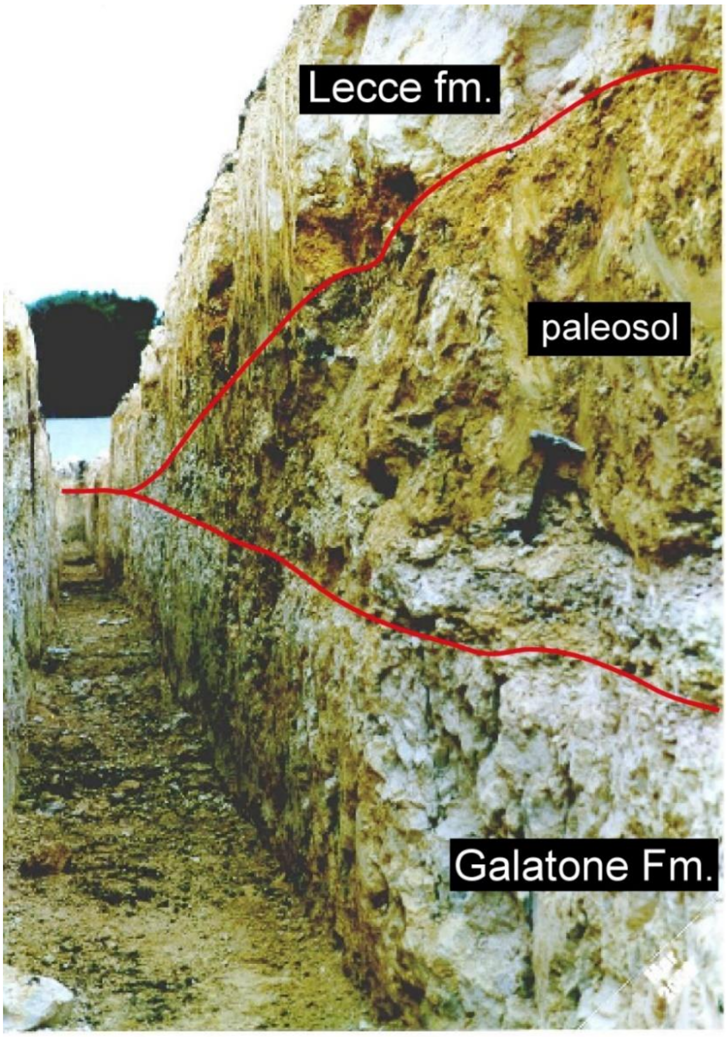


Fig. 8 - Transgressive erosional contact between the Lecce fm. and the underlying Galatone Fm. Locally these stratigraphic units are separated by a paleosol (ring road of Lecce city).

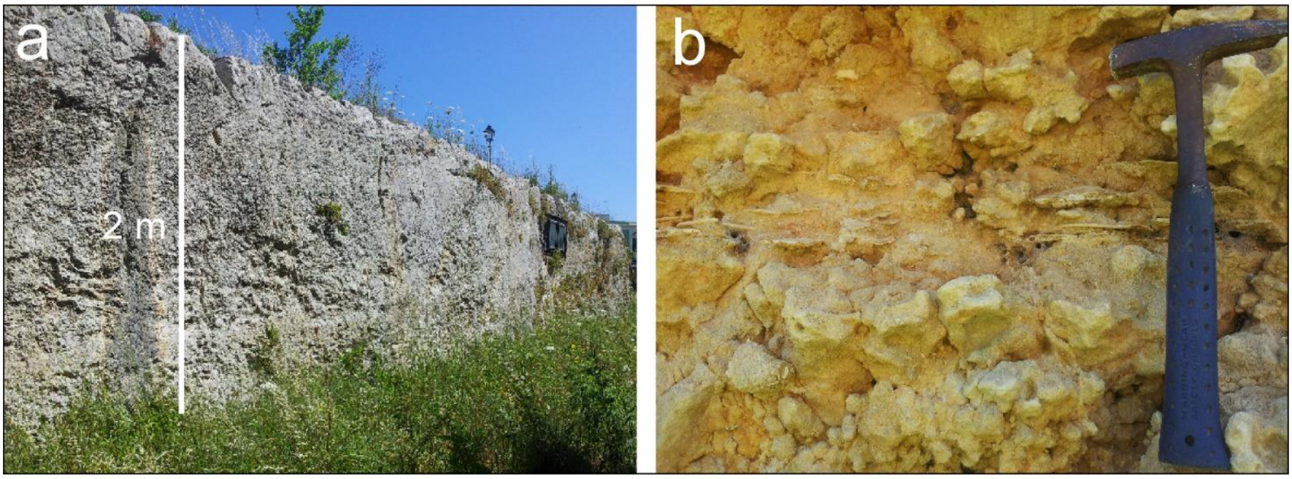


Fig. 9 - a) calcarenites of the Lecce fm. cropping out along the moat adjacent to the Copertino Castle; b) Detail showing the presence of *Scutella* specimen in Lecce fm. calcarenites.

2.2.8. Pietra leccese

The Pietra leccese formation constitutes a lithostratigraphic unit extensively occurring both in outcrop and in the subsurface in the Salento Peninsula, and developed over a period of about 11 My, from the late Burdigalian to the early Messinian (see Mazzei et al., 2009 with references therein). It reaches the maximum thickness of about 90 m in the Lecce area, whereas towards the Ionian and Adriatic coast the thicknesses of Pietra leccese is extremely thin or entirely absent. This unit lies unconformably both on the Cretaceous substrate (Fig. 10) and on the Lecce formation (see also Cazzato and Margiotta, 2021). It is separated from the former either by a limestone breccia 20-30 cm thick or by a thin phosphatic layer with apatite nodules. On the eastern margin of the Salento Peninsula, this thin phosphatic layer is replaced by a layer 10-30 cm thick, which constitutes a reddish or greenish-brown hardground containing phosphatized pebbles and known in literature as "*Aturia* level" (Föllmi et al., 2015; Vescogni et al., 2018 with references therein).

In its typical appearance, the Pietra leccese consists of a pale-yellow soft, and friable biomicrite rich in planktonic foraminifers and nannofossils (Mazzei, 1994) and with macrofossils consisting of pectinids, echinoids, bivalves, and brachiopods (Margiotta, 2006) (Fig. 11a). Overall, the sediment is very bioturbated and the stratification, poorly distinguished, appears in banks with thicknesses ranging from 50 to 100 cm (Fig. 11b). One of the features characterizing this unit is the presence of a high percentage of phosphatic and glauconitic grains whose frequency and abundance allowed the Authors (see Foresi et al., 2002; Balenzano et al., 2003; Bossio et al., 2006a; Margiotta, 2006; Mazzei et al., 2009; Chieco et al., 2021) to subdivide this unit into different intervals separated by three hiatuses with a duration variable from 1.2 to 3.7 Ma.

From older to younger, the first hiatus, with a duration of about 2.5 Ma, separates the upper Burdigalian nonglauconitic interval from the Langhian weakly glauconitic interval. The second hiatus, with a duration of about 2.5 Ma, separates the upper Langhian weakly glauconitic interval from the lower Tortonian intensely glauconitic interval. The third hiatus, with a duration ranging from 1.7 to 3.7 Ma, separates the lower Tortonian glauconite-rich interval from the middle Tortonian weakly glauconitic interval. A fourth hiatus was also recognized, but only in the area north of Lecce, where the uppermost Tortonian deposits directly overlie the middle Tortonian deposits. In Cursi–Melpignano area, the lower Tortonian intensely glauconitic interval is overlain by a lower Messinian weakly glauconitic interval constituted by a marly calcarenite rich in pectinids and brachiopods and with hummocky cross-stratification. This last interval of Pietra leccese suggests a decrease of water depth and a deposition in a shallow-marine or nearshore environment; it grades transitionally upward to the Andrano Calcarenite (Bossio et al., 2006a; Margiotta, 2006). Overall, the sedimentological and paleoecological data indicate for the Pietra leccese a deposition in an inner shelf passing towards the top of the succession to a lower shoreface.

Although the Pietra leccese spans a time interval of 11 Ma, its overall thickness is small respect to its duration. Balenzano et al. (2003), and Mazzei et al. (2009 with references therein) indicate that this reduced thickness could be interpreted as a consequence of a nondeposition and/or erosion induced by marine currents sweeping the seabed. The hiatuses occurring in this formation would be an expression of these processes.

We agree that marine currents can be particularly effective erosive agents, however, we believe that the formation of the hiatuses occurring in this lithostratigraphic unit can be more coherently explained in the sequence-stratigraphic context of the entire Paleogene-Quaternary succession of the Salento Peninsula.

Fig. 10 - Unconformity surface between the Pietra leccese and the Altamura limestone (north-east of Lecce). The passage between the two lithostratigraphic units is often marked by a 20-30 cm thick phosphatic layer with small nodules of apatite.

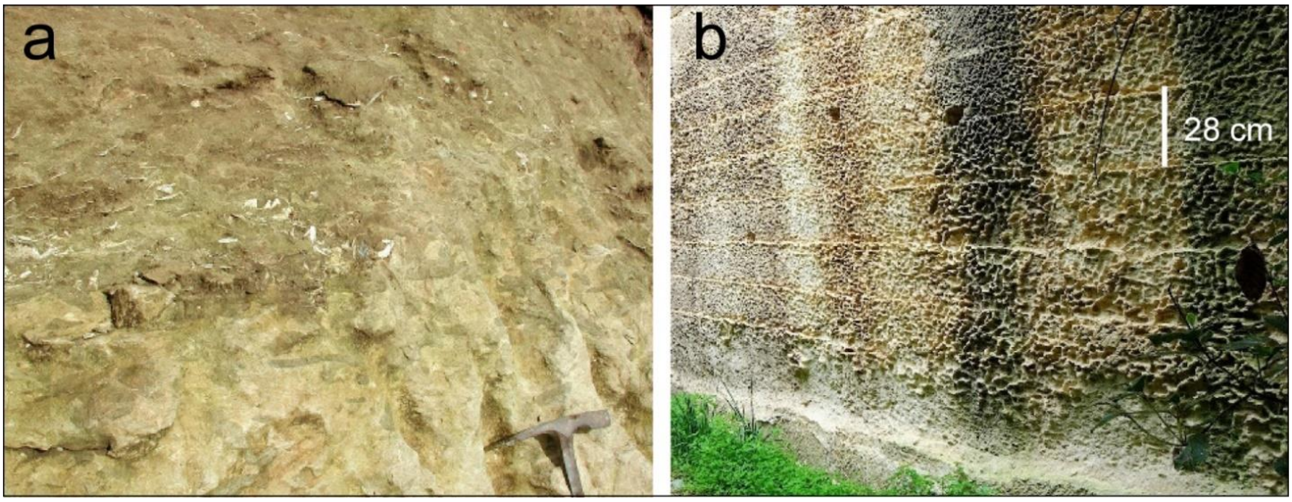


Fig. 11 - a) disarticulated valves of lamellibranchs in the glauconitic-rich calcarenite of the Pietra leccese; b) highly bioturbated fine-grained calcarenite of Pietra leccese.

2.2.9. Andrano Calcarenite

This unit, originally defined by Martinis (1967), crops out with reduced thickness along the internal and the eastern sectors of the Salento Peninsula (Bossio et al., 1994), whereas it reaches a thickness of about 90 meters in the subsurface (Margiotta, 2006). In the Leuca area, the Andrano calcarenites extensively crop out and lie discordantly, both on the oldest Miocene sediments and on the Cretaceous substrate (Bossio et al., 1994; Mazzei, 1994; Ricchetti and Ciaranfi, 2013). This unit shows a gradational boundary with the underlying Pietra leccese (Fig. 12a) and is constituted at the base by thin-bedded whitish fine-grained marly calcarenite with rare greenish granules of glauconite grading upward to wavy, subparallel bedded (30-40 cm) whitish/yellowish medium-grained marly calcarenites.

Fossils are very abundant and dispersed in the deposits or forming concentrated layers; the most frequent fossils are represented by serpulids, balanids, bryozoans, gastropods (essentially *Turritella* sp.), bivalves (*Chlamys* sp., *Cardium* sp., *Ostrea* sp., *Modiola* sp.) brachiopods and calcareous algae (Fig. 12b). The uppermost portion of the Andrano Calcarenite is constituted by a light gray fine-grained marly calcarenites with locally intercalated a thick greenish clay bed showing a rich assemblage of brackish macrofossils constituted by small gastropods (*Cerithium* sp.) and bivalves (*Cardium* sp.) (Margiotta, 2006). All these data indicate a vertical and transitional environmental change of the Andrano Calcarenite, passing from an inner shelf to a beach environment with local presence of brackish lagoonal conditions in the uppermost part of this succession. This last character is also evidenced by the presence of some benthic foraminifers as *Cribrononion articulatum*, a species living in lagoonal areas with fresh water supplies (Bossio et al., 2006a).

Based on micropaleontological data, the age of the Andrano Calcarenite is attributed to the early Messinian (Mazzei, 1994; Mazzei et a., 2009 and references therein) and most likely to the pre-evaporitic stage, although it is not excluded that these sediments may have been deposited during the initial phase of the Stage 1 of the Messinian Salinity Crisis (MSC) (see Hilgen et al., 2007; CIESM et al., 2008; Roveri et al., 2014a, b).

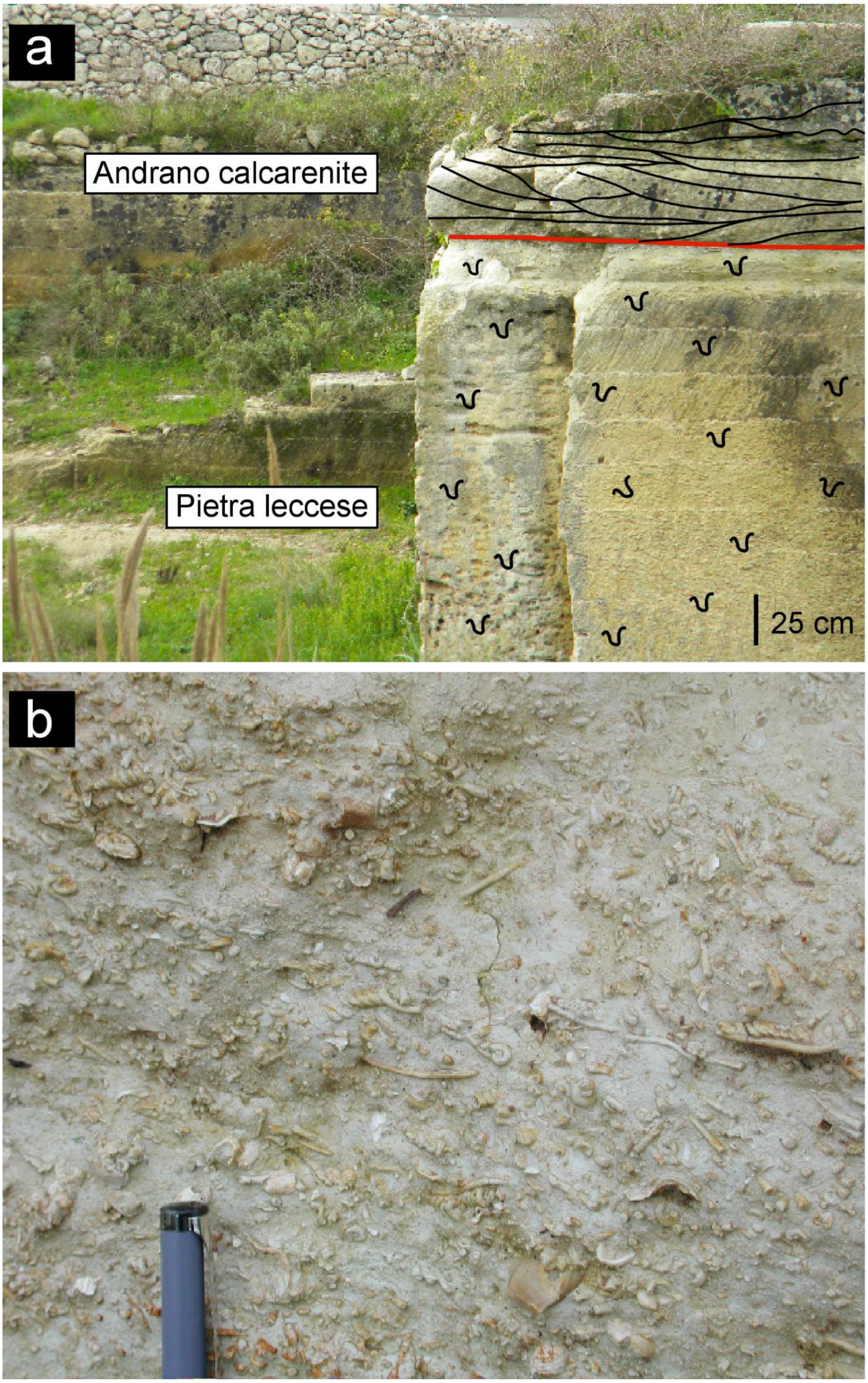


Fig. 12 - a) Stratigraphic contact between the Andrano Calcarenite showing a hummocky cross-stratification and the underlying highly bioturbated fine-grained calcarenite of the Pietra leccese; b) highly concentrated fossiliferous layer with serpulids, balanids, bryozoans, gastropods, bivalves, brachiopods and calcareous algae in the Andrano Calcarenite.

2.2.10. Novaglie formation

This unit was introduced by Bosellini et al. (1999), but it has not yet been formalized. It crops out discontinuously along the eastern coast of the Salento Peninsula from Porto di Tricase to Cape S. Maria di Leuca where it is also known by the name of Gagliano del Capo formation (Ricchetti and Ciaranfi,2013). Such unit lies discordantly on the pre-Miocene-units through an erosional surface on which a 10-50 cm thick phosphatic hardground occurs (the above-mentioned *Aturia* level). Based on benthic foraminifers and ostracod assemblages, the Novaglie formation was dated to the early Messinian by Bosellini et al. (1999, 2001), and considered by the Authors as heteropic of the Andrano Calcarenite.

The Novaglie formation shows a well-developed reef complex with coral reef, and clinostratified breccias forming a prograding slope and base-of-slope deposits (Bosellini et al., 2001, 2002) (Fig. 13). Palaeoecological data suggest that this Messinian reef was characterized by a heterogeneous reef-building biota, with *Halimeda* bioherms, *Porites* reefs, coralline algae and vermetid-microbial bioconstructions at which were associated, encrusting foraminifera, bryozoans and serpulids (Bosellini et al., 2002; Bosellini, 2006).

A more recent study indicates that this formation is constituted by three superimposed units called NF1, NF2, and NF3 that are separated by erosional surfaces colonized by microbial-vermentides bioconstructions (Vescogni et al., 2022) (Fig. 13).

The lower units are early Messinian in age (7.3-5.97 Ma); NF1 unit is 120 m thick and shows a complete margin-to-slope reef tract with reef rubble, *Halimeda* bioherms and packstones, rhodolith floatstones/rudstones, and bioclastic calcarenites. The overlying NF2 unit, 20 m thick, is constituted by coral bioconstructions of *Porites* reefs with a reduced thickness of proximal slope deposits. The NF3 unit, 10 m thick, consists of oolitic deposits associated with microbialites, colonies of *Porites*, and small vermetid and serpulid bioherms (Bosellini et al., 2001, 2002). The NF3 unit is late Messinian in age (5.97-5.60 Ma) (Vescogni et al., 2022) and is equivalent to the Terminal Carbonate Complex (TCC), a shallow-water carbonate unit strictly related to the Messinian Salinitiy Crisis that characterizes the terminal portion of the upper Messinian in several sector of the Mediterranean area (Krijgsman et al., 2001; Bourillot et al., 2020; Roveri et al., 2020 and references therein).

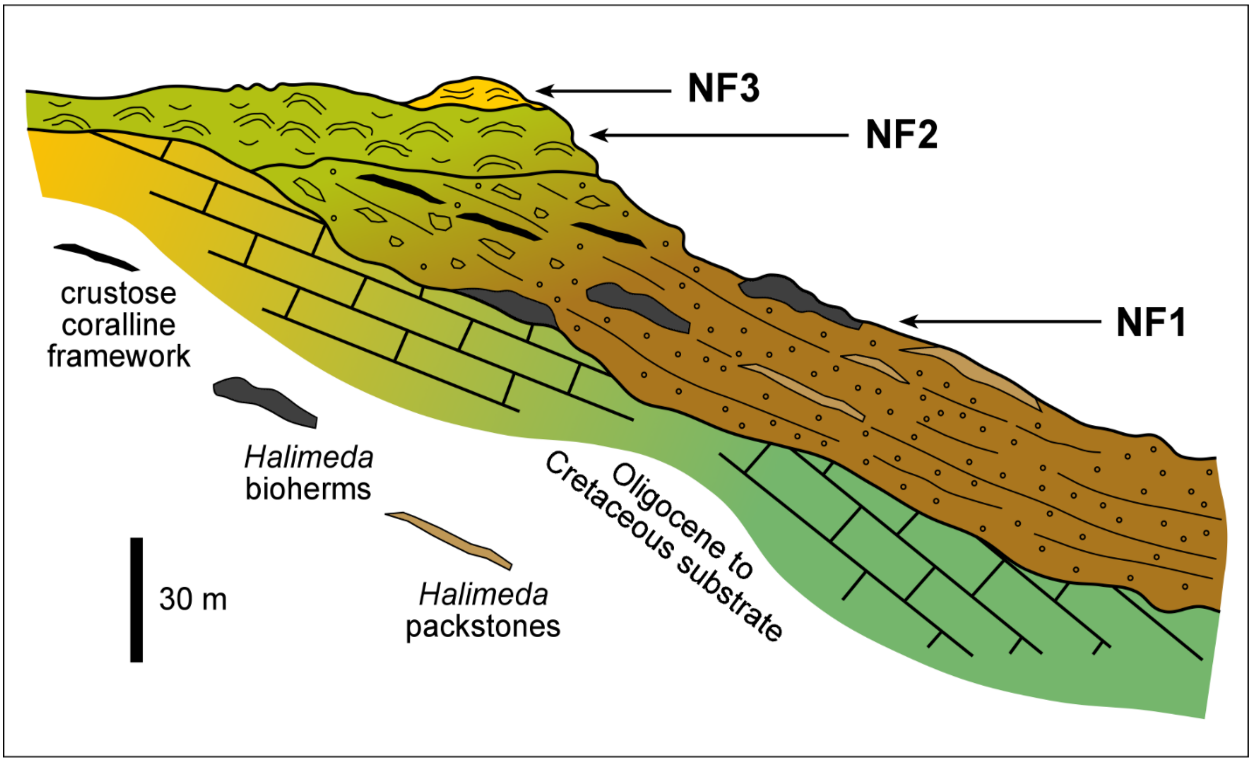


Fig. 13 - Deposition profile showing the reef-building biota and reef types characterizing the lower and upper Messinian deposits of the Novaglie fm. Note the subdivision of this formation into the three units NF1, NF2 and NF3 as proposed by Vescogni et al. (2022) (redrawn and modified from Bosellini et al., 2006).

2.2.11. Leuca Formation

The Leuca Formation, formalized by Bossio et al. (2002), is considered by these Authors the first Pliocene unit of the Salento Peninsula. It has been subdivided into two members, from bottom to top: 1) a lower breccia/conglomerate member with a sandy matrix and rare fossils (*Ostrea* and *Chlamys*), forming a thicker and more conspicuous chaotic unit with carbonate clasts (10 to 100 cm of diameter) (Fig. 14) derived, essentially, from underlying Andrano Calcarenite and Novaglie formation (on this basis, Ricchetti and Ciaranfi,2013 attributed this member to the Andrano Calcarenite and hypothesized their successive post-diagenetic redeposition through slumping mechanism). 2) an upper marly unit passing upward to a glauconitic mudstone rich in planktonic foraminifers with subordinate benthonic forms (Palmariggi member of Bossio et al., 2005), that would correspond to the Trubi unit of Bosellini et al. (1999) and Ricchetti and Ciaranfi (2013) (Fig. 15). The thickness of this formation is highly variable ranging from 1-2 m to 30 m. A particular recurring feature that has been recognized at the base of the formation, below the breccia/conglomerate member, is the presence of a compact dark-colored vacuolar limestone that is locally laminated. The scarce benthic microfauna present just above the base of the formation indicates very modest bathymetry. The latter increases rapidly in the lower portion of the upper member whose microfauna and other fossils assemblage suggests deposition in an inner shelf (offshore-transition) below the fair-weather wave base, due to the presence of shell layers concentrations indicating multiple phases of storm-wave reworking (D'Alessandro et al., 2004; Massari et al., 2009). The glauconitic mudstone of the upper member with its rich microfauna indicates instead an outer shelf environment (Bossio et al., 2006a).

The scarce microfaunal assemblage recognized in the lower member would indicate that this portion could be referred to the initial part of the Zanclean (Bossio et al., 2006a). However, the same Authors also evidence in these deposits the presence of *Globigerinoides seigliei*, a form occurring from Tortonian to Zanclean. It is evident that the age of the Leuca Formation is still debated due to a lack of accurate biostratigraphic markers. Bosellini et al. (1999) considered the breccia and conglomerate member a single formation of Late Messinian age whose genesis would be related to the sea-level fall associated with the late phase of the Messinian Salinity Crisis (MSC). The same authors attributed the second member of this unit to another formation of the lower Pliocene (Zanclean) age on the basis of the faunistic assemblage (see Bosellini et al., 1999; Ricchetti and Ciaranfi, 2013). These age attributions to the two members of the Leuca Formation are supported by this work (see paragraph discussion), and by the recent paper of Vescogni et al. (2022) that also assigns the vacuolar limestone occurring at the base of this formation and below the breccia deposits to the Terminal Carbonate Complex (TCC) of late Messinian age (5.97-5.60 Ma).

2.2.12. Uggiano la Chiesa formation

Such unit of Pliocene age crops out along the eastern coast of the peninsula and lies mostly on the Leuca Formation (Fig. 15) and locally on the older units; its thickness is variable, reaching the maximum value of about 50 m in the Poggiardo area (Bosellini et al., 1999; Bossio et al., 2006a) and 90 m in the Cesine area (Chieco et al., 2021).

Fig. 14 - Breccias constituting the lower member of the Leuca Formation, which consists of clasts derived prevalently by the Andrano Calcarenite and partly by Novaglie fm., immersed in a predominantly calcarenitic matrix (Masseria Torricella locality along the Lecce-San Cataldo highway).

Fig. 15 - Outcrop showing the vertical passage between the Leuca Fm. and the overlying Uggiano la Chiesa fm. through an erosional unconformity surface (white line) marked by the presence of a discontinuous conglomerate bed with phosphatic pebbles.

This formation is constituted in the lower portion by a discontinuous basal conglomerate 30-70 cm thick with phosphatic pebbles (Fig. 15) passing upward to fine-grained marly calcarenite in turn replaced by a yellow and well-stratified medium-grained calcarenite rich in foraminifers, ostracods, echinoderms, mollusks, bryozoan, and red algae.

Foraminifers and ostracods assemblages together with other fossils suggest for the lower portion of this formation an inner shelf/outer shelf environment characterized by low to moderate water energy, only episodically affected by storm-induced winnowing that gave rise to shell concentrations (D'Alessandro et al., 2004; Massari et al., 2009) (Fig. 16). An inner shelf environment is also suggested for the upper portion of this formation, characterized by a progressive decrease of the number of species. The fossil assemblages indicate a shallow-water environment where a stirring of the sea floor due to highly turbulent flows gave rise to the mixing of fauna and the formation of graded beds (D'Alessandro et al., 2004; Massari et al., 2009). All this suggests an initial deepening of the depositional environment passing upward to a shallower environment indicating a regressive trend (Fig. 16).

The planktonic foraminifers assemblage suggests a late Piacenzian-Gelasian age for the Uggiano la Chiesa formation (Bossio et al., 2005), although the same Authors (Bossio et al., 2006a), in other areas of the Salento extend the base of this formation to the Zanclean,considering that the calcareous plankton content can be ascribed the *Globorotalia puncticulata* and *Discoaster tamalis* zones.

2.2.13. Gravina Calcarenite

This formation, established by Azzaroli et al. (1968), has an age variable from Gelasian to Calabrian (Early Pleistocene) in the Murge area (Ciaranfi et al., 1988; Richetti et al., 1988), while its corresponding deposits in the Salento area, originally known as "Salento Calcarenite", have been attributed, to the Calabrian (probably substage Sicilian) by Bossio et al. (2006a), on the basis of the rich fossil assemblages (macrofossil are represented by bivalves as *Arctica islandica*, *Mya 29iachron*, and *Panopea norvegica*, and micro- and nannofossil are referred to the *Globorotalia truncatulinoides excelsa* and "small" *Gephyrocapsa* zones). The diachronic age of this formation indicates its time-transgressive character

Fig. 16 - Torre Sant'Andrea's rocky coast showing the vertical transitional passage between the lower portion (outer shelf) and the upper portion (inner shelf) of the Uggiano la Chiesa fm.

moving from the Murge (NW) to Salento (SE), thus covering a large area of the Apulia region, from the outer margin of the Bradanic trough, to the internal (inland depressions) and coastal sectors of the Salento Peninsula (Tropeano and Sabato, 2000; Pomar and Tropeano, 2001; D'Alessandro et al., 2004; Massari et al., 2001; Bossio et al., 2006a; Tropeano et al., 2004, 2022). This formation shows thicknesses variable from 10 to 40-50 m in outcrop and reaches 70-80 m in the subsurface (Giudici et al., 2012). In the Salento area it lies unconformably on an articulated substrate constituted by the variously faulted older units and consists of medium- to coarse grained fossiliferous bioclastic shelfal packstone/grainstone made up of heterozoan organisms (Fig. 17).

Fig. 17 – Outcrop of Gravina Calcarenite in the Porto Miggiano sector showing a medium-coarse grained fossiliferous bioclastic calcarenites, locally bioturbated, attributable to a lower shoreface/offshore-transition zone. Inside the ellipse a pen for scale.

2.2.14. Argille Subappennine

This formation lies transgressively on but in continuity of sedimentation with the Gravina Calcarenite, from which is often separated by a thick and fossiliferous marly calcarenite bed rich in brachiopods (*Terabratula scillae*) (Ricchetti and Ciaranfi, 2013). This unit has a widespread distribution along the western sector of the Murge area where it crops out extensively from the present-day sea level to an elevation of about 500 m. In the Salento area this formation crops out with a reduced thickness (a few meters) on very small areas; whereas in the subsurface the thickness increases to about 230 m towards the western sector, in the direction of the Bradanic Trough, within the depressions placed between the structural highs of the Cretaceous substrate (Margiotta and Negri, 2004; Giudici et al., 2012; Ricchetti and Ciaranfi, 2013).

In the Murge sector, this formation consists of gray-light blue clays and marl-clays, deposited in a relatively deep-water environment (from bathyal to shallow sublittoral zone). In the Salento area, it is constituted by blue-gray marly-silty clay with macrofossil assemblage constituted by lamellibranchs, brachiopods, corals, algal nodules, and arborescent bryozoans (D'Alessandro and Massari, 1997) and with a rich microfauna represented by benthic and planktonic foraminifers. Due to the morphological variability of the depositional areas related to the structural setting of the Salento Peninsula, this formation shows different types of deposits, with marginal facies having clinoform deposits and a rich assemblage of macrofossils (lamellibranchs, brachiopods, corals, and bryozoans), passing to basinal facies towards the more distal and depressed sectors, where the macrofossils are represented only by lamellibranchs and gastropods (D'Alessandro and Massari, 1997). Both fossiliferous assemblages and sedimentological data suggest a circalittoral environment where the seafloor was interested by low sedimentation rates and episodically swept by storm-induced currents which probably locally accelerated their velocity due to the seaway confinement; such storm events winnowed the bottom, redistributing the bioclastic detritus both over a wide area or concentrating it in single beds (D'Alessandro and Massari, 1997).

The age of this unit, based on the microfaunistic assemblage, has been referred to as a generic Calabrian (Ciaranfi and Ricchetti, 2013), although considering the age of the underlying Gravina Calcarenites, attributed to the Sicilian substage (Bossio et al., 2006a), it should be referred to the end of the Calabrian and to the beginning of the Middle Pleistocene.

2.2.15. Pleistocene marine terraced deposits

These deposits consist of different lithostratigraphic units ranging in thickness from a few to ten meters. Such deposits are separated by unconformity surfaces constituting marine abrasions surfaces on which they lie transgressively and with an onlap geometry.

Such units crop out at different altitude and with different extensions or in reduced limbs both on the Murge and in the Salento area, they essentially consist of coastal coarse-grained bioclastic carbonate sediments ranging from backshore to shoreface and open shelf environments. Recently these units have been grouped into a unique supersynthem named "Supersintema salentino" by Ciaranfi and Ricchetti (2013). The genesis of these marine terraces has been attributed by the Authors (Ciaranfi et al., 1988; Richetti et al., 1988; Ciaranfi and Ricchetti, 2013) to the strong interaction between the glacio-eustatic sea level changes and the coeval regional uplift affecting the Apulia foreland during the Middle-Late Pleistocene (Ricchetti et al., 1988; Doglioni et al., 1994, 1996). Ciaranfi et al. (1988) individuated sixteen terraced deposits placed at decreasing elevations from the inland to the coastal areas and highlighted how the distribution of these deposits was strongly controlled by pre-existing substrate morphology. On this basis they indirectly constrain the formation of these marine terraces to an interval of time comprised between the late Sicilian and the present (the last 750 kyr).

More recently a detailed study has been conducted on the marine terraces of the Salento Ionian coast (De Santis et al., 2021, with references therein). These Authors applying the synchronous correlation technique and the amino acid racemization, have refined with more detail the Middle-Late Pleistocene terrace phases and the uplift history of this sector of the Apulia region, proposing two possible hypotheses of evolution that could explain the geomorphological evolution of the area. The first hypothesis indicates an uplift rate of 0.15 mm/yr between 590 and 130 kyr BP (Middle Pleistocene, between MIS 15 and 6), and an uplift rate of 0.7 mm/yr from 130 kyr BP to the present (Late Pleistocene/Holocene, between MIS 6 to 1). The second hypothesis considers a constant uplift rate of about 0.12 mm/yr for the entire period of the Middle-Late Pleistocene. The Authors also individuate six positions of the paleoshorelines, developed during the highstand phases that were dated to 119 kyr BP (MIS 5.5 second peak), 125 kyr BP (MIS 5.5 first peak), 240 kyr BP (MIS 7.5), 340 kyr BP (MIS 9.3), 478 kyr BP (MIS 13.1), for the first and second hypothesis. The latter different in age for the oldest paleoshoreline, being 560 kyr BP (MIS 15.3) for the first hypothesis and 550 kyr BP (MIS 15.1) for the second hypothesis respectively. De Santis et al. (2021)

highlighted that the number of preserved paleoshorelines is controlled by the uplift rates and by the preservation capacity of these deposits, considering the probable cannibalization and re-occupation of the areas from the younger sea level highstands over the older sea-level highstands.

3. DATA AND METHODS

3.1. WELL DATA

The stratigraphic architecture and paleogeography of the Salento Peninsula during the Cenozoic was reconstructed through field observations and utilizing a database of 350 wells (total depth variable from 30 to 220 m) collected by public administration and private companies, which are well-distributed on the peninsula, covering an area of about 2500 km^2. All the wells have provided a description of the stratigraphy and lithological and textural information. Among these, the deepest and more representative wells of the subsurface sedimentary succession (140 wells), covering the entire study area, were chosen for the construction of thirteen correlation panels (nine WSW-ENE and four NNW-SSE oriented) to depict the present stratigraphic-structural setting of the investigated area (Fig. 19, 20a, 20b, and 20c). Each well was geolocated using the Qgis software; later, following manual correlation and interpretation we built the correlation panels using Lithotec 5000 software. For further stratigraphic control, we also utilized all the well's stratigraphic descriptions,closest to those used for the construction of the correlation panels.

In order to assess the Cenozoic stratigraphic evolution of the Salento peninsula, we applied the flattening procedure to the correlation panels, by using as datum planes the tops of all the formations from Oligocene to Pleistocene: 1) Galatone Formation and the heteropic Castro limestone and Porto Badisco calcarenite (upper Oligocene), 2) Lecce formation (upper Oligocene-Lower Miocene), 3) Pietra leccese (Lower-Upper Miocene), 4) Andrano Calcarenite (Upper Miocene), 5) Leuca Formation (Upper Miocene-Lower Pliocene), 6) Uggiano la Chiesa formation (Lower Pliocene-Lower Pleistocene), 7) Gravina Calcarenite (lower Pleistocene), 8) Argille Subappennine (Lower-Middle Pleistocene). This procedure was not applied to the Eocene deposits due to their reduced thickness and to their small areal distribution. This flattening procedure allowed to remove the effects of the tectonic deformation subsequent to the datum plane. In this way, it was possible to construct 117 correlation panels showing what would have been the original stratigraphic relationships among the different stratigraphic units over time. Finally, these panels were utilized to produce eight paleogeographic schemes of the Salento Peninsula, from the Oligocene until the Pleistocene, by using a 3D modeling software (Move 2017). Each scheme is linked to each stratigraphic unit and shows the areal extension of the emerged and submerged sectors during its deposition (Figs. 22, 23, 24, and 25). We also produced the maps of the Cretaceous substrate at the time of deposition of each stratigraphic unit (Fig. 21).

The data of the seismic profiles allowed us to extend for same formations the investigated area to the offshore, both in the Adriatic and Ionian sectors (Figs. 35, and 36).

The correlation panels, together with the paleogeographic schemes and the general stacking pattern of the entire Cenozoic sedimentary succession, allowed also to produce a sequence-stratigraphic scheme of the Salento Peninsula, where we recognized composite and simple high- and low-rank depositional sequences (Fig. 37)

3.2. FIELD DATA

Although well and seismic data were used for the stratigraphic and paleogeographic reconstructions of the Salento area in subaerial and submerged sectors respectively, a local geological survey with measurements of stratigraphic sections of some formations (Altamura limestone, Castro limestone, Porto Badisco calcarenite, Galatone Fm., Pietra leccese, Gravina Calcarenite and Argille Subappennine) in different points of the Salento area was also carried out. The facies analysis of these formations was beyond the scope of this thesis; nevertheless, the field data were very useful to clarify some stratigraphic relationships between the different formations, moreovera sampling of the same units was carried out in order to obtain measurements of porosity and mineral composition and, consequently the velocity-porosity relations in the sampled formations to be compared with those measured in an exploration well occurring in the Adriatic area (Giove 002).

3.3. LABORATORY DATA

In order to obtain velocity-porosity relations and to compare them with those derived by the well Giove 002, five lithostratigraphic units were sampled: Altamura limestone, Castro limestone, Porto Badisco calcarenite, Pietra leccese, and Argille Subappennine. The samples were cut with a drilling machine to obtain cylinders of standard dimensions. The porosity of each sample was measured with the Helium Pycnometer and successively the measurement of Vp and Vs waves was carried out with the tool Mystras Eurovision. The Vp and Vs waves were measured in 3 different directions on the samples, namely along the X, Y and Z axes and it was possible to verify the velocity differences due to the characteristics of the rocks, such as texture and distribution of the pores.

3.4. SEISMIC DATA

The seismic profiles utilized in this thesis were derived from the publicly available Italian national database ViDEPI (www.videpi.com)(71 seismic lines already processed) and from the ENI oil company, which made 19 seismic profiles available (Fig. 26). All these seismic profiles have a very poor definition and low resolution, consequently these profiles were used to investigate the shallower horizons. Initially, these profiles were converted from PDF to SEG-Y format utilizing the program MATLAB 2020b, through the code image2segy. This allowed an easier and more accurate interpretation, while their geolocalization was possible by using the 3D modeling softwares MOVE and Petrel.

Only a few seismic profiles, the F76-16, F75-49, and D-476A intercepted three exploration wells, Giove 002, Lieta 1, and Merlo 1 respectively (Figs. 25, 26, 27, 28, 29 and 30), which were used to calibrate the main reflectors. Consequently, the interpretation of seismic profiles was made in time after the conversion from depth to time of the wells Giove 002, Lieta 1 and Merlo 1, by using the software Petrel 2017.the time-depth conversion of the 90 seismic profiles was made after their interpretation. For this purpose, it was important to know the interval velocities of the main formations that were extracted from the sonic log of the Giove 002 well (Table 1). The interval velocities calculated from the sonic log, represent the real velocity of Vp waves in situ; successively they were compared to those ones obtained from the laboratory samples taken from the single formations (Table 2). Once the time-depth conversion was completed, five main horizons were defined and utilized to construct a 3D model from which was derived some paleogeographic settings of the Salento peninsula submerged sector. Anyway, using some of the correlation panels on land, and their continuation with some seismic profiles (Fig. 32), it was possible to produce eight land-sea correlation panels, four SW-NE oriented and four NW-SE oriented (Figs. 33 and 34) that show the sequence stratigraphic framework of the Salento sedimentary succession.

Seismic Unit	Interval Velocity (m/s)
Water	1500
Seismic Unit 5 (Pleistocene-Holocene)	1800
Seismic Unit 4 (Upper Pliocene)	1975
Seismic Unit 3 (Lower Pliocene)	1975
Seismic Unit 2 (Oligo-Miocene)	4700
Seismic Unit 1 (Cretaceous)	5100

Table 1 - Velocity model derived from the Giove 002 sonic log.

Seismic Unit	Interval Velocity (m/s) Giove 002 well	Interval Velocity (m/s) Laboratory
Water	1500	1500
Seismic Unit 5 (Pleistocene-Holocene)	1800	1950
Seismic Unit 4 (Upper Pliocene)	1975	2100
Seismic Unit 3 (Lower Pliocene)	1975	2100
Seismic Unit 2 (Oligo-Miocene)	4700	4975
Seismic Unit 1 (Cretaceous)	5100	5700

Table 2 - Comparison between the velocity model derived from the Giove 002 sonic log and the velocity model derived from the measurements on the samples of the lithostratigraphic units.

3.5. CLIMATIC INFLUENCE AND EUSTATIC SEA-LEVEL CHANGES

The period of time (last 65 Ma) during which the discontinuous carbonate sedimentation interested the inland, margins and currently submerged portion of the Salento Peninsula, was characterized by deep climatic changes associated with fluctuations of global mean sea level (GMSL) of different frequency and amplitude (Fig. 18).

In fact, during the Cenozoic, changes in climate, and CO_2 concentrations marked the transition from a warm greenhouse long-term global climate characterized by high values of atmospheric CO_2 and ice-free conditions to a cold icehouse with low atmospheric CO_2 concentrations and large extension of ice sheets and ice caps (Zachos et al., 2001a, b; Bohaty and Zachos, 2003; Miller et al., 1991; 2011, 2020; De Vleeschouwer et al., 2017 and references therein).

Numerous data derived by several Authors in the years have evidenced the following points (see figure 18).

1) The hothouse Early Eocene (56.0-47.8 Ma) was characterized by peak warmth, peak sea levels, and high CO_2 concentrations suggesting mostly ice-free conditions (Lowenstein and Demicco, 2006; Foster et al., 2013). Nevertheless, at least four global sea-level falls of ~ 15 to 30 m are recorded and considered related to ice-volume increase (Miller et al., 2020).
2) The Middle Eocene was characterized by optimum climatic conditions (Middle Eocene Climatic Optimum, MECO; Zachos et al., 2001), which led the Earth to be almost completely free of ice. Sea level changes of 15 to 40 meters occurred during the Middle to Late Eocene as a result of the growth and collapse of small ice sheets, which led to the final phase of deglaciation during the Late Eocene (Fung et al., 2019; Miller et al., 2020).
3) The most important and most impacting climatic event occurred at the transition between Eocene and Oligocene (EOT) (the Oi1 event; Miller et al., 1991; Zachos et al., 1996; 2001) with the passage from warm greenhouse to cold icehouse conditions due to the development of the Large Antarctic Ice Sheets, which led to a minimum sea-level fall ~ 50 m. From the Oligocene to Early Miocene large-ice volume variations

occurred giving rise to sea-level changes of ~ 50 to 60 m (Coxall et al., 2005; Miller et al., 2020); in particular, sea-level falls of ~ 25 m and ~ 50 m are estimated at 33.9 and 33.65 Ma (Rupelian) respectively, that were followed by a sea-level rise of ~35-44 m at ca. 32 Ma (Boulila et al., 2011). The Oi2 event (passage from Rupelian to Chattian and the Mi1 event (passage from Chattian to Aquitanian) produced sea-level falls of a similar amplitude of the Oi1 with a sea-level rise of 30-40 m in between, suggesting phases of expansion and retreat of the Antarctica ice sheets with 1.2 Ma cycles (Boulila et al., 2011; Miller et al., 2020).

4) The Middle Miocene Climatic Optimum (MMCO) between 17.0 and 14.8 Ma (Holbourn et al., 2013) was in general characterized by small sea-level changes (< 20 m), with the only exceptions of the Mi2 (16.0 Ma), Mi3a (14.8 Ma), and Mi3 (13.8 Ma) events during which falls of sea-level of ~ 40 m, ~ 30 m, and ~ 50 m respectively occurred.
5) Starting from the MMCO three main cooling phases Mi3a (14.8 Ma), Mi3 (13.8 Ma), and Mi4 (12.8 Ma) with sea-level falls of ~ 30 m, ~ 50 m, and ~ 20-30 m respectively occurred, all related to the grew and permanent presence of the East Antarctic Ice Sheet (Kennett, 1977). All the literature data suggest that the sea level in the late Middle to Late Miocene remained surprisingly steady, rarely exceeding 20 m above the present, and only a fall of - 30 m occurred at ~ 8.2 Ma (Miller et al., 2020). Dominant sea level cyclicity was the 41-ka tilt (De Vleeschouwer et al., 2017) that persisted during the Messinian Salinity Crisis with little sea-level change.
6) During the Early Pliocene (about 5.33 to 3.60 Ma), the amplitude of Milankovitch-driven sea-level oscillations increased, with progressively greater peak sea levels above the present one of about 10 to 20 m. The Pliocene Climatic Optimum (PCO) was reached during the interval 3.3-2.85 Ma (Late Pliocene) (Dowsett et al., 1999; Raymo et al., 2018) with a sea-level peak of ~ 20 m above the present one ca 3.0 Ma (Miller et al., 2012; Dumitru et al., 2019). Such sea-level fluctuations were strongly controlled by the growth and decay of the East Antarctic and Northern hemisphere ice sheets.

7) The greatest variations in the sea level amplitude were reached within the last 2.7 Ma (Quaternary), due to the growth of the large Northern Hemisphere ice sheets. This was a continuous process punctuated by an increased number of glacial and interglacial periods (Shackleton et al., 1984; Miller and Wright, 2017; Miller et al., 2020; Jacob et al., 2020) with sea-level lowering reaching 120–130 m below present. The cyclicity associated with the 41-ka tilt forcing characterized the sea level fluctuations (20-50 m) from 2.5 Ma to 1 Ma, whereas sea level changes up to 130 m below the present and with cyclicity of 100-ka have been dominant in the last 800 ka. In the same period, sea level lowering of 10 to 60 m was related to the precessional (19 and 23 ka) and tilt (41 ka) scale (Miller et al., 2020).

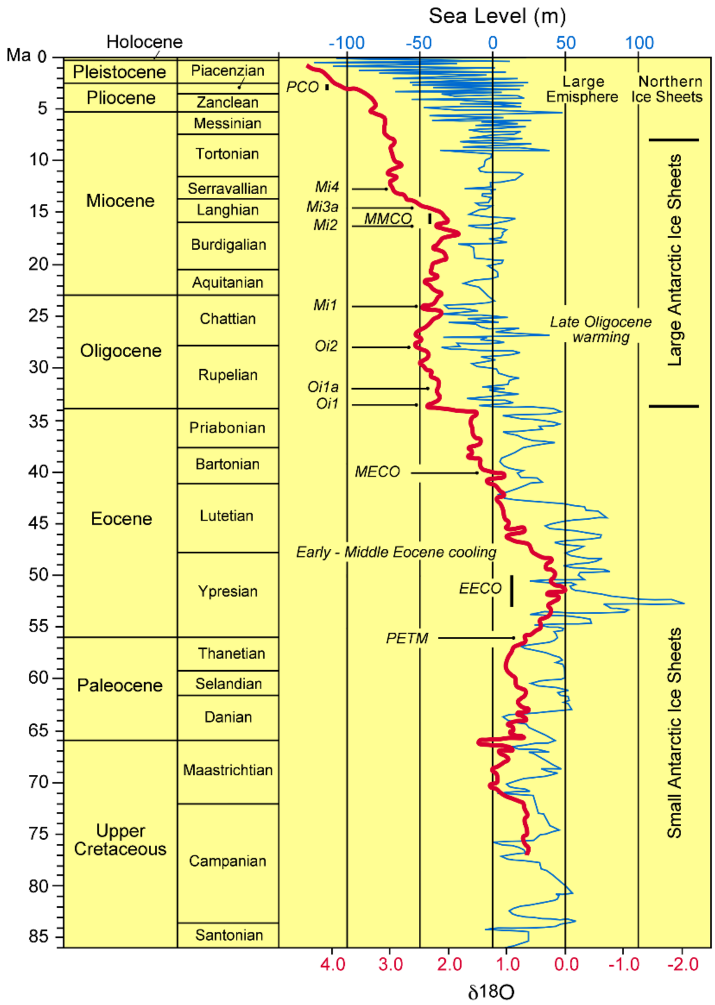


Fig. 18 - Sea level record for the past 85 million years derived by the New Jersey continental margin (see Miller et al., 2011 with references therein) with a synthesis of the oxygen isotopic record of Cramer et al. (2009). The main climatic events are also reported. PETM (Paleocene-Eocene Thermal Maximum); EECO (Early Eocene Climatic Optimum); MECO (Middle Eocene Climatic Optimum); MMCO (Middle Miocene Climatic Optimum); PCO (Pliocene Climatic Optimum). Redrawn and modified from Miller et al. (2011).

4. RESULTS

4.1. CORRELATION PANELS AND PALEOGEOGRAPHIC SETTING FROM WELL DATA

For the land sector of the Salento Peninsula 140 wells were utilized for the construction of 117 correlation panels, 29 of which are presented in this study to show the stratigraphic-structural relationships among the lithostratigraphic units forming the framework of the Salento Peninsula starting from the end of the Cretaceous to the present. These units, which are separated by erosional surfaces, are only partially superposed on each other. They crop out with a reduced thickness and number in the internal sectors of the Peninsula and with a greater thickness and number along the south-eastern coast. In general, the stratigraphic record is more complete, but still discontinuous, on the eastern side of the Peninsula (Adriatic) with respect to the western side (Ionic). This stratigraphic architecture conditioned the construction of the correlation panels and the paleogeographic schemes showing the articulated morphology of the Cretaceous substrate (Altamura limestone) (Fig. 21), at the time of deposition of each stratigraphic unit, starting from the upper Oligocene to the present. Paleocene deposits are neither present in the subsurface, nor in outcrop, whereas the Eocene ones are found in outcrop and for a reduced thickness only along the coastal eastern margin of the peninsula. In figures 19 and 20a, b, and c are reported the tracks of the correlation panels (those with Arab numerals are ENE-WSW oriented and those with Roman numerals are NNW-SSE oriented) and the current stratigraphic-structural setting, while in figures 22, 23, 24, and 25 are reported the paleogeographic schemes and the correlation panels.

These show, respectively, the emerged and submerged areas and the stratigraphic-structural setting of each considered formation at the time of its deposition. The figure 21 shows the maps of the Cretaceous substrate at the time of deposition of each stratigraphic unit.

4.1.1. The present stratigraphic-structural setting

Panel 1 (Fig. 20a) shows the Cretaceous substrate affected by some normal faults that have produced a small and tabular depression in the central portion, which contains reduced thicknesses of the Pleistocene Gravina Calcarenites, Argille Subappennine and marine terraced deposits. A relatively similar situation is also found in panel 2 (Fig. 20a), although two structural depressions are present in the western and eastern sectors. The latter are well-developed in panel 3 (Fig. 20a) and filled with the Miocene Pietra leccese and Andrano Calcarenite. The faults movement is sealed by the subsequent deposition of the Pleistocene units.

Panel 4 (Fig. 20a) shows a more articulated stratigraphic setting with a western sector where the Cretaceous substrate crops outs with a thin cover of Oligocene and Miocene deposits and the central and eastern sectors characterized by the presence of a faulted and deep structural depression filled with the Oligocene and Miocene units. The pinch-out geometries shown by the deposits indicate that the sedimentation was coeval to normal faulting whose activity continued up to the Pliocene along the Adriatic coast and up to the Pleistocene in the central sector of Salento Peninsula.

Panel 5 (Fig. 20a) further differs from the previous one and shows an elevated fault block in the central portion of the panel where the Cretaceous substrate is covered only by the Gravina Calcarenite, and with two deep structural depressions on the eastern and western sides filled with units ranging in age from the middle Chattian to the Pleistocene.

Panel 6 (Fig. 20b) shows, on the eastern side, the continuation of the structural depression found in panel 5. This structure, active since the early Chattian, continued to deepen until the lower Pleistocene. In the central and western sectors, the Cretaceous substrate generally appears very superficial. Above, the deposits of the Pietra leccese and, sporadically, the Gravina Calcarenites and the Argille subappennine are present with very reduced thickness. This raised area of the Cretaceous substrate represents the northernmost portion of the Serre Salentine.

Panel 7 (Fig. 20b) shows a very articulated structure with the Cretaceous substrate interested by several normal faults with ten to hundred meters of displacement. The western and eastern depressed sectors are always recognizable and filled with Miocene to Middle Pleistocene deposits. The Cretaceous substrate crops out in the central sector forming a well-pronounced horst (Serre Salentine) on the sides of which the Middle-Upper Pleistocene deposits onlap.

Panel 8 (Fig. 20b) like panel 7 shows a strongly articulated geometry with several normal faults forming a classic horst and graben structure. The grabens are some hundred meters deep and are mainly filled with deposits of variable thickness having age between the early Miocene and the Pleistocene. Single horsts of the Cretaceous substrate are representative of the Serre Salentine.

Panel 9 (Fig. 20b) although of smaller extension, shows the same geometric characteristics as panel 8. The more depressed central sector hosts the greater thicknesses of Pietra leccese and Gravina Calcarenite. The western sector is characterized by the presence of the Cretaceous horst attributed to Serre Salentine.

Panel I (Fig. 20c) extend along the Salento Ionian coast and shows a horst and graben structure of the Cretaceous substrate. A graben is more pronounced in the northern sector and hosts deposits from the Oligocene to the Early Pleistocene in age.

Panel II (Fig. 20c) has the northern sector where the Cretaceous substrate crops out that is covered by a very thin thickness of more recent deposits. Moving south the Cretaceous substrate deepens thanks to a series of normal faults with pronounced displacement and is covered by deposits ranging in age from the Middle Miocene to the Middle Pleistocene.

Panel III (Fig. 20c) shows a structural setting similar to panel II. Towards the south, the stratigraphic architecture is more complex and characterized by a horst and graben structure, with several high-angle normal faults having displacements of several tens of meters. Grabens are filled with deposits ranging in age from the Oligocene to the Early Pleistocene.

Panel IV (Fig. 20c) is located on the Adriatic coast and shows a structural setting characterized by a faults system with a similar orientation to those recognized in the previous panels whose displacement deepens the Cretaceous substrate moving from north to south. Consequently, the thickness and the age of the units filling such structural depression increase from north to south, a fact that is consistent with the stratigraphic data indicating a progressive transgression of the deposits from the Oligocene to the Miocene.

Fig. 19 - Location of the wells (black-red points) and tracks of the correlation panels of figures 20a, b, c.

4.1.2. The paleogeographic setting of the different lithostratigraphic units

The reconstructed paleogeographic schemes of the investigated area cover a time interval from the Oligocene to Pleistocene and are referred to: 1) Galatone Formation and the heteropic units of the Castro limestone and Porto Badisco calcarenite; 2) Lecce formation; 3) Pietra leccese; 4) Andrano Calcarenite; 5) Leuca Formation; 6) Uggiano la Chiesa formation; 7) Gravina Calcarenite and 8) Argille Subappennine (Figs 22, 23, 24, and 25).

The oldest formation is the Cretaceous Altamura limestone which is tectonically tilted although at places it is horizontal or inclined seaward or landward. The Torre Tiggiano limestone (Middle Eocene) shows a structural attitude like the Cretaceous substrate on

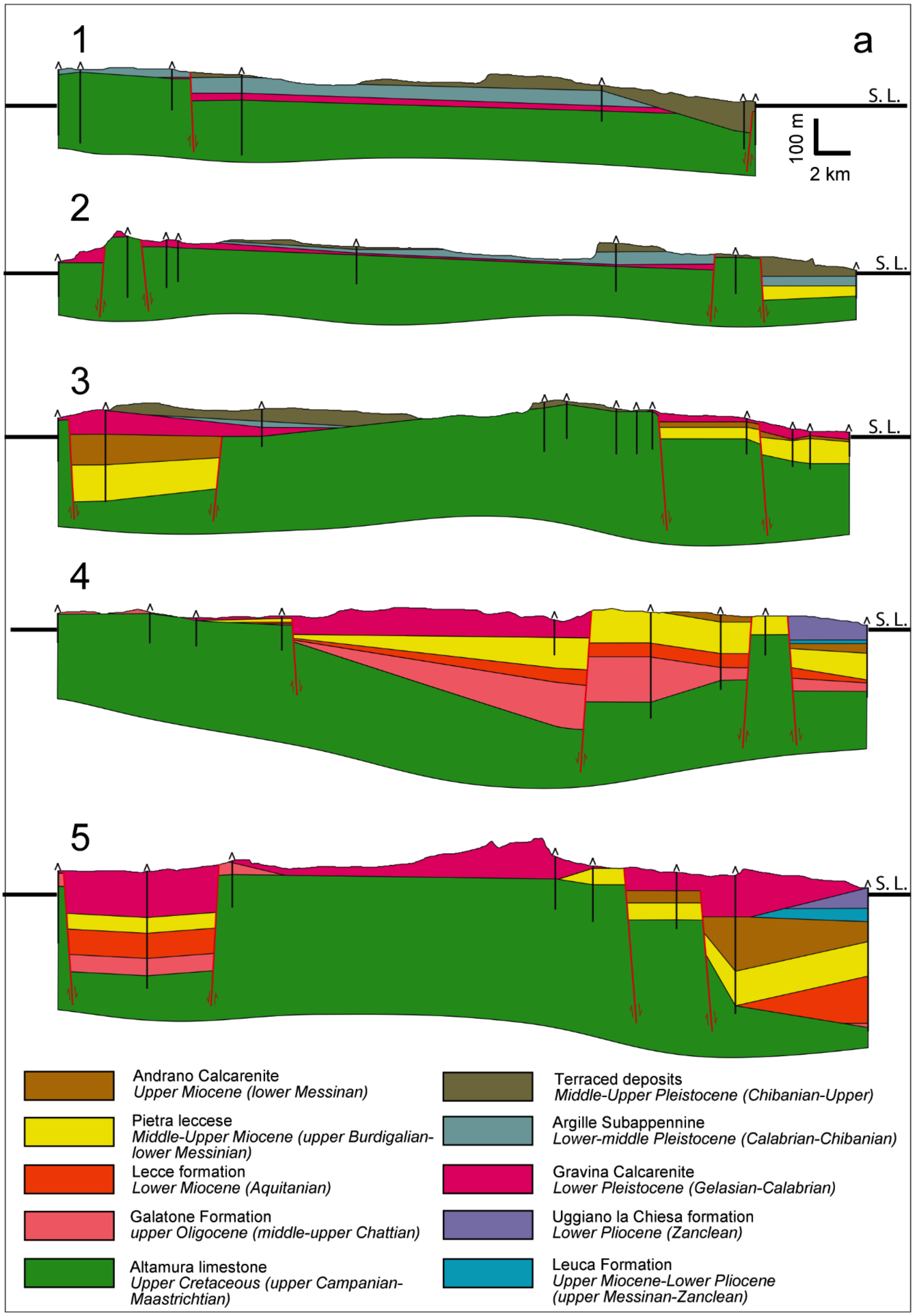


Fig. 20 - a, b) Correlation panels WSW-ENE and c) NNW-SSE oriented showing the present stratigraphic and structural setting of the lithostratigraphic units forming the backbone of the Salento Peninsula.

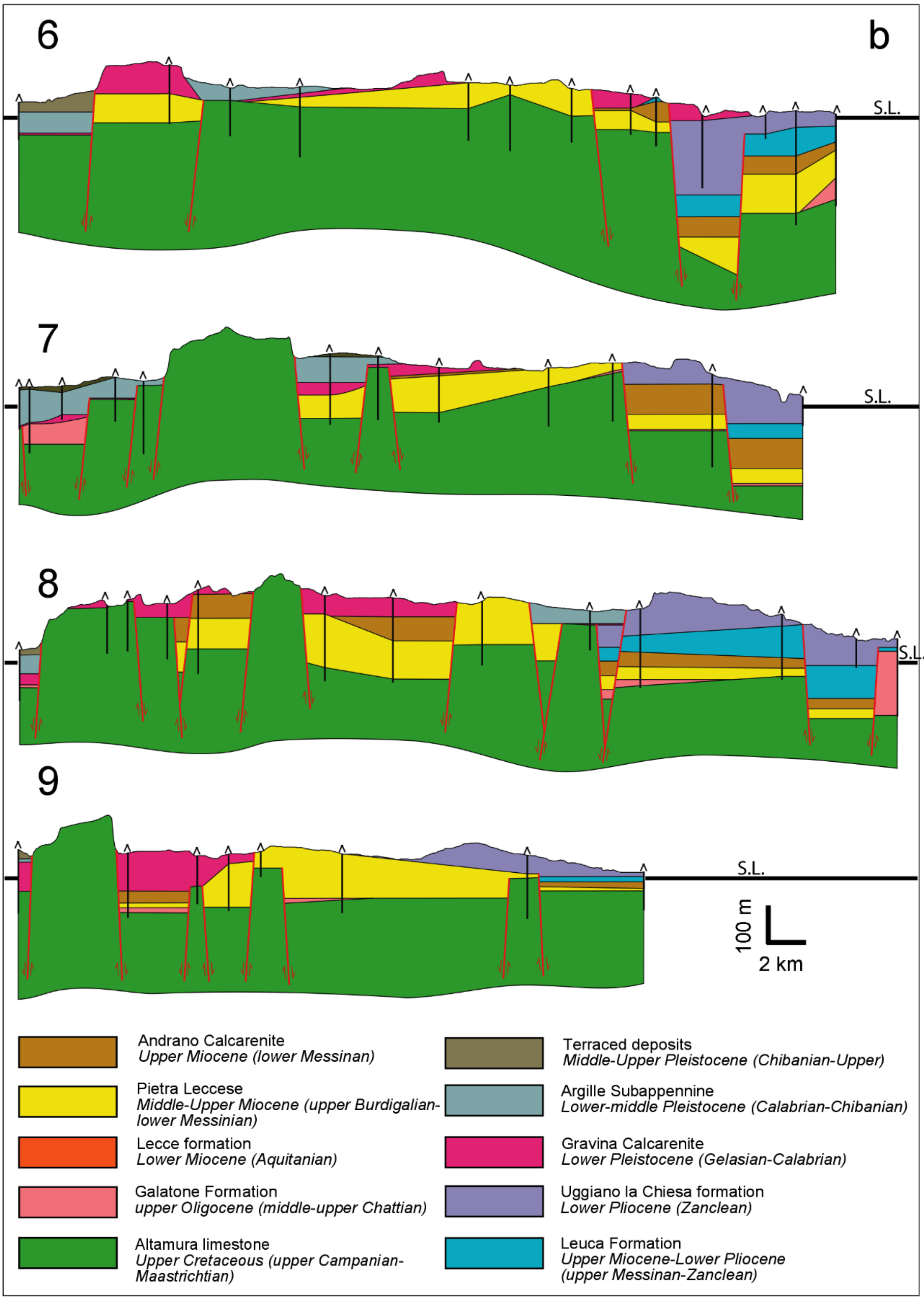


Fig. 20 – continued.

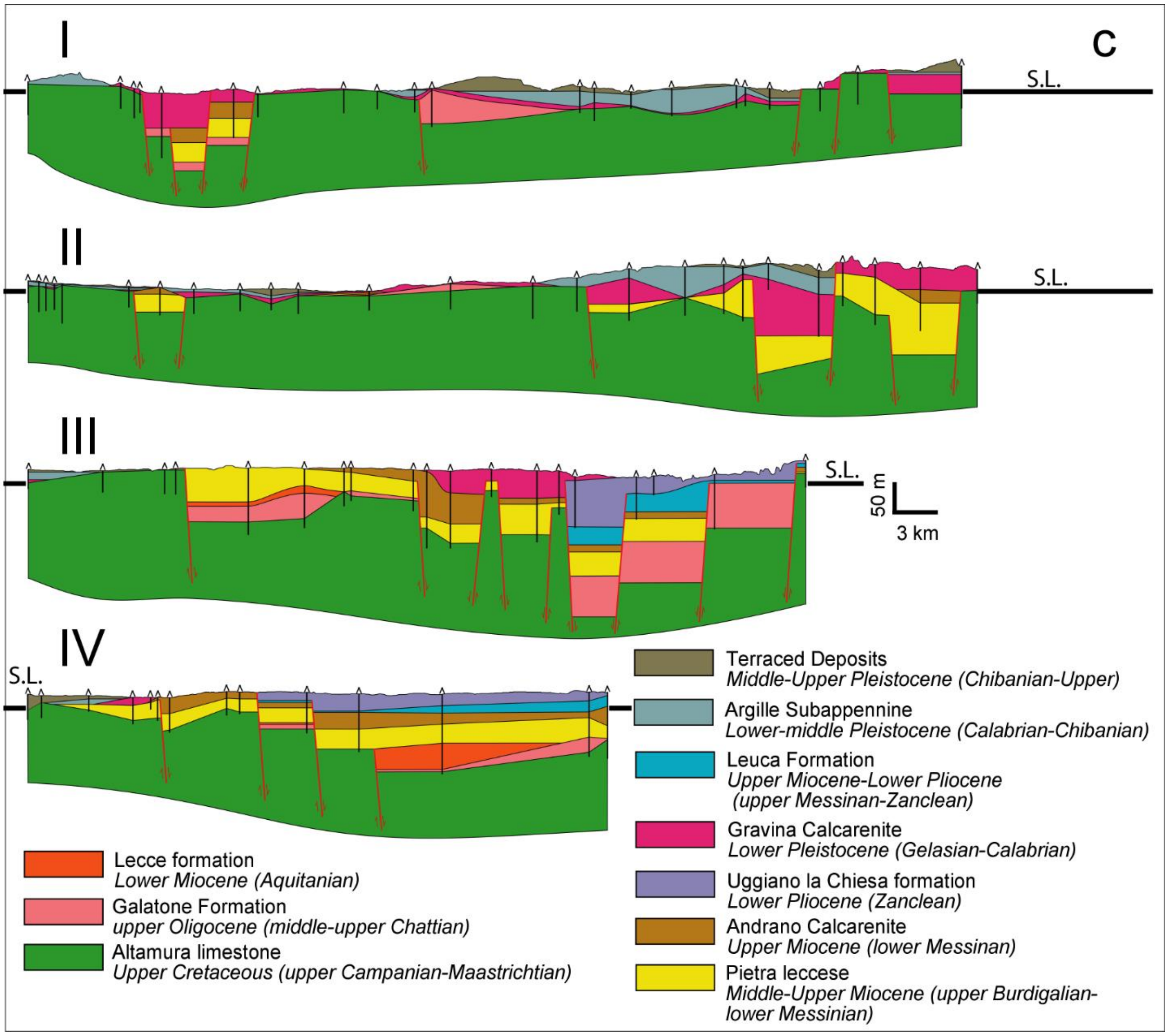


Fig. 20 – continued.

which it lies through a strongly discordant erosional surface. This unit that is constituted by bioclastic sands probably formed a rather continuous belt along the entire eastern coast of Salento. It was deposited in a shallow-water high-energy wave-influenced environment, affected by rework and transport by currents (Bosellini et al., 1999; Tomassetti et al., 2016). The second unit of the Eocene age is represented by the Priabonian Torre Specchia la Guardia limestone. This formation constitutes a clinostratified wedge which lies on Cretaceous or Middle Eocene platform deposits through an angular unconformity (Bosellini et al., 1999). These last Authors interpret these sediments as forereef slope facies and do not recognize internal platform facies. It was impossible to produce a paleogeographic scheme for the Eocene deposits due to the scanty and discontinuous outcrops.

The paleogeographic scheme depicting the study area at the time of deposition of the Galatone Formation (Upper Oligocene) shows two well-differentiated emerged areas separated by a shallow-water seaway forming a restricted lagoon/lacustrine environment, connecting the Adriatic and Ionian sectors of the Salento Peninsula (Fig. 22a). This unit sedimented in this seaway and prevalently along the eastern sector of the Peninsula (see also Esu et al., 2005; Bossio et al., 2009) where it laterally passes seaward to the units of the Castro limestone and Porto Badisco calcarenite (middle-upper Chattian in age) (Fig. 7). Similarly, to the latter units, the Galatone Formation lies unconformably on Cretaceous substrate from which it is locally separated by a thick (17 m) bed of residual red clay. Besides as revealed by the stratigraphy of deep wells, such unit can be subdivided into a lower and upper portion (about 50 and 20 m thick respectively), being its lacustrine/lagoonal carbonate deposits separated by a 5 m thick residual clay bed (see Bossio et al., 2006a). We proposed that this deposit formed during the emersion and subsequent erosion responsible for the formation of the unconformity surface separating the Castro limestone and the Porto Badisco calcarenite.

The Castro limestone is separated from the underlying Eocene and Cretaceous deposits by a major unconformity. This unit was interpreted as a fringing reef complex with depositional facies ranging from back reef to reef slope by Bosellini et al. (1999) and Bosellini (2006), and as deposited along distally steepened ramp by Pomar et al. (2014). Based on our paleogeographic scheme and considering the stratigraphic relationships with the Galatone Formation and with the Eocene-Cretaceous substrate, the model of the fringing reef complex of the Castro limestone recently well-documented by Bosellini et al. (2021), results more appropriate respect to the Pomar et al. (2014) model. The presence of seagrass meadows, as evidenced by these last Authors and their landward passage to the lagoonal/lacustrine facies of the Galatone Formation is not in contrast with the environmental context suggested by Bosellini et al. (1999), Bosellini (2006), and Bosellini et al. (2021), considering that seagrasses (growth and productivity) may coexist and interact with the coral reefs as they served as nurseries and shelter for reef fish and for other species of organisms (Björk et al., 2008; Carlson et al., 2021).

The Porto Badisco calcarenite is separated by the underlying Castro Limestone by an erosional unconformity whose physical expression has been also recognized in the Galatone Formation (see previous discussion) (Fig. 7). The depositional model of Porto Badisco calcarenite proposed by Pomar et al. (2014) includes a homoclinal carbonate ramp where six lithofacies distributed from the inner to the outer ramp have been recognized, and where the Authors did not observe any slope break. In particular, the inner ramp would have been characterized by wackestone/packstones with small benthic foraminifers suggesting the presence of seagrass meadow. The middle ramp would be dominated by packstones with large rotaliids and small coral mounds interfingering basinwards with rhodolythic floatstones/rudstones and large lepidocyclinids packstones. The outer ramp would have been characterized by the presence of fine calcarenites rich in skeletal debris fragments that derive from the inner and middle ramp. Pomar et al. (2014) (see also Tomassetti et al., 2018) explain the distribution of these lithofacies along their "homoclinal ramp" as a result of a hydrodynamic setting essentially due to the propagation of internal waves. According to these Authors, this ramp system does not show the characteristics of a wave-dominated system that can explain events with high turbulence capable of eroding, redistributing, and depositing coarse-grained deposits (their four lithofacies, rhodolithic floatstone to rudstone) located in the middle ramp sector. Although the Authors describes this lithofacies assemblage very well, it is not excluded that this assemblage can be explained also with the revised ramp model proposed by Moscariello et al. (2018), where the passage from the middle to the outer ramp takes place through a ramp slope with a very low gradient. Here the rhodolithic floatstone to rudstone lithofacies would accumulate, forming lobate deposits filling erosional depressions, the deposition of which would take place because of storm currents that would transfer sediments from the inner ramp to the ramp slope/outer ramp through density flows in supercritical conditions. This is beyond the scope of this work. Instead, we can observe that the passage from the Castro limestone to Porto Badisco calcarenite marks the evolution from a carbonate system with a well-developed fringing reef complex, typical of a flat-topped rimmed platform, to a carbonate ramp system where the production of sediment and the increase in the diffusion of transported sediment play a fundamental role in controlling the geometry of the platform (see discussion in Williams et al., 2011). Regarding this latter aspect, the formation of the ramp systems would be favored during phases of relative sea level rise which would tend to move the places of sediment production by distributing them along the depositional profile, thus favoring the development of carbonate ramps with a low gradient. The transgressive character that both the upper portion of the Galatone Formation (see Bossio et al., 2006a, b) and the heteropic Porto Badisco calcarenite show on the vertical section is consistent with this type of interpretation and with the transgressive trend that continues even with the deposition of the subsequent units, represented by the Lecce formation and by the Pietra leccese respectively.

The paleogeographic scheme at the time of deposition of the Lecce formation (Fig. 22b) is similar to that of Galatone Formation having always a well-developed seaway connecting the Ionian with the Adriatic sectors. The Lecce formation is constituted by marine deposits and lies unconformably on the lacustrine/lagoonal deposits of the Galatone Formation. As observed in the correlation panel (Fig. 22b), this unit is thicker in the eastern sector of the Salento Peninsula where it infills a series of structural depressions that continuously deepened during the sedimentation of this formation. The thickness of this unit tends to reduce westwards where it onlaps on the Cretaceous substrate and Galatone Formation. This is coherent with the general transgressive trend characterizing the late Upper Chattian/Lower Miocene deposits, indicating progressive landward flooding of the Salento Peninsula moving from the eastern to western sectors.

The transgressive phase from east to west is particularly evident in the paleogeographic scheme and in the correlation panels related to the Pietra leccese (Fig. 23a). Such formation was deposited during a long period of time (about 11 Ma, from late Burdigalian to early Messinian). It shows a maximum thickness of about 100 m in the eastern sectors, whereas westward the thickness tends to reduce and this unit onlaps directly onto the Cretaceous substrate (Fig. 23a). The reduced thickness of this formation with respect to the time span during which it was deposited can be explained by the presence of a series of disconformities marking significant physical and temporal gaps in the sedimentation. The paleogeographic scheme and the correlation panels show how the Salento Peninsula was almost completely submerged at that time. Exceptions are visible in the area north of Lecce, where subaerial conditions persisted, and in the south-western sector, where the Cretaceous substrate directly crops out (Serre Salentine). To the south and southeast, the Pietra leccese is widely represented by a phosphoritic hardground, known in the literature as "*Aturia* Level" (Vescogni et al., 2018 with reference therein), that constitutes an important sequence-stratigraphic element of the investigated area.

The last formation of late Miocene age, to which the paleogeographic scheme of figure 23b refers, is the Andrano Calcarenite; this unit, about 80 m thick, occurs in the subsurface and mainly crops out on the eastern side of the peninsula. It shows a regressive depositional trend and together with the underlying transgressive Pietra leccese formation constitutes a transgressive-regressive cycle closing the Miocene in the whole Salento Peninsula (see also Bossio et al., 2006a) at the top of which an important unconformity surface occurs that can be traced basin-wide in the Mediterranean area. The paleogeographic scheme (Fig. 23b) shows that the central portion of the Salento Peninsula was in subaerial conditions while the submerged areas of the platform were located along the present western, eastern and southern coasts. The edge of the eastern coast was characterized by the presence of a reef complex whose deposits, attributed to an informal lithostratigraphic unit named Novaglie formation (Bosellini et al., 1999; Bosellini, 2006), mantles discordantly the underlying Cretaceous to Oligocene formations. Such reef complex is exposed for about 17 km between Tricase Porto and Capo S. Maria di Leuca and was hosted within a paleo-embayment of the rocky coast. It is represented by a complete coral reef tract and the associated clinostratified fore-reef slope developed only locally (Bosellini, 2006). The stratigraphic relationships between the Andrano Calcarenites and the Novaglie formation have never been perfectly defined, although in the stratigraphic schemes of Bosellini et al. (1999) and Bosellini (2006) both units are considered heteropic. Although both these formations are early Messinian in age, our fieldwork and other stratigraphic considerations suggest a different stratigraphic relationship between these two units which will be discussed in the paragraph regarding the sequence stratigraphic framework of the entire sedimentary succession.

The paleogeographic scheme and the correlation panels related to the Leuca Formation (Fig. 24a) (Late Messinian-Early Pliocene) show the central sector of the Peninsula in subaerial condition and Ionian and Adriatic sectors submerged. This unit lies unconformably on the Andrano Calcarenites and the oldest formations, and occurs both in outcrop and in the subsurface along the Adriatic sector thus suggesting subsidence of this margin under the effect of the westward migration of the Dinarides-Albanides-Hellenides. This unit, as described previously, is characterized by a lower breccia/conglomerate member with carbonate clasts derived essentially from the underlying Andrano Calcarenite and an upper marly unit passing upward to a glauconitic mudstone (Bossio et al., 2006a).

The association of two very different members constituting the Leuca Formation has placed some problems in the interpretation. A possible explanation has been proposed by Ricchetti and Ciaranfi (2013) that attribute the breccia/conglomerates member as belonging to Andrano Calcarenite. Based on field observations and stratigraphic correlations, taking into account the age of microfauna occurring in the Leuca Formation (Bossio et al., 2006a), and in agreement with Bosellini et al. (1999), it is here suggested that the vacuolar limestone occurring at the base of the Leuca unit as well as the breccia/conglomerates member would represent the terminal portion of the Messinian and the lower boundary of the formation should be attributed to the Messinian Erosional Surface (MES) (Lofi et al., 2005). This surface marks the acme of the Messinian Salinity Crisis (Stage 2 of MES; CIESM et al., 2008; Roveri et al., 2014a, b) that was triggered by a combination of a Mediterranean tectonic phase related to the movements between the African and Eurasian plate, associated to climatic change (glacial period related to the TG14 and TG12 oxygen isotope stages). The combined action of these processes would have produced a relative sea-level fall, the magnitude of which is still under discussion (Roveri et al., 2016 and Manzi et al., 2018 indicate a fall of 100-200 m; up to 800 m it is suggested by Druckman et al., 1995; 800-900 m by Amadori et al., 2018, while Lofi et al., 2005 and Bache et al., 2009 indicate a fall of more than 1500 m) and the formation of large-scale mass wasting processes along the Mediterranean margins, leading to the accumulation of resedimented evaporites, carbonate and clastic deposits (Lofi et al., 2005; Roveri et al., 2008a, b; Bertoni and Cartwright, 2007; Gorini et al., 2015; Roveri et al., 2018). In this light, the breccia/conglomerate member of the Leuca Formation would constitute a slope-to-base-of-slope deposit formed during a lowstand phase representative of the Stage 2 and partially of the Stage 3 of the MSC, while the upper member of this formation would record the post-Messinian flooding of Pliocene age. However, this interpretation will be resumed later and contextualized in the sequence-stratigraphic scheme proposed for the Paleogene to Quaternary sedimentary succession of the Salento Peninsula. The figure 23b shows the paleogeographic reconstruction and the correlation panels of the Salento Peninsula during the sedimentation of the Uggiano La Chiesa formation (Lower Pliocene-Lower Pleistocene). These sketches show a paleogeographic setting similar to the previous one but with a more articulated coast. Such unit, onlapping on the Leuca Formation and locally on the older units crops out only along the eastern coast of the peninsula (see A-A' and B-B' panels, Fig. 24b); it is characterized by outer/inner shelf deposits at the base evolving upward to a shallower environment indicating a regressive depositional trend. In this context, the Uggiano la Chiesa formation constitutes the last unit recording a major influence of the Dinarides-Albanides-Hellenides on the sedimentation of the eastern coast of the Salento Peninsula. The paleogeographic reconstruction related to the sedimentation phase of the Gravina Calcarenite (Lower Pleistocene) (Fig. 25a) shows a clear depositional change of the Salento Peninsula compared to the previous one. The emerged areas were essentially localized along the eastern coast whereas the central and the western sectors were completely submerged. Such a setting shows a change in the geological evolution of Salento Peninsula that reflects the major influence of the eastward migration of the Apennine chain on the Apulian Platform foreland. In fact, the Gravina Calcarenite represents the opening of the Pleistocene sedimentary cycle on the western margin of the Apulian foreland and marks the progressive transgressive phase on an articulated substrate from the western sectors towards the eastern ones of the Salento Peninsula. Both the paleogeographic sketch and the A-A', B-B' panels shows a very articulated paleo-coast with the presence of well-developed bays. Based on the literature data (see Massari et al., 2001; D'Alessandro et al., 2004; Tropeano et al., 2004, 2022 with references therein) and considering the reconstructed paleogeography here presented, we suggest two different depositional setting of the Gravina Calcarenite in the Salento area (see also Bosellini et al., 1999).

The first hypothesis suggestsa well-developed shelf environment on the western side of the peninsula (essentially an inner shelf with depositional profile dipping southwestward), where seafloor was swept by bottom currents and episodic storm-driven flows. The vertical record of these deposits evidence a transgressive to regressive trend evolving from nearshore to inner/mid shelf and back to inner shelf. The progradational trend characterizing the upper portion of this unit is locally substituted by an aggradational stratal pattern that grade in the uppermost part in a low-angle progradational trend. On top this unit is present an unconformity surface that has been interpreted as a karstified subaerial surface (D'Alessandro et al., 2004).

The second hypothesis indicates a faulted rocky coast on the eastern margin of the peninsula forming an escarpment made up of older carbonate unit (from Cretaceous to Miocene) on which slope and base-of-slope deposits occurred (Tropeano et al., 2004, 2022; Mateu-Vicens et al., 2008). The latter developing within the morphostructural indentations of the cliffed coast consist of 25°/30°seaward dipping clinobeds forming isolated fan-shaped bodies. These bodies about 1 km wide and 40-50 m thick, were fed by a shallower carbonate factory characterized by a fossil assemblage dominated by coralline algae and subordinately by encrusting bryozoans, echinoids, and benthic foraminifers, which suggest the presence of seagrass meadows and deposition in a euphotic/mesophotic zone. Moreover, the high inclination and the internal architecture of the clinobeds suggest a more or less continuous formation of gravity flows as well as of slumps and other soft-sediment deformation that were probably triggered by syn-sedimentary tectonics (Tropeano et al., 2004, 2022; Mateu-Vicens et al., 2008).

The last paleogeographic reconstruction (Fig. 25b) refers to the Salento Peninsula during the deposition of the Argille Subappennine (Latest Calabrian-Early Chibanian). This unit lies conformably on the Gravina Calcarenite and reaches its maximum thickness in the Bradanic foredeep, whereas it is reduced to a few meters on the eastern sector of the Salento Peninsula. Two large gulfs opened to north and south occurred along the Ionian sector, where this unit fills the articulated morphology of the substrate inflecting westwards due to the load induced by the eastward migration of the Apennine chain (see correlation panels A-A' and B-B').

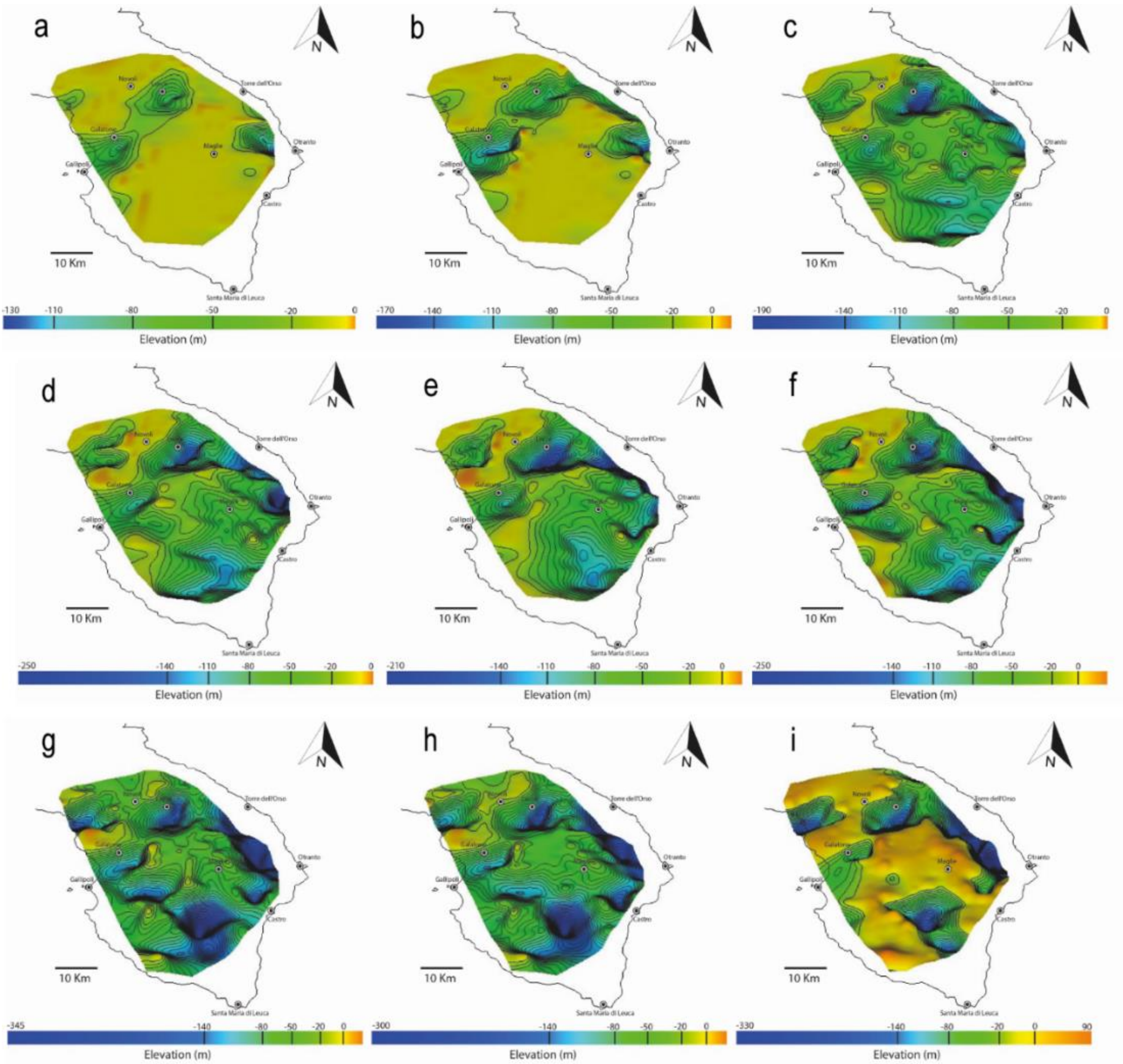


Fig. 21 - Maps of the Cretaceous substrate at the deposition time of each lithostratigraphic unit: a) Galatone Fm.; b) Lecce fm.; c) Pietra leccese; d) Andrano Calcarenite; e) Leuca Fm.; f) Uggiano la Chiesa fm.; g) Gravina Calcarenite; h) Argille Subappennine; i) Present.

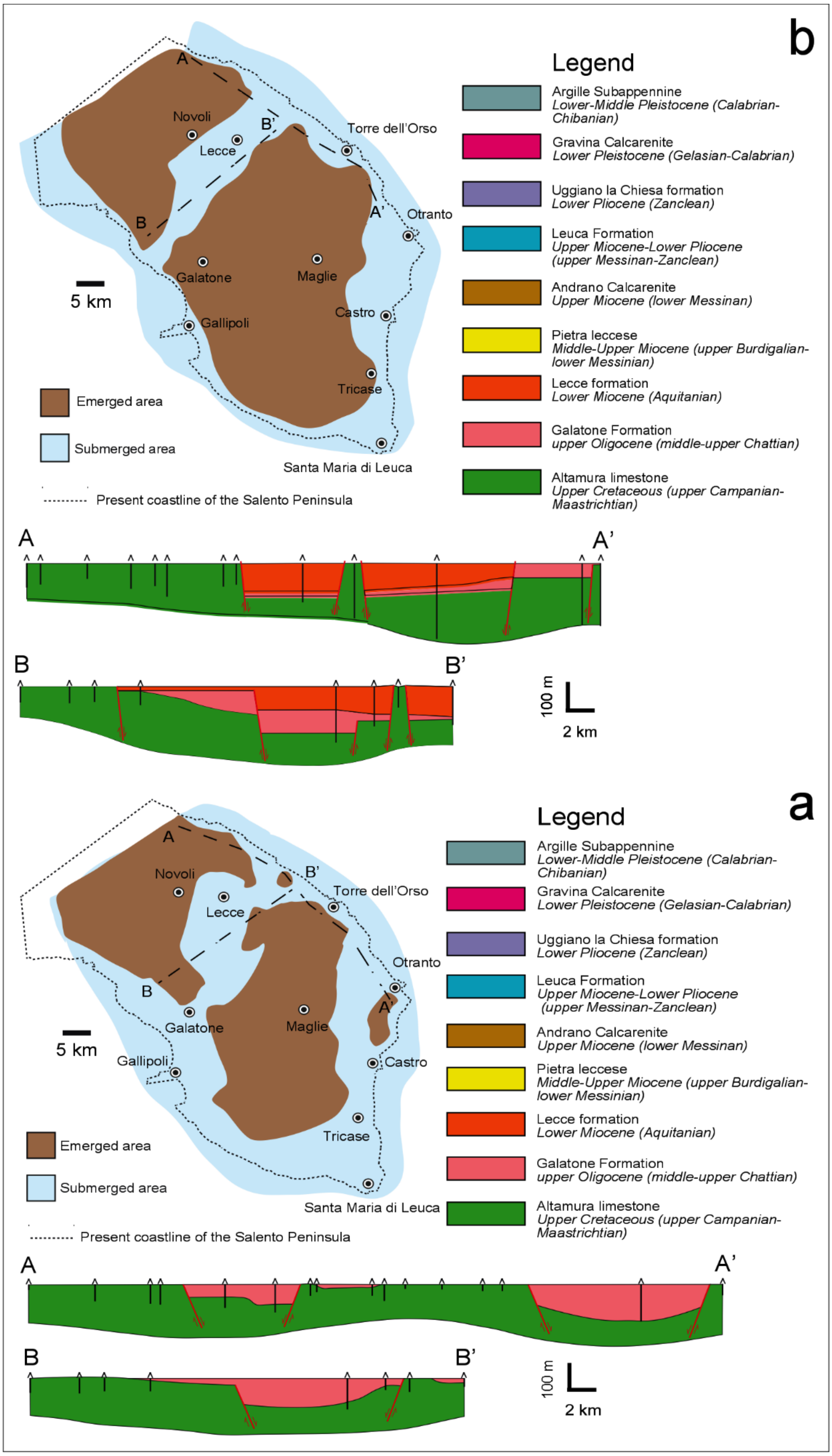


Fig. 22 - Paleogeographic setting and correlation panels at the deposition time of Galatone Fm. (a) and Lecce fm. (b) respectively.

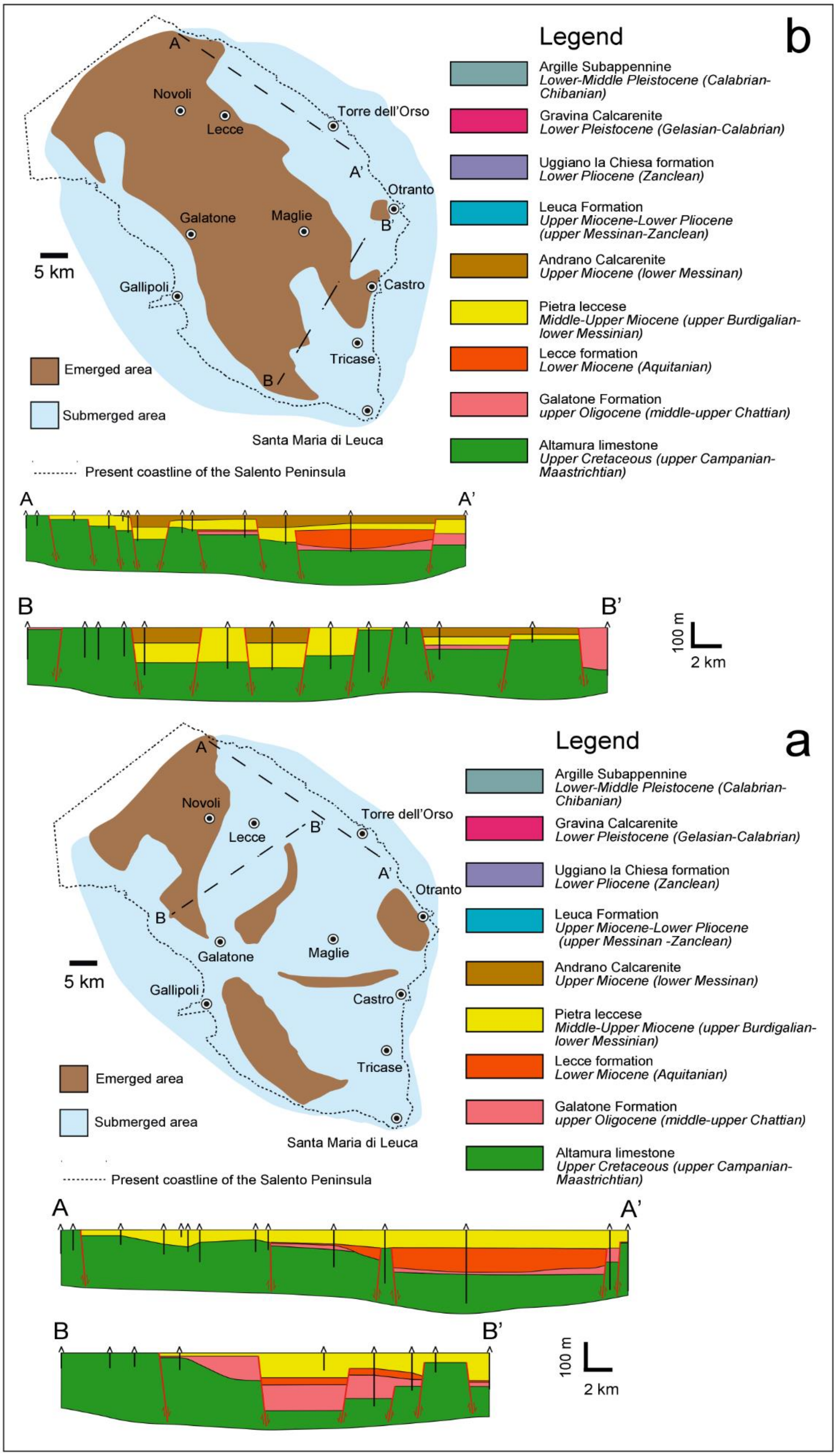


Fig. 23 - Paleogeographic setting and correlation panels at the deposition time of Pietra leccese (a) and Andrano Calcarenite (b) respectively.

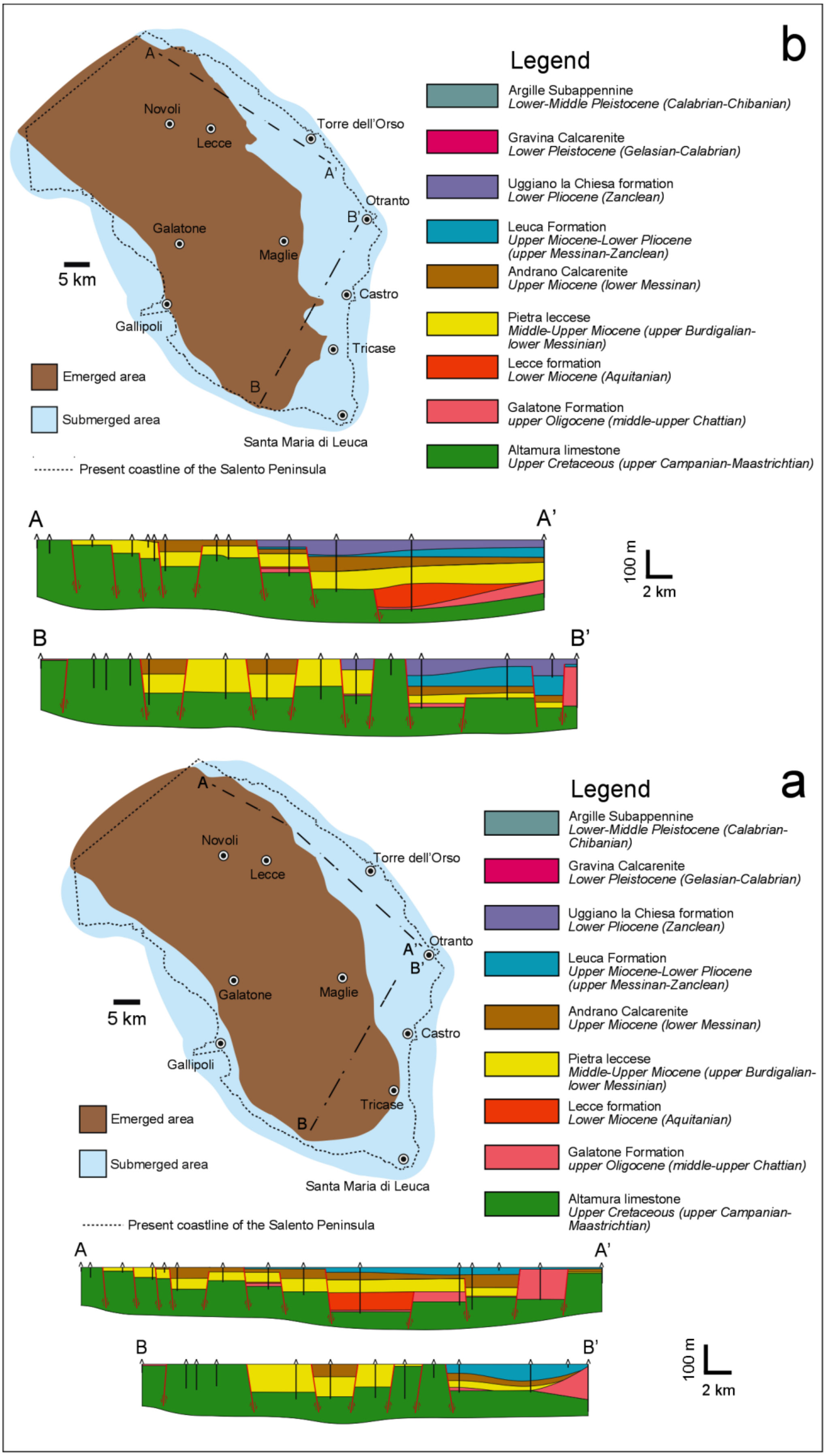


Fig. 24 - Paleogeographic setting and correlation panels at the deposition time of Leuca fm. (a) and Uggiano la Chiesa fm. (b) respectively.

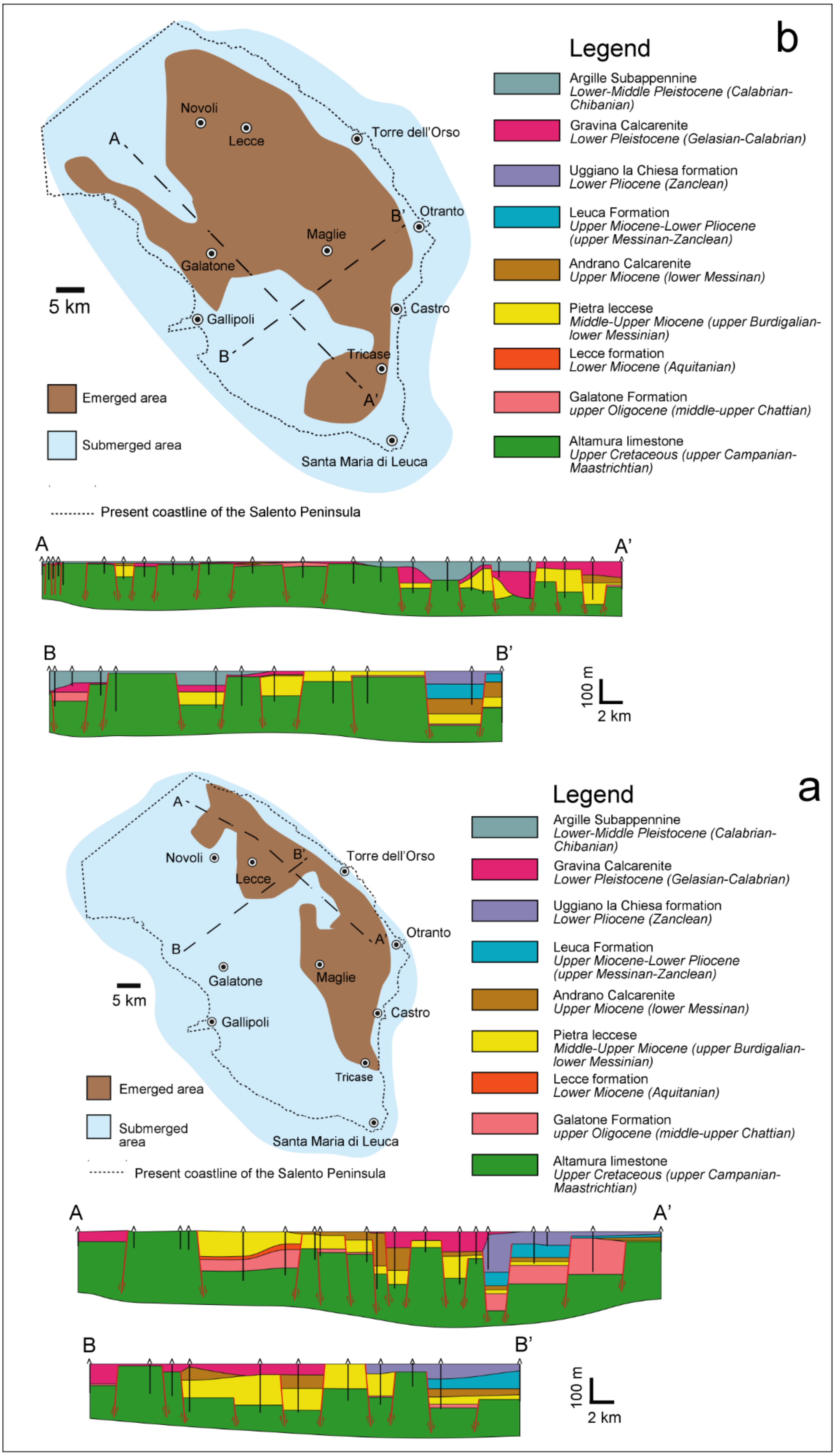


Fig. 25 - Paleogeographic setting and correlation panels at deposition time of Gravina Calcarenite (a) and Argille Subappennine (b) respectively.

4.2. SEISMIC STRATIGRAPHIC INTERPRETATION AND PALEOGEOGRAPHIC SETTING

4.2.1. Main seismic horizons and seismic units.

The offshore sector of the Salento Peninsula was investigated using 90 seismic profiles that cover the entire sector between the Adriatic Sea and the Ionian Sea (Fig.26). The calibration of these profiles using three exploration wells (Giove 002, Lieta 1 and Merlo 1) made it possible to recognize and trace five main seismic horizons (surfaces) corresponding to lithological changes and unconformities that bound seismic units (discrete natural stratigraphic packages) within which local seismic surfaces and their reflection terminations have been recognized based on their geometric configuration, continuity, amplitude, frequency, and interval velocity. The main recognized seismic horizons are: 1) top of Cretaceous strata; 2) top Miocene strata (Messinian); 3) top of Lower Pliocene; 4) top of Upper Pliocene; 5) top of the Pleistocene-Holocene succession. In order to better constrains the significance of seismic horizons we also considered other data derived by literature (i.e., Aiello and Budillon, 2004; Iannace et al., 2016; Maesano et al., 2020; Cicala et al., 2021). These horizons bound the seismic units 1, 2, 3, 4, and 5 (Figs. 27, 28, 29, 30, and 31).

Horizon 1 and Seismic Unit 1 - horizon 1 is a high amplitude reflector and occurs at the top of a seismic unit attributed to the Cretaceous deposits. It is recognized as high-relief truncation surface on which the deposits of the Cenozoic succession onlap. This truncation surface constitutes an unconformity probably recording a subaerial exposure of the Cretaceous substrate. The latter is characterized by low-amplitude and discontinuous reflectors in the lower portion, passing upward to high-amplitude reflectors through a probable discontinuity surface occurring within the Cretaceous succession.

Horizon 2 and Seismic Unit 2 - horizon 2 constitutes a very high-amplitude continuous and hummocky reflector that is interpreted to represent the Messinian Erosional Surface (MES), an important unconformity surface well recognized in seismic profiles in the Mediterranean area. This horizon constitutes the top of seismic unit 2 which shows high- to moderate amplitude and parallel to subparallel reflectors that are attributed to the Oligocene-Miocene deposits time-equivalent to the lithostratigraphic units cropping out along the Adriatic side of the Salento Peninsula: Castro limestone, Porto Badisco calcarenite, and Pietra leccese. Here the deposits of the seismic unit 2 onlap onto the unconformity at the top of Cretaceous substrate, while they are absent along the Ionian side of the Salento Peninsula where, the Plio-Pleistocene deposits occur directly onto the Cretaceous substrate.

Horizon 3 and Seismic Unit 3 - horizon 3 constitutes the top of seismic unit 3, such unit has a variable thickness, being 40 m thick in the Lieta 1 well, 65 m thick in the Merlo 1 well, and 20 m thick in the Giove 002 well, so evidencing a thickness increase moving eastward and southward. Contrary to seismic unit 2, unit 3 is well distributed both on the eastern and western sides of the Salento Peninsula. It shows low amplitude and high continuity reflectors that onlap onto the Oligo-Miocene substratum along the Adriatic side and onto the Cretaceous substratum along the Ionian side. The lithology of this unit is essentially composed by marly deposits attributable to the upper member of the Leuca Formation (the Trubi unit of Bosellini et al. (1999) and Ricchetti and Ciaranfi (2013).

Horizon 4 and Seismic Unit 4 - horizon 4 constitutes the top of seismic unit 4, this unit is very thin (15 m) and has been only recognized in the Merlo 1 well. It shows low amplitude and high continuity parallel and subparallel reflectors that onlap onto seismic unit 3. The unit is constituted by Upper Pliocene clay that should be time-equivalent to the Uggiano la Chiesa formation.

Horizon 5 and Seismic Unit 5 – horizon 5 corresponds with the present sea bottom and represents the top of seismic unit 5, This unit is distributed both along the Adriatic and Ionian sides of the Salento Peninsula, although with locally different reflection configurations, and has been recognized in the Lieta 1, Merlo 1, and Giove 002 wells. In particular, it is characterized by low amplitude and continuity reflections showing chaotic and/or locally wedge-shaped configurations along the Ionian margin of the Salento Peninsula, whereas it is characterized by low amplitude and high continuity reflections with parallel/subparallel to wedge-shaped clinoforms on the Adriatic side of the peninsula. Such unit consists of the Pleistocene and Holocene deposits (essentially those probably time-equivalent to the Gravina Calcarenite and Argille Subappennine).

4.2.2. Interpretation of some seismic profiles.

The main horizons and the seismic units were tracked in all seismic profile. In the following text are described some seismic lines in the Adriatic and Ionian sectors that have been calibrated with the Lieta 1, Merlo 1 and Giove 002 wells.

The F76-16 profile is in the Adriatic sector, is NW-SE oriented, and has been calibrated with the Giove 002 well. Along this seismic profile, it is possible to observe the deepening of the Cretaceous substratum, the thin and constant thickness of seismic unit 2, and a thickness increase of the seismic unit 3 that onlap onto the Oligo-Miocene substrate (seismic unit 2) moving from the southeast to the northwest. Seismic unit 4 does not occur along this profile and seismic unit 5, which shows a regular and constant thickness for almost the entire length profile, lies down directly onto seismic unit 3 through an erosive unconformity surface. Giove 002 well is located above a structural high bordered by normal faults (Fig. 27).
The F75-49 seismic profile (Fig. 28) is in the Adriatic sector (Otranto offshore) and is NNE-SSW oriented; it was calibrated with the Merlo 1 well. Also, this profile shows the presence of structural highs bordered by normal faults on one of which is located the Merlo 1 well (Fig. 28). The NW-SE oriented extensional faults is derived by the cross correlation with the other seismic profile, and produce a displacement of the Cretaceous substrate (seismic unit 1), and of the Oligo-Miocene and Lower Pliocene deposits (seismic units 2 and 3 respectively). These faults are sealed by the younger seismic units 4 and 5 that onlap on the older deposits (see also the interpretation of the seismic profiles by Butler et al., 2009). This seismic profile intercepts the edge of the Salento continental shelf at its southwestern end where there is a clear change in the configuration of the reflectors of seismic unit 5, interpreted as a clinoform wedge of the continental slope (Fig. 28).

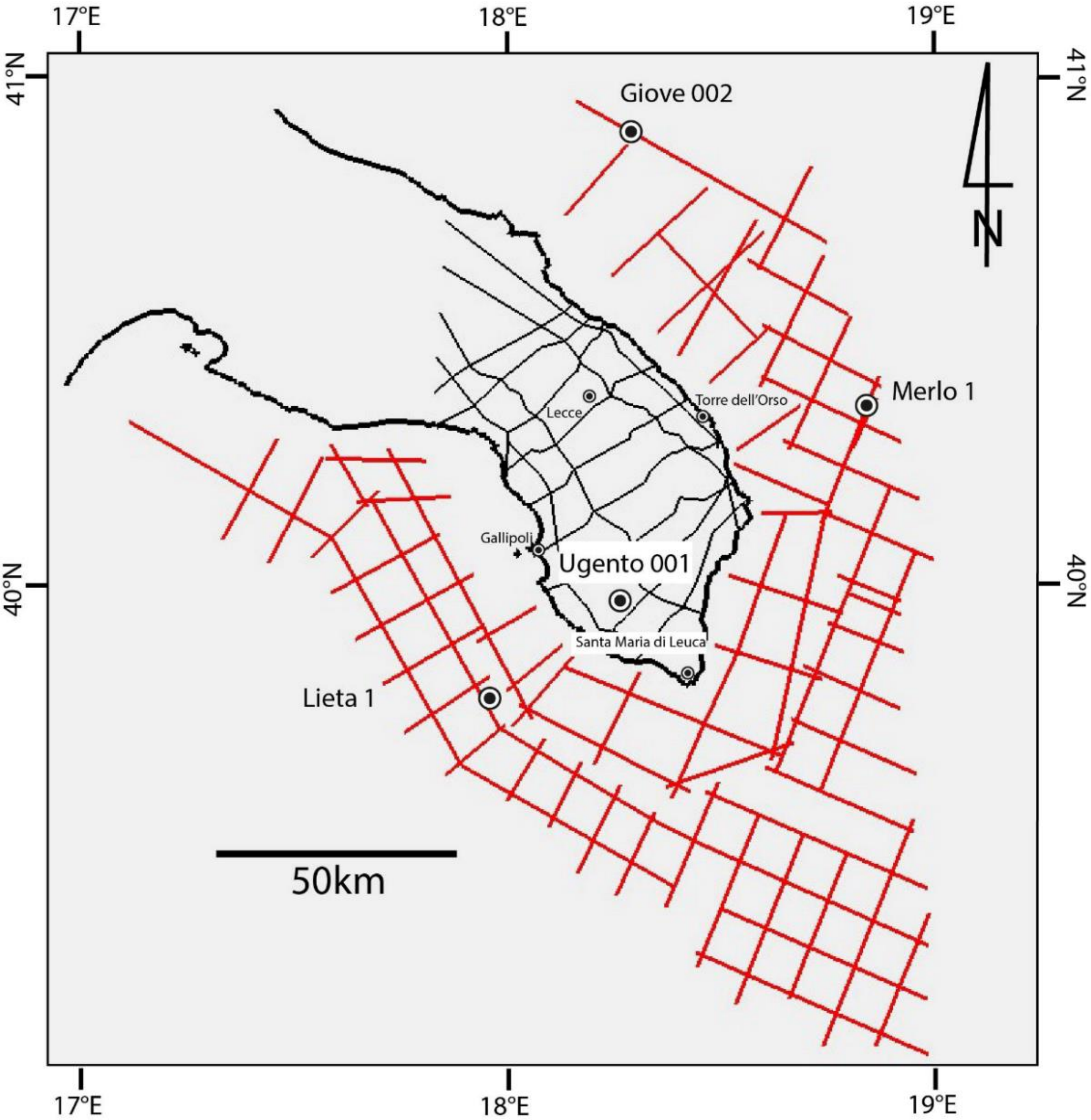


Fig. 26 - Location of the exploration wells Giove 002, Merlo 1, Ugento 001, and Lieta 001 (black and white points) in the Apulia foreland and tracks of the seismic profiles (red lines) utilized in this thesis (ViDEPI database). The black lines on the Salento Peninsula are the tracks of the correlation panels of figures 20 a, b, and c.

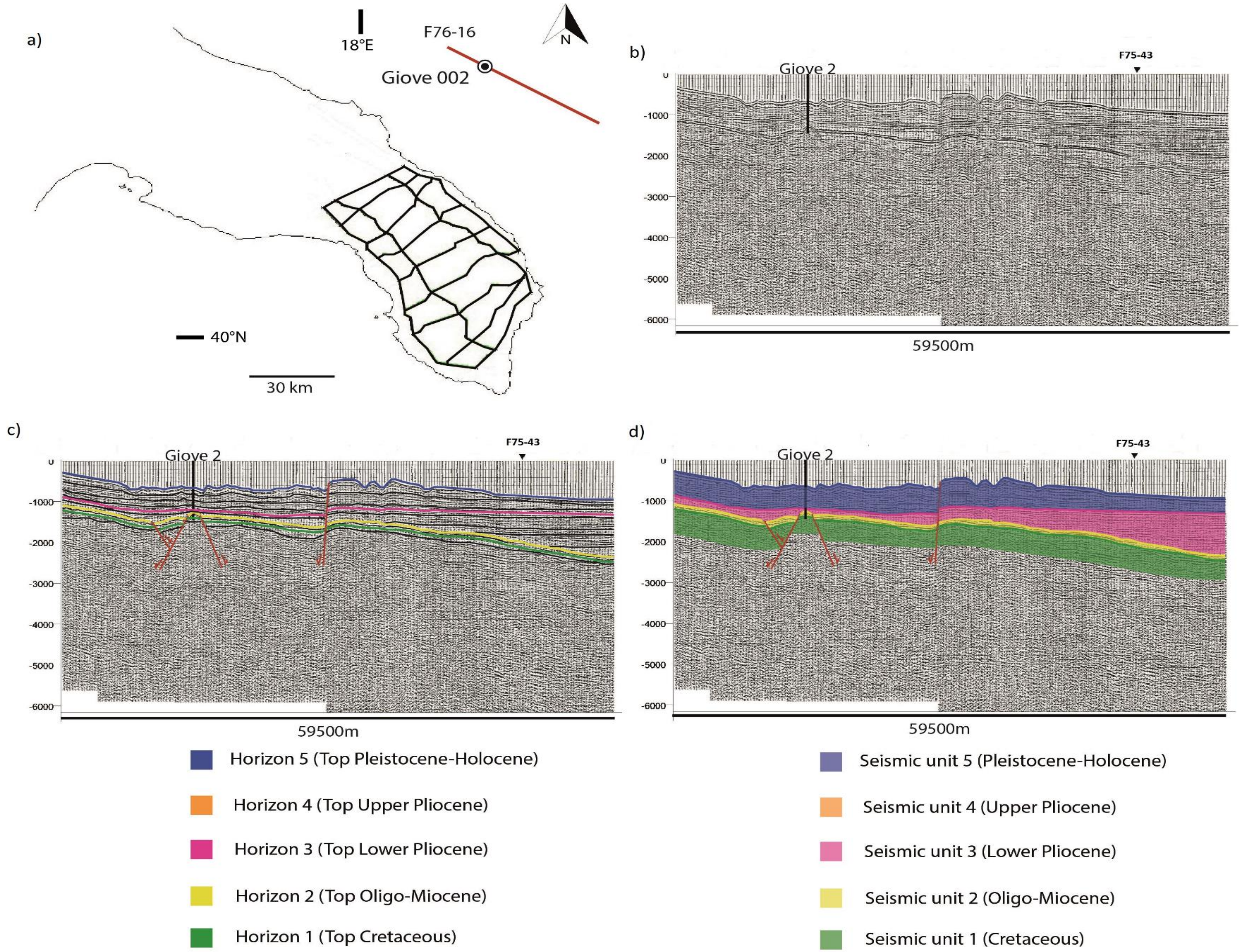


Fig. 27 - Location (a), uninterpreted (b), and interpreted (c and d) seismic profile F76-16 across the Apulia Foreland.

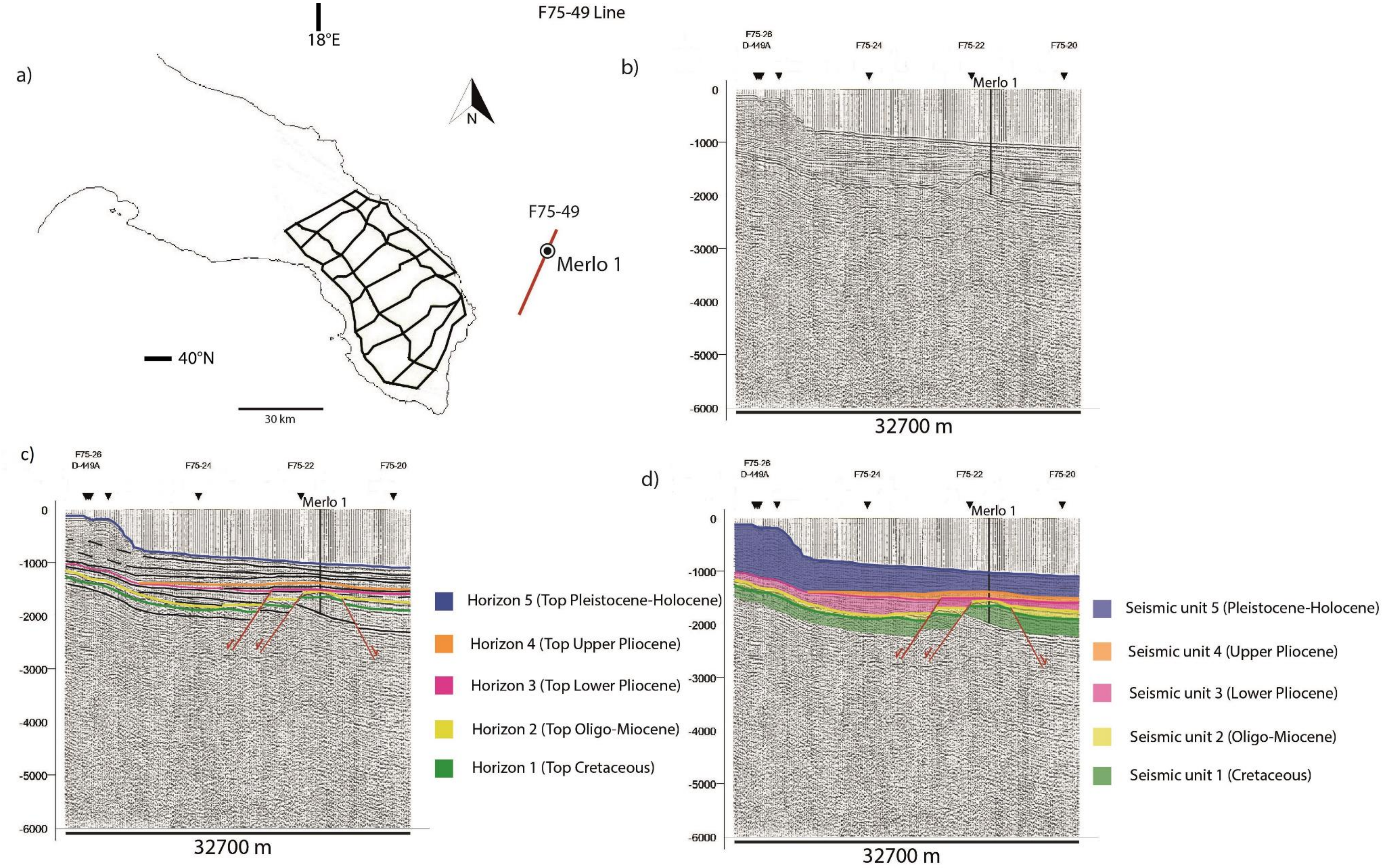


Fig. 28 - Location (a), uninterpreted (b), and interpreted (c and d) seismic profile F75-49 across the Apulia Foreland

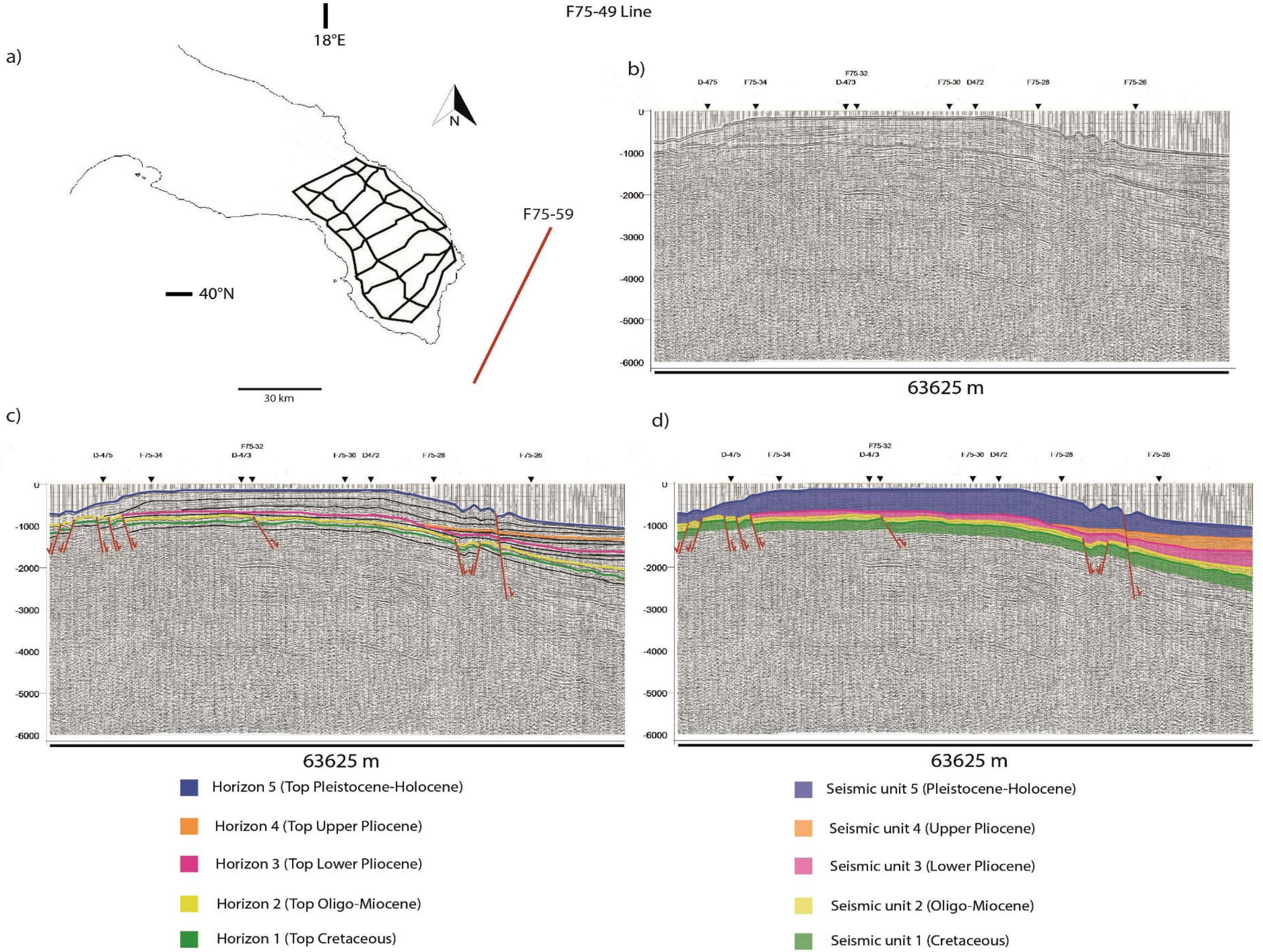


Fig. 29 - Location (a), uninterpreted (b), and interpreted (c and d) seismic profile F75-59 across the Apulia Foreland.

The F75-59 seismic profile is NNE-SSW oriented and extends in the offshore sector in front of S. Maria di Leuca where the Apulia swell develops (Fig. 29). In this seismic profile, NW-SE trending extensional fault systems interesting terrain of different ages occur, spanning from Upper Cretaceous to the Holocene. The geometry of the profile is that of a large anticline due to the convergence of the two opposite chains, the Dinarides-Albanides-Hellenid from the east and the Apennines from the west. The major thickness of the central bulge is attributed to the Pleistocene/Holocene deposits (Seismic unit 5) that show parallel high continuity reflectors wedging towards the west and east. The thickness of the older seismic units increases eastward. Most of the normal faults are sealed by the horizon 3 and only some faults have an activity that continues after the lower Pliocene, as suggested by Volpi et al. (2017) and Maesano et al. (2020). The seismic profile D-478 (Fig. 30) is SW-NE oriented and is located in the Ionian sector. It shows the onlap of the seismic units 3 and 5 onto the Upper Cretaceous substrate and several extensional faults that displace the Upper Cretaceous deposits (seismic unit 1) and the seismic units 3 and 5. The seismic units 2 and 4 are completely absent. The discordant contact between the Cretaceous substrate and the overlying units suggests that the activity of the fault continued until the Holocene. The evidence of the faults activity, should be highlighted by the movement of the present sea bottom that is displaced by several tens of meters. The movement of these faults is thought to be related to the load induced by the eastward migration of the Apennine chain.

The seismic profile D-467A (Fig. 31) stretches parallel to the Ionian coastal margin of the Salento Peninsula and was calibrated thanks to the presence of the Lieta 1 well, which is located on a structural high and in correspondence with an extensional fault whose activity would have continued until at the end of the lower Pliocene. Also, in this seismic section, the deposits of the Cretaceous substrate are onlapped by seismic units 3 and 5, whileseismic units 2 and 4 are missing. Their absence is probably due to erosion duringphases of emersion of the area at the end of the Miocene (formation of the MES) and at the end of the Lower Pliocene. These phases of emersion should be related to the eastward migration of the Apennine chain front.

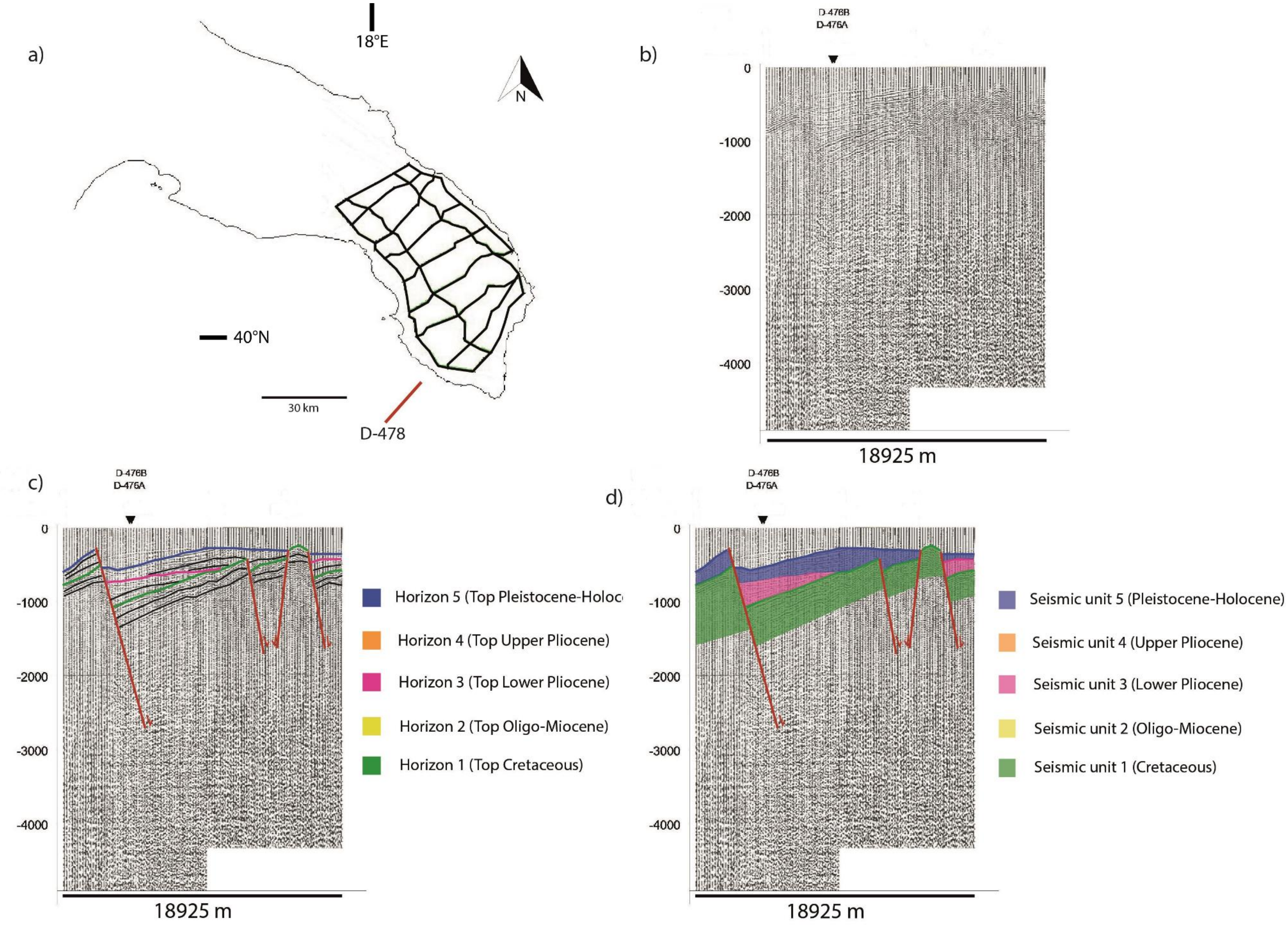


Fig. 30 - Location (a), uninterpreted (b), and interpreted (c and d) seismic profile D-478 across the Apulia Foreland.

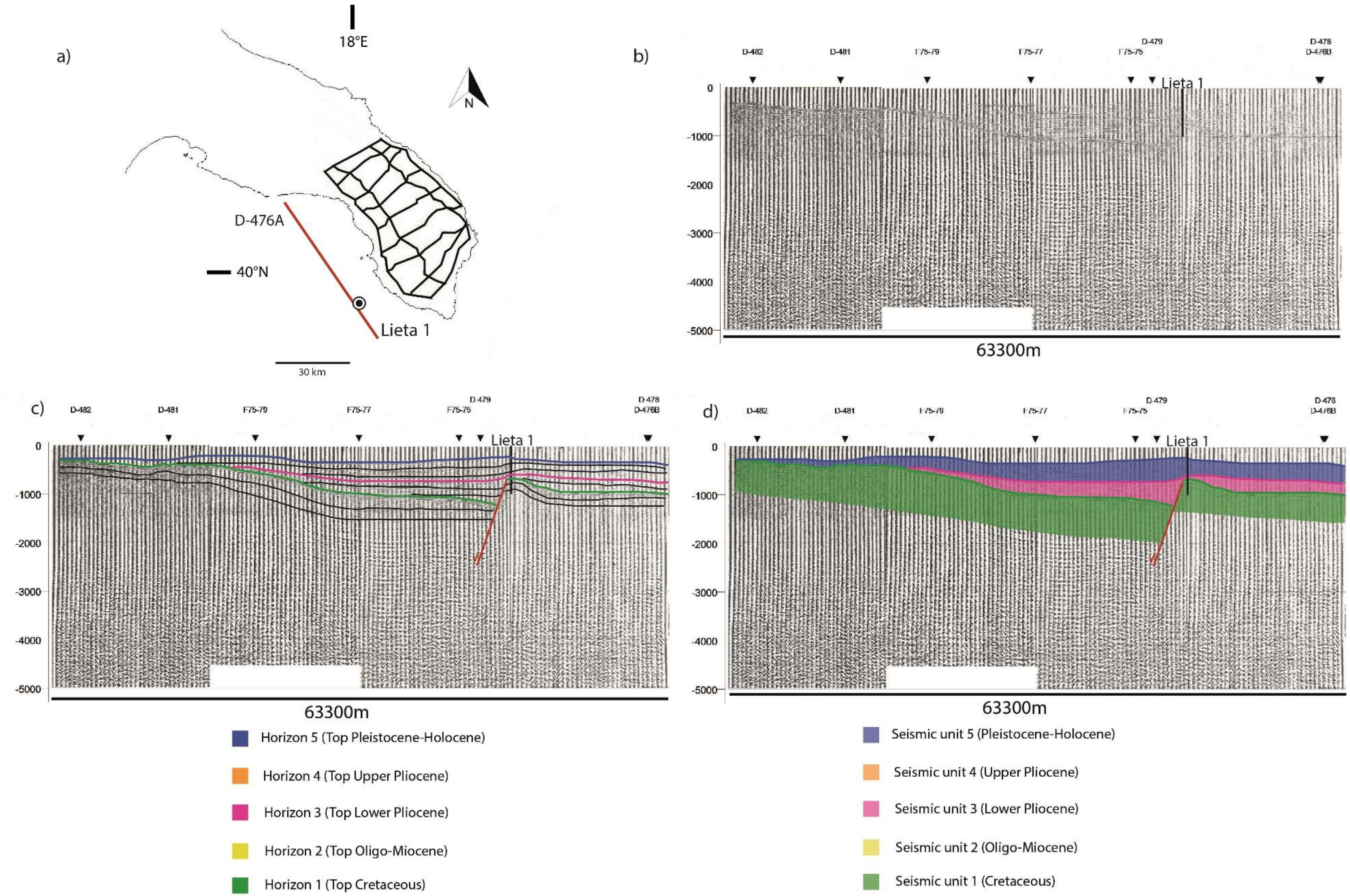


Fig. 31 - Location (a), uninterpreted (b), and interpreted (c and d) seismic profile D-476A across the Apulia Foreland.

4.2.3. Land-sea stratigraphic sections.

In order to relate the structural setting of the lithostratigraphic units cropping onshore with those ones present in the offshore sectors of the Salento Peninsula (see seismic profiles), eight land-sea stratigraphic cross-sections were produced, four oriented NE-SW and four oriented NW-SE (see Fig. 32 for their location). The analysis of these sections highlights how the Salento Peninsula constitutes the emerged culmination of a regional anticline resulting from the subduction of the Adria Plate beneath the Dinarides-Albanides-Hellenides and Apennines orogens (Doglioni et al., 1994, 1996, 1999; Argnani et al., 2001, and references therein). The NW-SE oriented axis of this structure plunges southward, where the two flanks converge in the Apulia swell sector (see also Auroux et al., 1985; Maesano et al., 2020; Cicala et al., 2021).

All these sections (Figs. 33 and 34), particularly those NE-SW oriented, show several high-angle extensional faults dipping to the northeast and southwest, that in the Ionian sector to exhibit a dip-slip component of movements (see Cicala et al., 2021). In particular these faults displace essentially the Cretaceous substrate and the overlying deposits of the seismic unit 2, 3, and 4 in the Adriatic sector, whereas in the Ionian sector these faults are active for all the Pliocene and Quaternary since the displacement of the current sea floor indicates a more recent activity of these faults.

The same stratigraphic sections show also that the Cretaceous/Eocene substrate of the emerged portion of the Salento Peninsula is unconformably covered by thin and discontinuous Oligocene to Quaternary deposits. The latter are thickerin the offshore sectorgreater, where they constitute the filling of the Dinarides-Albanides-Hellenides, and Apennines foreland basins.

Particularly evident is the greater and variable thickness, as well as the good preservation of all seismic units in the Adriatic sector, whereas they are of reduced thickness and/or absent in the Ionian sector, where in its northern portion the seismic unit 5 (Pleistocene-Holocene) rests directly on the Cretaceous substrate through an unconformity surface marking a hiatus of about 60 million years (Fig. 33, stratigraphic section 1). Relevant is the thickness of the Pleistocene-Holocene deposits (seismic unit

5) occurring on the Adriatic side of the Salento Peninsula where these deposits are well-developed showing a prograding reflection configuration (i.e. clinoforms) typical of a shelf/slope environment.

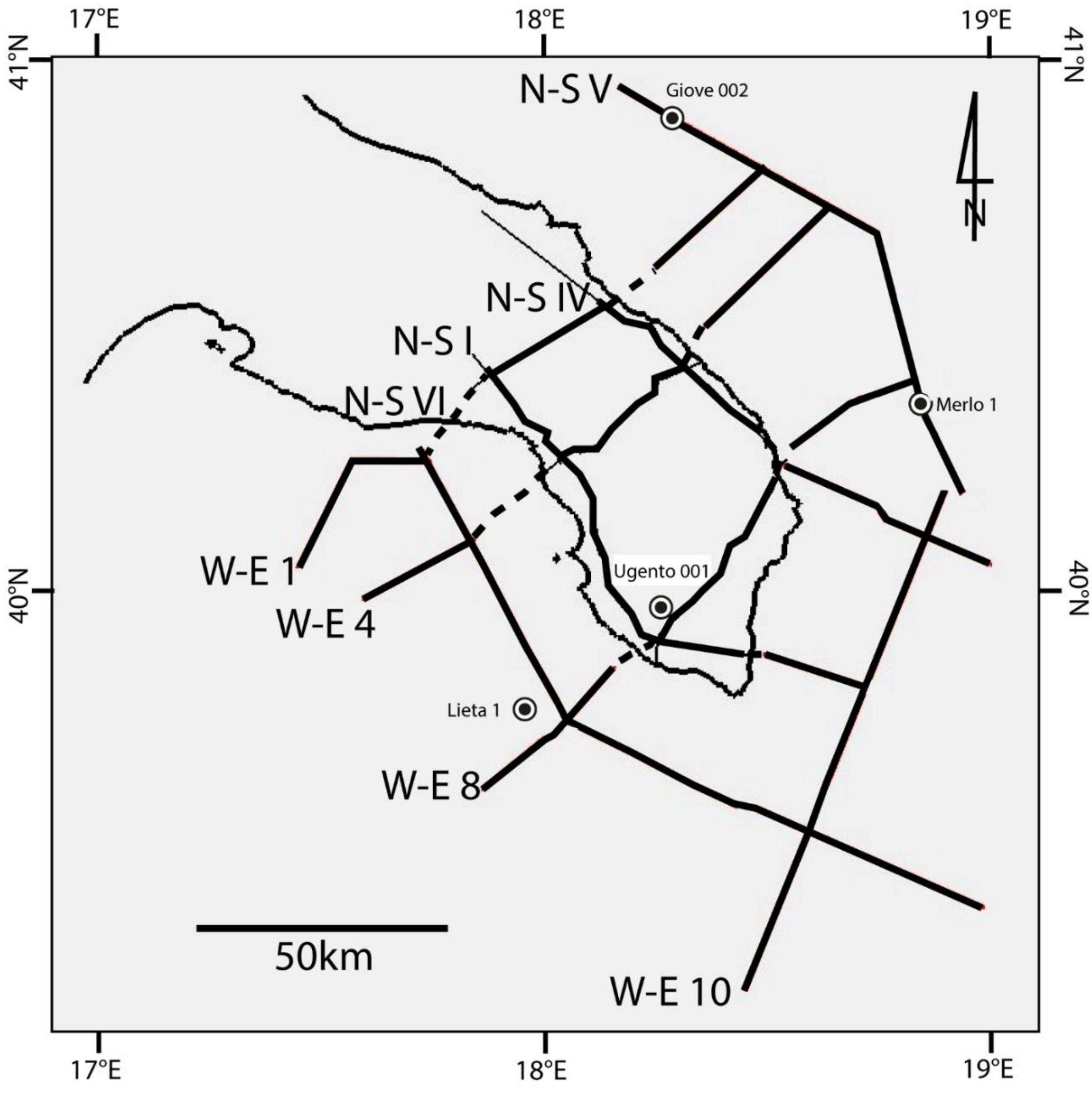


Fig. 32 - Tracks of the land-sea cross-sections.

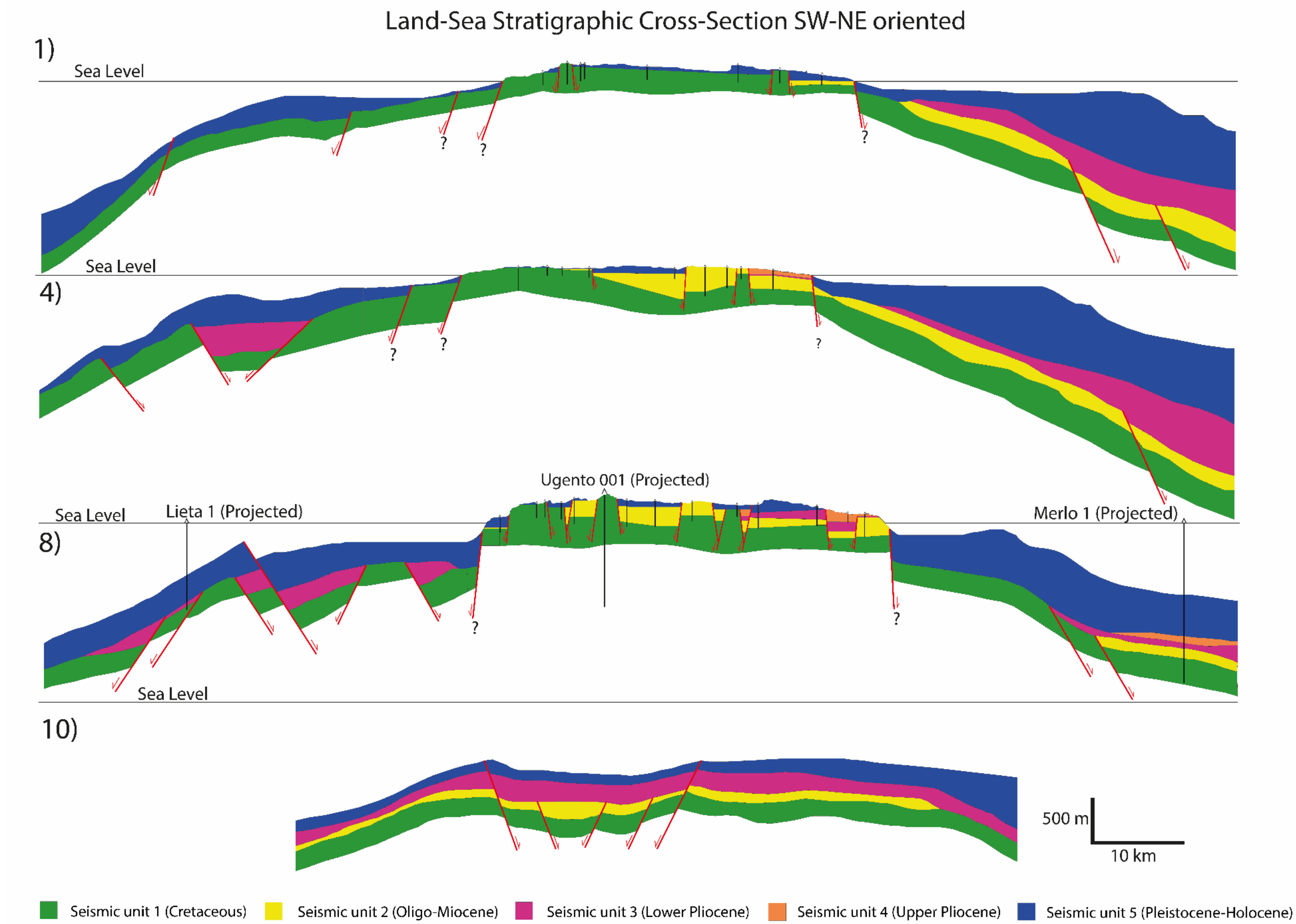


Fig. 33 - Land-sea correlation panels, SW-NE oriented, showing the present stratigraphic-structural setting of the emerged and submerged sectors of the Salento Peninsula. The extensional faults are NW-SE oriented.

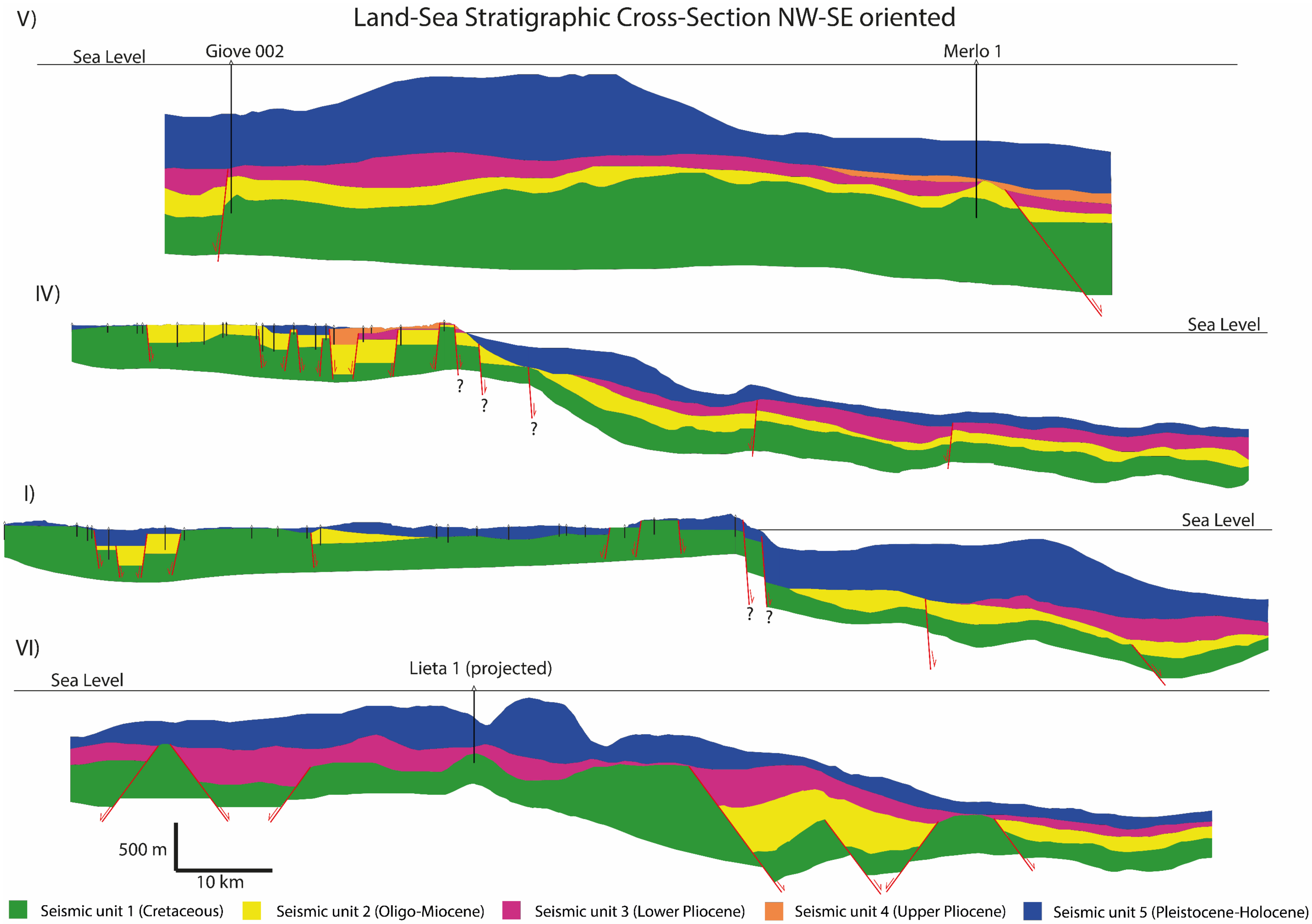


Fig. 34 - Land-sea correlation panels, NW-SE oriented, showing the present stratigraphic-structural setting of the emerged and submerged sectors of the Salento Peninsula.

5. DISCUSSION

The peculiarity of the Apulian foreland and the Salento Peninsula, in particular, is that it constitutes the foreland of two chains that migrate in opposite directions: the Dinarides-Albanides-Hellenides towards W-SW and the Apennine towards E-NE. However, the role played by these two belts in terms of control over sedimentation in the Salento area did not occur in the same way and at the same time. This is recorded in the different stacking patterns of the deposits, in their reduced thickness, in their areal distribution, in their different degree of preservation, in their sedimentary trends reflecting relative sea level changes and carbonate productivity, and finally in the presence in this sedimentary succession of several unconformity surfaces and stratigraphic discontinuities, which cover a period of time of several million years.

5.1. THE GEODYNAMIC CONTEXT

The previous field data and paleogeographic reconstructions show how the Cenozoic carbonate deposits of the Salento peninsula sedimented in shallow-water conditions, having a preserved overall thickness of about 200 m, considering the subsurface and the outcrop deposits. The Cenozoic carbonate units occur mainly on the eastern margin of the peninsula, whereas they are missing or have small thicknesses on top of the platform and on the Ionian margin. What factors influenced the carbonate sedimentation and why the thickness of these deposits is so reduced considering that this succession covers the time interval of the last 65 Ma?

It is here suggested that the timing of migration and deformation of the two belts occurring on the Adriatic and Ionian sides of the Salento Peninsula (Dinarides-Albanides-Ellenides and Appennines respectively) assumed an important role, considering that such migration should be responsible for the downward flexing of the lithosphere and consequently of the formation 1) of forebulge uplift that caused erosion and stratigraphic condensation; 2) of the forebulge unconformity (Crampton and Allen, 1995), separating the pre- from the syn- and post-orogenic sedimentary succession; 3) of the onlap of the syn-orogenic wedge-shaped shallow-water carbonates onto the Upper Cretaceous pre-orogenic carbonate substrate.

Anyway, considering the high thickness of the Adria Plate (about 100 km) (Doglioni et al., 1994) (see also figure 1c), the large radius of curvature, and the reduced thickness of the post-orogenic sedimentary succession, it can be inferred that starting from the Oligocene subsidence rate was relatively low along the Adriatic margin of the peninsula, with an increase during the Miocene, in particular during the deposition of the Pietra leccese, which onlapped onto the Cretaceous and the Oligocene and lower Miocene deposits, so recording a deepening of the underlying substrate. This is well evidenced in figure 34a and b which clearly shows the westward and north-westward migration of the Miocene transgression during the deposition of the Pietra leccese, a period of time that marks the maximum phase of marine ingression in this area, which in turn should be connected with a relative sea-level rise strictly controlled by the eastward migration of the Dinarides-Albanides-Hellenides chain (see also Maravelis et al., 2012, and Karakitsios, 2013 for the more internal portion of the Hellenides foreland basin). On the contrary, on the Ionian margin of the peninsula the flexural bending was more pronounced with a faster subsidence rate at least starting from the Late Pliocene/Early Pleistocene, due to the load of the Apennine chain and to the eastward roll-back of the Adria Plate (see also Cicala et al., 2021). This is evidenced by figures 36a and 36 b, showing a marked difference between the emerged and submerged sectors of the Salento Peninsula with the Ionian sector that records a rapid deepening that should be related to the load induced by the migration of the Apennine chain.

Summing up, the different thicknesses and preservation of the sedimentary successions on the Adriatic and Ionian sides of the Salento Peninsula seem to reflectdifferent subsidence rate of the two foreland basins associated with different migration rate of the two chains.. The higher thicknesses of the seismic units on the Adriatic side would suggest a slower migration of the Hellenides with lower but constant rates of subsidence of the foreland basin; the latter would record in its more external portion (near the shelf edge of the Salento Peninsula) a subsidence rate of about 0.05 mm/yr, starting from the early Oligocene. This value agrees with the subsidence rates (< 0.3 mm/yr) that characterize the foredeep with east-directed subduction (Lenci and Doglioni, 2007). On the contrary, on the Ionian side, the major inflection of the foreland margin, and the presence of only seismic units 3 and 5 suggest a faster eastward advancement of the Apennines chain, and higher subsidence rates (about 0.13 mm/yr) near the shelf edge of the Salento Peninsula starting from the Early Pliocene (see also Doglioni et al., 1999 with references therein). This value would increase in the deepest part of the foredeep (Taranto trench) where a value of about 1mm/yr has been calculated by Cicala et al. (2021) that agrees with the subsidence rates (~ 1.0 mm/yr) characterize the foredeep with west-directed subduction (Lenci and Doglioni, 2007).

These data are in agreement with the considerations of Dorobek (1995) about the distribution of the carbonate platform and reefal facies developing in the distal foreland area far from terrigenous influx. The Author evidences that the most important factor controlling carbonate platform morphology and sedimentation in foreland basins is the lithosphere flexure rate that influences three main and important elements: i) the ramp depositional gradient; ii) the subsidence rate, and iii) the water depth along the depositional profile. He also suggests that high flexural rigidity would favor the formation of large carbonate platforms with ramp profile; the latter were able to keep up with the subsidence rate for long periods of time without being subject to drowning but only to aggradation and retrogradation processes, and in some cases also progradation, as recorded on the Adriatic side of the Salento Peninsula during the deposition of this carbonate succession. On the contrary, plates with low flexural rigidity should give rise to narrower carbonate platforms which should be more prone to drowning.

The previous considerations suggest that the two margins of the Salento Peninsula behaved differently with respect to the migration and convergence rates of the two orogenic belts and the proximity of the foreland to the chains themselves. As pointed out by Galewski (1998), the convergence rate exerts an important control over the rate of tectonic subsidence,being the latter directly proportional to the convergence rate. In particular, the effects of the load and deformation induced by the westward advance of the Dinarides-Albanides-Hellenids produced tectonic subsidence which, although it did not lead to the drowning of the platform, allowed a general phase of progradation/aggradation during the Eocene and the Oligocene and a transgressive/retrogradation phase starting from the beginning of the Miocene (Lecce formation), which had its maximum development during the deposition of the Pietra leccese. During this whole phase, the effects of the eastward migration of the Apennine chain were practically irrelevant on the stratigraphy of Salento Peninsula, which shows a greater sedimentary preservation only on the side facing the Dinarides-Albanides-Hellenids, while on the raised Ionian side the carbonate sedimentation and, subsequently, the siliciclastic sedimentation began only from the Pleistocene. From the beginning of the Middle Pleistocene, the Salento area was then subject to uplift (Doglioni et al., 1996; Spalluto et al., 2010) and the thin shallow-waters carbonate deposits of Lower Pleistocene age were subaerially exposed and subjected to erosion.

Summing up, starting from the end of the Cretaceous the Salento area experienced uplift and erosion induced by the isostatic loading related to the flexural bending of the subducting lithosphere and the W-NW-ward and E-NE-ward migration of the Dinarides-Albanides- Ellenides and southern Apennines belts respectively (see also Sabbatino et al., 2021; Maesano et al., 2021; Cicala et al., 2021). This process produced a regional unconformity (forebulge unconformity), extensional fracturing, and faulting in the uppermost part of the lithosphere during the Paleocene-early Eocene and stasis of the shallow-water carbonate sedimentation. The latter was re-established starting from the late Eocene up to the Pleistocene, with the onset of flexural subsidence, that became more accentuated during the Miocene (see also Sabbatino et al., 2021 and references therein). The onset of the flexural subsidence is recorded by the onlap of the shallow-water carbonate time-transgressive deposits overlying the pre-orogenic substrate whose age is different along the Adriatic (older) and Ionian (younger) sectors of the Salento Peninsula. This carbonate sedimentation was marked by several hiati bounding the stratigraphic units forming the sedimentary succession cropping out in the Salento Peninsula. Consequently, most of these deposits are almost absent in the internal areas of Salento, whereas they are better preserved on the eastern margin with respect to the western margin of the peninsula. This suggests that the transgressive/retrogradation phase that started from the beginning of the Miocene proceeded from the south-eastern sector to the north-western one (see paleogeographic schemes) under the influence of the tectonic subsidence induced by the migration of the advancing Dinarides-Albanides-Ellenides thrust belt.

5.3. SEQUENCE STRATIGRAPHY

All the climatic and related eustatic sea-level changes together with the geodynamic context impacted the stratigraphic and paleogeographic evolution of the Salento Peninsula. Consequently, relative sea-level changes of different frequencies and amplitude developed, although the definition of the influence of these processes on the variation of accommodation space was not simply to distinguish.

Overall, it is evident by eustatic sea-level and oxygen isotope curves (see figure 18) that the last 50 Ma coincides with a long-term eustatic fall in sea level punctuated by several cycles of different orders and amplitude. Climate changes were generated by periodic and quasi-periodic variations of the Earth's orbital parameters (eccentricity, obliquity, and precession) and produced high-frequency eustatic sea-level oscillations with amplitude ranging from tens to hundred meters. During these periods both global deep-sea oxygen and carbon isotopes records show some important climate changes starting from the Oligocene to the present, that produced the expansion and decay of Antarctica and Northern Hemisphere ice sheets. In fact, the growth and retreat of these ice sheets caused 50-60 m sea-level variation on the 10^6 -year scale beginning at 33.5 Ma (at the passage from Eocene to Oligocene), which were amplified during the last 2.6 Ma due to the growth /decay of the Northern Hemisphere ice sheets. The latter produced sea-level changes < 60 m with a cyclicity of 41,000 years (obliquity cycles) during the Early Pleistocene, whereas during the Middle and Late Pleistocene sea-level changes were more than 100 m with a cyclicity of 100.000 years (eccentricity cycles) (see Miller et al., 2020).

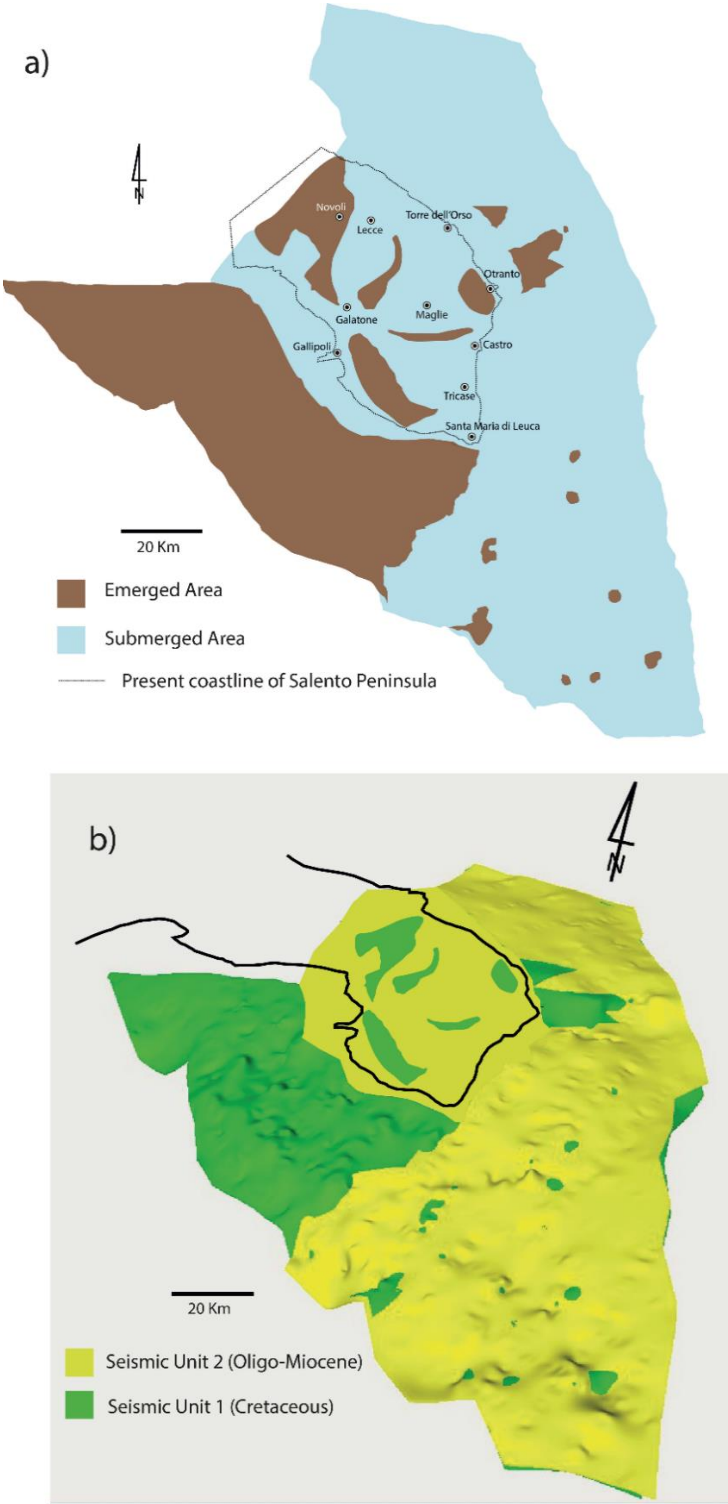
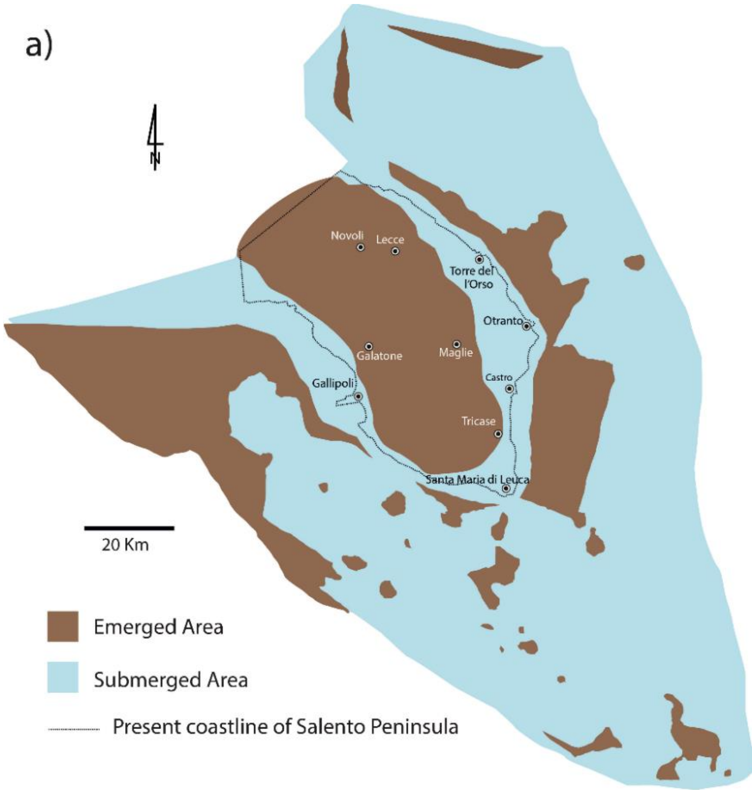


Fig. 35 - a) reconstructed paleogeographic setting of the Salento Peninsula and of the surrounding sectors (Lower Messinian); b) map showing the onlap extension of the Miocene deposits onto the older stratigraphic units. See text for further discussions.



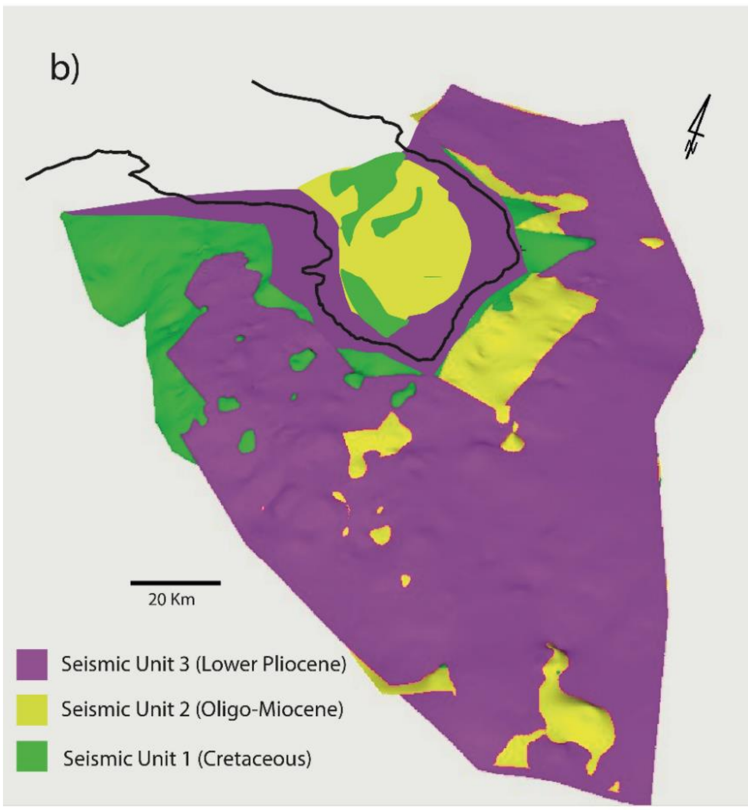


Fig. 36 - a) reconstructed paleogeographic setting of the Salento Peninsula and of the surrounding sectors at the end of Lower Pliocene (Zanclean); b) map showing the onlap extension of the Lower Pliocene deposits onto the older stratigraphic units. See text for further discussions.

Consequently, during this long period of time, the eustatic fall counteracted at first the effects on the coastal onlap record of the subsidence related to the flexural bending of the Salento Adriatic foreland due to the migration of the Dinaric-Albanides-Hellenides chains and, starting from the end of the Late Miocene, the flexural bending of the Salento Ionian foreland due to migration of the Apennine chain.

On this basis,integrating the data presents in this thesiswith the data from literature, it was possible to frame the stratigraphic architecture of Salento Peninsula into a sequence stratigraphic scheme that allowed us to highlight and better clarify the stratigraphic relationships between the different lithostratigraphic units recording the relative sea-level variation of different frequency and amplitude. The final stratigraphic architecture is not just a simple vertical overlap of the lithostratigraphic units but rather a complex lateral-vertical organization of the different units which constitutes the expression of the strong interactions between tectonic and climatic/eustatic changes. These two processes worked both simultaneously and out of phase during time producing variations of accommodation space and influencing carbonate sedimentation. The result of this was a sedimentary succession with a reduced thickness (~ 200 m), if compared to the interval time during which it was deposited (the last 60 Ma), where the several lithostratigraphic units are bounded by unconformity surfaces associated with erosional vacuities, indicating significant breaks in the stratigraphic record of the Salento Peninsula. These units representUBSU unconformity-bounded stratigraphic units) (Salvador, 1987; 1994), show facies types and a stratal architecture that allowed us to define them as depositional sequences.

On this basis the post-Cretaceous succession of the Salento Peninsula has been subdivided into two high rank composite sequences, named Lecce 1 and Lecce 2, which have very different durations and within of which lowstand (LST), transgressive (TST) and highstand (HST) systems tracts occur, with rather reduced thicknesses. Both these sequences consist of several lower rank simple and composite depositional sequences (*sensu* Mitchum and Van Wagoner, 1991; Catuneanu et al., 2011 with references therein), with a duration ranging from hundreds of thousands to a few million years, that have a good correspondence with the formal and informal lithostratigraphic units of the investigated area (Fig. 37).

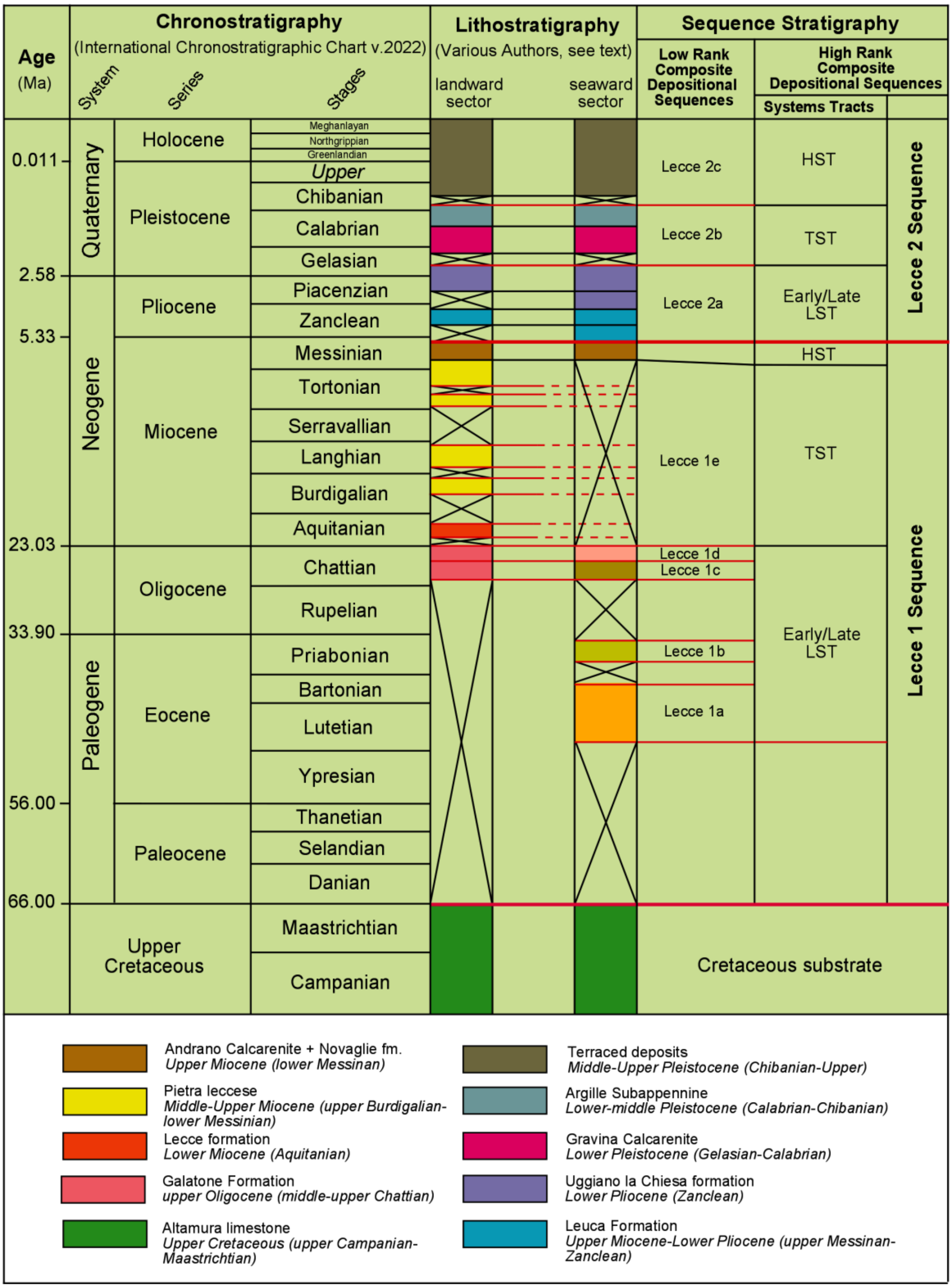


Fig. 37 - Chronostratigraphic and sequence-stratigraphic scheme of the Cenozoic deposits of the Salento Peninsula. HST: Highstand Systems Tract; TST: Transgressive Systems Tract; LST: Lowstand Systems Tract.

5.3.1. The high-rank composite sequence Lecce 1

This sequence (Figs. 37, and 38) is bounded by two unconformity surfaces placed on top of the Cretaceous Altamura limestone and on top of the Andrano Calcarenite and Novaglie formations respectively. In particular, the basal unconformity of the Lecce 1 sequence is tectonically controlled and represents the forebulge unconformity, a discontinuity placed between the pre-orogenic and the syn- to post-bulge deposits, that is the first stratigraphic expression of the foreland flexural stage (Crampton and Allen, 1995). This unconformity led the subaerial exposure of the innermost sectors of the Apulian platform and to the formation of a karstic landscape and a thick reddish residual deposit. The Lecce 1 sequence has a duration of ~ 60 Myrs although the stratigraphic gaps within it cover a time lap of 35 Myrs. It consists of six low-rank composite sequences with a variable duration from 1.6 to 12 Ma, the boundaries of which are represented by sharp erosional surfaces, recording basinward and downward shifts of facies, and local subaerial exposure with paleosols formation. All these sequences essentially occurred along the eastern sectors of the Salento, while they are absent or present with very reduced thickness in the central portion and on the western margin of the Peninsula.

Based on their depositional characters and stacking pattern the Torre Tiggiano limestone and the Specchia la Guardia limestone, together with the Castro limestone, Porto Badisco calcarenite, and the Galatone Formation form the LST of Lecce 1 sequence. The Lecce formation and Pietra leccese are referable to the TST, while the Andrano calcarenite and the Novaglie formation developed entirely during the HST of the Lecce 1 sequence (Fig. 37).

A hiatus covering an interval time of ~18 My (all the Paleocene and the Early Eocene) separates the Cretaceous substratum from the first Cenozoic unconformity-bounded unit, known in the literature as Torre Tiggiano limestone. This unit, in agreement with Bosellini et al. (1999), constituted part of a low-rank composite depositional sequence onlapping onto the Cretaceous substrate, that was deposited probably along the whole eastern margin of the Salento Peninsula from Otranto to S.

Maria di Leuca. The deposition of this sequence, that we named Lecce 1a, occurred at the turn of the MECO, during a rise of sea level, and as such we suggest that the preserved deposits could belong to the TST and/or the HST of the Lecce 1a sequence. These deposits are tectonically tilted and probably follow a deformation phase related to the westward migration of the Dinarides-Albanides-Hellenides belt (see also Bosellini et al., 1999). This process occurred before the deposition of the overlying clinostratified reef slope deposits of Torre Specchia la Guardia limestone (late Priabonian in age). We consider the latter another incomplete sequence, named Lecce 1b, whose deposition occurred before the Oi1 event. For this reason and considering also the oxygen and eustatic curves showing a period or relative sea level rise (see figure 36), we retain that Torre Specchia la Guardia limestone onlapping onto the Cretaceous and Middle Eocene deposits belong to the TST/HST of Lecce 1b sequence.

Both these Eocene sequences were deposited only along the eastern coast of the Salento Peninsula, suggesting that the western and internal portions of the Salento were in subaerial conditions. Also, considering that both sequences were deposited during the eustatic sea-level fall following the EECO we retain that both sequences belong to the Early Lowstand Systems Tract of the high-rank Lecce 1 sequence.

The EOT constitutes an important climatic phase during the development of the Lecce 1 sequence coincident with the Oi1 event (Miller et al., 1991; Zachos et al., 1996; 2001) recording the passage from warm greenhouse to cold icehouse conditions. Two eustatic sea-level falls at 33.9 Ma (25 m) and 33.65 Ma (Oi1 event) (50 m) are recorded at this passage (Coxall et al., 2005; Miller et al., 2020); these falls together with the other eustatic variations of several tens of meters characterizing the Lower Oligocene (Rupelian) (see figure 18) not allowed the preservation of the deposits in the Salento area which only records the formation of three lithostratigraphic units of Chattian age that rest on the underlying Upper Cretaceous and Eocene deposits: the fringing reef complex of the Castro limestone and the ramp system of the Porto Badisco limestone, both passing landward to the lacustrine-lagoon deposits of the Galatone Formation (see figure 38). These units are bounded above and below by unconformity surfaces and are interpreted as two low rank composite depositional sequences named Lecce 1c and Lecce 1d respectively. The cropping out portions of these sequences constitutes, according to our interpretation, the preserved deposits of the late lowstand and the transgressive systems tracts. Both these sequences developed during a stationary phase of the eustatic sea level between the Oi2 and Mi1 events. More in detail, the deposition of the Castro limestone occurred at the turn and immediately after the Late Oligocene Warming and records through the facies belt shift a prograding coral reef complex (see also Bosellini et al., 2021). The latter show internal erosional surfaces recording relative sea-level variation and the deposition of a stack of stratigraphic units interpreted as depositional sequences (see also Bosellini et al., 2021), that we attribute to the late lowstand systems tract of the Lecce 1c sequence, being the TST and HST completely eroded by the successive relative sea-level fall.

Deposition of the Castro limestone was followed after a short period of time by the deposition of the Porto Badisco calcarenites which is separated by an erosional unconformity. The Porto Badisco calcarenite show internally the presence of further unconformity surfaces, bounding units interpreted as low rank depositional sequences with a retrogradational stacking pattern (Fig. 39). The strike and dip correlation panels of the Porto Badisco calcarenite, derived by the integration of literature data (see detailed facies analysis conducted by Pomar et al., 2014 and Tomassetti et al., 2018) and by field data with new survey and measure of stratigraphic sections whose facies subdivision and nomenclature follow the same of the previous Authors.

Based on what said previously and considering the position of Lecce1c and Lecce1d sequences, respect to the overlying and underlying deposits, showing a progradational and aggradational stacking pattern, we attribute the deposition of these composite sequences to the Late Lowstand Systems Tract of the high rank Lecce 1 sequence (Figs. 38, and 39).

The deposition of the Lecce formation (lower Aquitanian) occurred during an eustatic sea-level rise subsequently to Mi1 event. This unconformity bounded unit, lies unconformably on the underlying Galatone Formation and constitutes the expression of a single depositional sequence where only the transgressive systems tract deposits are preserved. This unit records, in fact, a transgressive phase in the Salento area (Fig. 38) that would be linked to the contextual long-term flexural subsidence induced by the migration of the Dinarides-Albanides-Hellnides belt (see also Bosellini et al., 1999), a process that continued also during the deposition of the Pietra leccese. The latter, upper Burdigalian-lower Messinian in age, was deposited in an inner shelf to lower shoreface environments and is characterized by phosphatic and glauconitic grains whose frequency and abundance increase upward and then decrease towards the top of this formation, where the Pietra leccese transitionally passes upwards to the shallow-water deposits of Andrano Calcarenite. Mazzei et al. (2009) subdivided the Pietra leccese into three different intervals separated by three hiatuses with a duration ranging from 1.2 to 3.7 My. The formation of these hiatus was attributed to the action of marine currents that swept the seabed. Although the marine currents can be very effective to erode the seabed, we retain that the recognized long-lasting hiatuses can be better explained by relative sea-level falls. The latter, in shelfal areas, would have favored the erosion through the wave scouring induced by a decrease in bathymetry, a process that would have increased the erosive action of the currents on the seafloor. Basically, we interpret the hiatuses and the associated erosional surfaces occurring in the Pietra leccese, as the expression of regressive surfaces of marine erosion (Plint, 1988; Posamentier and Allen, 1999; Catuneanu et al., 2011) that forms during forced regression in wave-dominated shallow-water setting. In sequence stratigraphy, these surfaces have the role of sequence boundaries that become correlative conformities towards the sea where starved sedimentation occurs. Consequently, we consider the Pietra leccese unit as constituted by the superimposition of three depositional sequences, each with a duration of ~ 1 My, and with a clear retrogradational stacking pattern, of which only the deposits of the transgressive systems tracts are preserved (Fig. 38). During the deposition of the Pietra Leccese, the transgression proceeded from east to west producing the migration of the depositional depocenter towards the internal sector of the Peninsula, and a coeval starvation phase in the eastern sector.

Here a condensed phosphatic layer (10-20 cm thick), known in literature as "*Aturia* level" (Giannelli et al., 1965; Bosellini et al., 1999; Bossio et al., 2000-2001) was deposited between the early Serravallian-late Tortonian (Föllmi et al., 2015; Vescogni et al., 2018), in a period of time where the oceanographic circulation in the Mediterranean basin changed due to the intermittent connection with the Indian Ocean (see Popov et al., 2004). This process, that modified the seawater chemistry of the basin and the faunal assemblages, produced after the Burdigalian the disappearance of the large benthic foraminifera that had dominated carbonate production in the Aquitanian and the increase of red algae and bryozoans, which colonized most of the carbonate ramp systems during the Middle and Late Miocene (see Cornacchia et al., 2020, 2021 with references therein). In the external sector of the Salento Peninsula the "*Aturia* level" level lies between the carbonate sequences of Oligocene age (Castro limestone and Porto Badisco calcarenite) and the lower Messinian Andrano Calcarenite and reef unit of the Novaglie formation, while in the internal sector of the Peninsula it rests directly on the Cretaceous substratum (Fig. 38). Consequently, this level incorporates, in a very reduced thickness, all the sequence boundaries occurring in the Pietra leccese, in the form of correlative conformities; as such this level constitutes the expression of the condensed section (maximum flooding surface, mfs) that separates, the TST from the HST of the high rank sequence Lecce 1 (Fig. 38). Furthermore, where this level rests directly on the Porto Badisco calcarenite, it overlaps on the first transgressive surface that separates the LST from the TST of the Lecce 1 sequence (Fig. 38). Based on the previous discussion we consider both Lecce formation and Pietra leccese as deposited during the TST of the high rank sequence Lecce 1.

The Pietra leccese pass transitionally upward, through the interposition of the "*Aturia* level" to the Andrano Calcarenite (lower-upper Messinian) whose sedimentological and paleontological characters suggest deposition from inner shelf to beach environments with the local presence of brackish lagoonal deposits at the top of this unit. On this basis we consider this formation to be the product of deposition during the HST of the Lecce 1 sequence. Of the same age is the Novaglie formation, a coral reef complex cropping out along the eastern coastal border of the Salento Peninsula, from Porto di Tricase to S. Maria di Leuca. This unit, which has been recently investigated with great detail by Vescogni et al. (2022), lies unconformably onto the pre-Miocene formations through an erosional surface on which the "*Aturia* level" occurs; it has been considered as heteropic of the Andrano Calcarenites by Bosellini et al. (1999; 2001, 2002) and Bosellini (2006). Such literature data suggest that this unit would constitute a composite sequence formed by superimposition of three low-rank depositional sequences having thicknesses variable from tens to hundred meters (see Vescogni et al. 2022 for further details). Although the Novaglie fm. was deposited during the HST of the Lecce 1 sequence, the lateral passage with the Andrano Calcarenite has never been described in outcrop; also, the type of deposits of these formations, their stratigraphic relationships with the underlying units and the data derived from our paleogeographic reconstruction seem to suggest a different scenario. On this basis we interpret the Novaglie fm. as a composite low-rank depositional sequence (Fig. 40) that developed during the deposition of the HST of the Lecce 1 sequence as a result of high-frequency relative sea-level fluctuations that characterized the Early Messinian of the Mediterranean area (see also Esteban,1996; Pedley,1996) under the control of climatic changes (see also Vescogni et al., 2022). Also, considering that the thickness of the three small sequences forming the Novaglie fm. tend to decrease upward, we interpret this as the product of the deposition during the late lowstand systems tract of this low-rank composite sequence, being the transgressive and highstand deposits represented by the Andrano Calcarenite (see figure 38). Summing up, the final portion of the high rank Lecce 1 sequence is represented by a composite sequence, named Lecce 1e, that include the following lithostratigraphic units: Lecce fm., Pietra leccese, Andrano Calcarenite, Novaglie fm. All these units are representative of the TST (Lecce fm. and Pietra leccese) and HST (Andrano Calcarenite and Novaglie fm.) of the high-rank Lecce 1 sequence (Fig. 38).

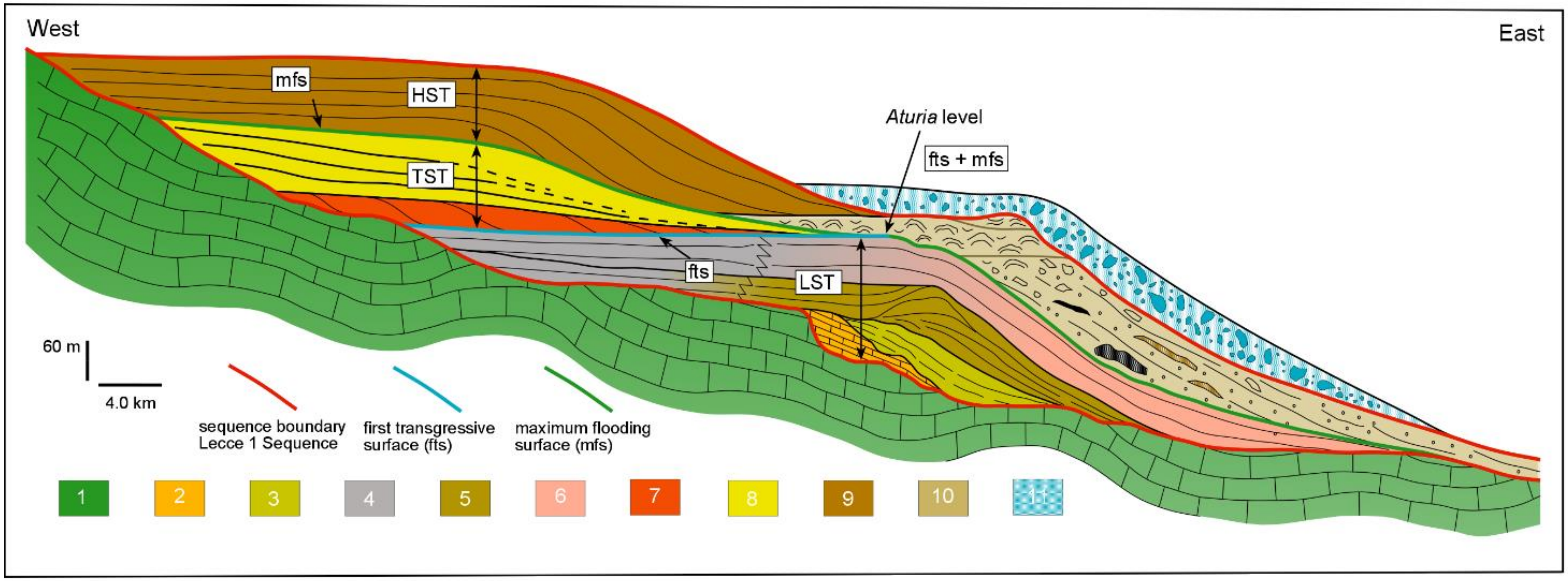


Fig. 38 - Stratigraphic cross-section showing the depositional architecture of the composite high-rank Lecce 1 Depositional Sequence between the central and eastern sectors of the Salento Peninsula. 1: Altamura limestone; 2: Torre Tiggiano limestone; 3: Torre Specchia la Guardia limestone; 4: Galatone Fm.; 5: Castro limestone; 6: Porto Badisco calcarenite; 7: Lecce fm.; 8: Pietra leccese; 9: Andrano Calcarenite; 10: Novaglie fm.; 11: Leuca Fm. (breccia member); HST: highstand systems tract; TST: transgressive systems tract; LST: lowstand systems tracts; fts: first transgressive surface; mfs: maximum flooding surface. For further explanations, the readers are referred to the text.

5.3.2. The high-rank composite sequence Lecce 2

The high-rank sequence Lecce 2 is bounded below by the unconformity surface corresponding to the Messinian Erosional Surface (MES) (Fig. 40) on which lie down the breccia deposits of the Leuca Formation (Figs. 38 and 40). The upper boundary of this composite sequence is represented by the present subaerial and submerged depositional surface. Thus, this sequence comprises the sedimentary succession that developed during the last 5.6 My; it constitutes an incomplete and still evolving sequence that contains three low-rank sequences named Lecce 2a, Lecce 2b, and Lecce 2c stacked to constitute the LST, TST, and HST of the Lecce 2 sequence respectively. All these sequences developed essentially during the Pliocene and Pleistocene and are strongly influenced by the high frequency and high amplitude glacio-eustatic sea-level changes. Consequently, considering the foreland setting of the area, the genesis of the sequence boundaries and the general stacking pattern of these sequences reflect the close interaction between tectonic uplift/subsidence and glacio-eustatic sea-level oscillations with typical Milankovitch cyclicities.

The sequence boundary of the Lecce 2a coincides with the MES while the top is represented by an unconformity surface at the base of the Gravina Calcarenite. The Lecce 2a sequence comprises the Leuca Fm. and the Uggiano la Chiesa fm. The former shows, after the breccia deposits, a general upward deepening trend recording the passage from the inner to the outer shelf at the top of which a glauconitic mudstone rich in planktonic foraminifers occurs. On the latter, a discontinuous conglomerate with phosphatic pebbles occurs passing upward to shelfal fine-grained marly calcarenite in turn replaced by shallow-water and coastal medium-grained calcarenite with a reach assemblage of foraminifers, ostracods, mollusks, and red algae. We interpret this succession as the expression of a depositional sequence in which the deposits of the Leuca Fm. are representative of the LST and the TST, while the deposits of the Uggiano la Chiesa fm. are considered to represent the final portion of the TST and the HST. We placed the first transgressive surface (fts) at top of the breccia deposits while the maximum flooding surface with the condensed section should coincide with the glauconitic mudstone and the discontinuous conglomerate with phosphatic pebbles.

The Lecce 2b sequence is made up of the deposits of the Gravina Calcarenite and the Argille subappennine. It constitutes an incomplete sequence where only the TST deposits are preserved, being the LST deposits probably preserved in the Ionian submerged sector of the Salento Peninsula, while most of the HST deposits were eroded due to the high-frequency and high-amplitude relative sea-level changes occurring starting from the Middle Pleistocene. As such, most of these sediments records a clear transgressive trend moving from NW to SE and from SW to NE, reflecting the influence of the Appennine thrust migration starting from the Early Pleistocene. On this basis, we attribute the Gravina Calcarenite to the TST, while the Argille subappennine that are in the continuity of sedimentation with the Gravina Calcarenite should record the final phase of the TST and the initial phase of the HST of the Lecce 2b sequence. Consequently, the mfs of this sequence could be placed at the passage between the Gravina Calcarenite and the Argille subappennine formation.

The Lecce 2c sequence is a composite sequence that groups the Pleistocene marine terraced deposits forming the Salentino Supersinthem, a unit constituted by at least seven synthems bounded by unconformity surfaces (Ciaranfi and Ricchetti, 2013). Such synthems, which are essentially constituted by calcarenite coastal deposits, can be interpreted as incomplete depositional sequences that together form the composite low-rank sequence Lecce 2c. The latter is bounded below by a diachronous and composite (polygenic) erosional surface that cuts the older units of Cretaceous, Miocene, Pliocene and Early Pleistocene age, and above by the present emerged and submerged depositional surface. Overall, the Lecce 2c sequence covers a large area extending from depressed sectors interposed between the reliefs forming NW-SE elongated structural highs of Cretaceous age (Serre Salentine) and the coastal sector of the Peninsula.

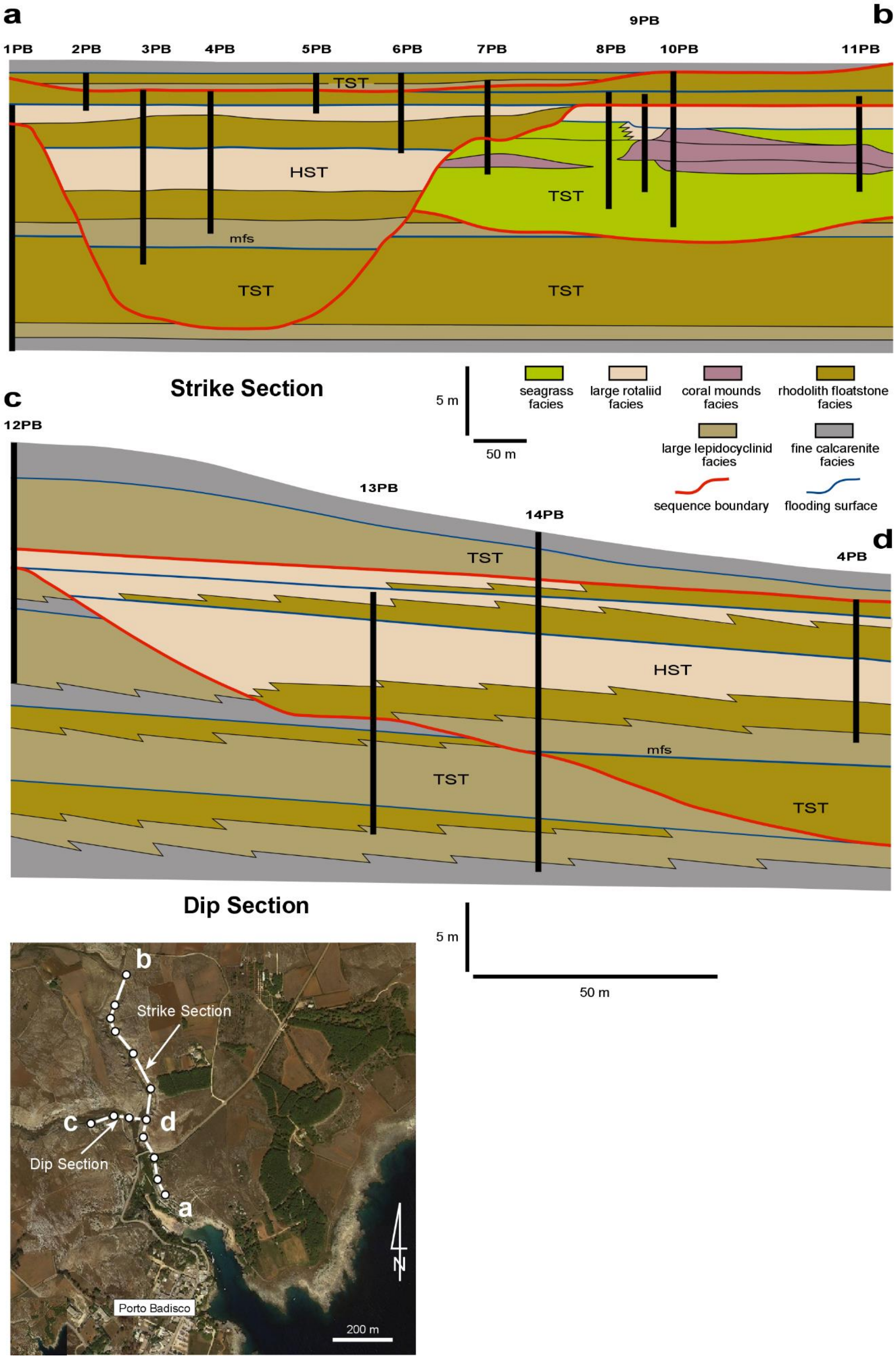


Fig. 39 - Strike and dip cross-sections of the Porto Badisco calcarenite documenting the sequence stratigraphy and facies architecture of these stratal units. The construction of these correlation panels derive by the integration of new field data and the data derived from Pomar et al. 2014 and Tomassetti et al. 2018.

The most important feature of the Lecce 2c sequence is represented by its internal stratigraphic organization that shows a general trend characterized by a seaward stack of the incomplete low-rank depositional sequences forming the terraced deposits developed along the coastal sector of the Salento Peninsula. This trend is considered to be the result of the interaction of two main factors: (i) the high frequency sea-level fluctuations related to glacio-eustasy; and (ii) the discontinuous regional tectonic uplift that affected the Salento Peninsula starting from the Middle Pleistocene. Such uplift just recognized by Ricchetti et al. (1988) was more recently interpreted by Doglioni et al. (1994, 1996) as being due to the variable degree of flexure of the central Adriatic lithosphere (70 km thick) with respect to the thicker Apulia (110 km) (Billi and Salvini, 2003). This would have produced an uplift rate of the Apulia region of ~ 0.5 mm/yr that would have forced the seaward migration of the low-rank sequences, thus contributing to define the final stacking pattern of the Lecce 2c sequence.

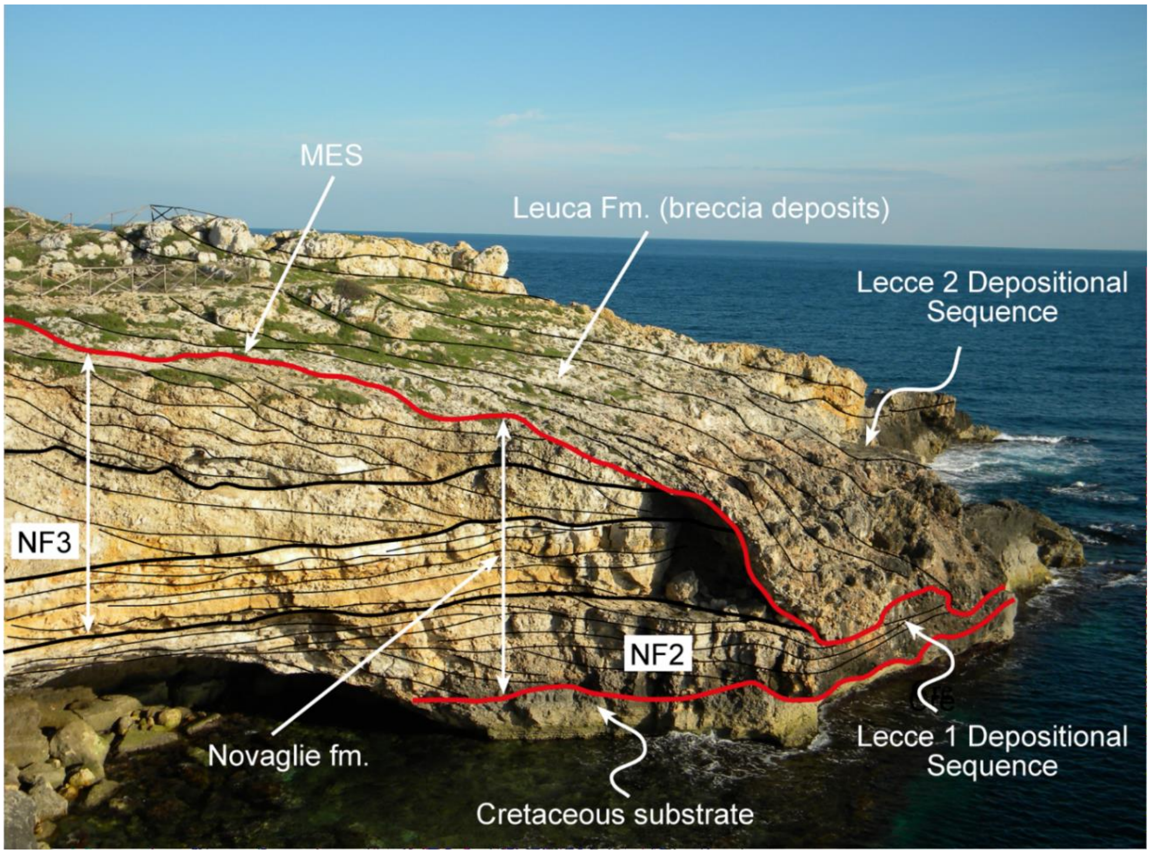


Fig. 40 - Stratigraphic succession cropping out in correspondence of Punta Ristola (Santa Maria di Leuca) showing the superimposition of the two composite high-rank depositional sequences Lecce 1 and Lecce 2 (red lines). Moving seaward the sequence boundaries of the two sequences merge due to the erosion related to the sea-level fall connected to the formation of the MES. For further explanation, the readers are referred to the text.

6. CONCLUSIONS

In foreland basins most of the carbonate platforms generally occur along the forebulge, a sector generating in response to flexural loading of the orogenic wedge; such platforms record with their deposits the variation of accommodation space induced not only by the uplift and flexural subsidence but also by the eustatic sea-level changes. The Salento Peninsula is unique under this point of view as it constituted an initial pre-orogenic carbonate platform that was interested in deformation and flexural subsidence during the orogenic events (syn-orogenic platform, *sensu* Dorobek, 1995) due to the construction of two chains that migrate in opposite directions: the Dinarides-Albanides-Hellenides chain that moves from NE to SW and the Apennine chain that moves from SW to NE. How the migration rates of these two chains have influenced the sedimentation and stratigraphic organization of the Tertiary/Quaternary succession of the Salento Peninsula is the subject of this thesis in which different paleogeographic schemes covering this time interval are presented. The schemes show how the structural setting of the area has changed over time giving rise to a sedimentary succession showing a pervasive multifold cyclicity and internally characterized by a stack of composite and simple depositional sequences of different duration and frequency.

Following the considerations and the reconstructed paleogeographic evolution of the Salento Peninsula the main conclusions derived from our work are the following:

1) The Apulia platform, at the end of the Cretaceous and during most of the Paleogene, emerged as a result of the collisional phase between the European and African plates. This process was responsible for the formation of the NW-SE extensional faults that affected the emerged and submerged sectors of the Salento Peninsula since the end of the Cretaceous, although for the offshore area, there are evidence that some NW-SE normal faults start their activity in the Calabrian (Maesano et al., 2020; Chizzini et al., 2022).

2) During the Eocene the sedimentation occurred only along the eastern sector of the Salento Peninsula between Otranto and S. Maria di Leuca, while the internal sector was probably in subaerial condition.

3) During the Oligocene, sedimentation continued in the eastern sector of the peninsula, although reduced thicknesses of lacustrine/lagoonal sediments (Galatone Fm.) began to deposit in the internal and western sectors. The effects of an initial transgression are expressed by the deposition of the Lecce fm. in the Aquitanian.

4) In the Miocene, with the deposition of the Pietra Leccese, the effects of this transgressive phase are better expressed. The transgression proceeded from the eastern to the western sectors and is well recorded by three main subunits developing in the Pietra leccese, which show an increase in the content of glauconite from the bottom to the top and a clear retrogradational stacking pattern. The increase in accommodation space is believed to be connected to the flexural subsidence induced by the westward migration of the Dinarides-Albanides-Hellenides thrust belt.

5) During the eastward progradation of the Andrano Calcarenite (Messinian) the accommodation space was reduced as a consequence of the reduced migration rate of the Dinarides-Albanides-Hellenides thrust belt; contextually the Ionian margin recorded an increased migration rate of the Apennine thrust belt.

6) In the Salento area the unique deposits referable to the Messinian Salinity Crisis are represented by the reef complex of the Novaglie fm. Strictly related to the Messinian Erosional Surface (MES) are the breccia deposits of the Leuca fm. whose deposition occurs following the sea-level fall giving rise to the formation of the MES.

7) The effects of the eastward migration of the Apennine thrust front are well highlighted by the initial deposition of the Gravina Calcarenite, and by the successive deposition of the Argille Subappennine, marking a deepening trend due to the increase of flexural subsidence related to the migration of the Apennine chain.

8) The final phase of the geodynamic evolution of the Apulian area in general and of the Salento, in particular, is still in progress. A discontinuous and uneven uplift of the entire chain-foredeep-foreland system starting from the Middle Pleistocene

produced a general retreat of the sea towards the present coastline due to the interaction between the tectonic uplift and the glacio-eustatic sea-level changes that are to be considered the main factors responsible for the current terraced modeling of both the coastal sectors of the Salento Peninsula.

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Web site

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SUPPLEMENTARY MATERIALS

No.	Name
1	F75-18
2	D79-22
3	D81-006
4	D-449A
5	D-450
6	D-467
7	D-468
8	D-469
9	D-470
10	D-471
11	D472
12	D-473
13	D-474A
14	D-475
15	**D-476A**
16	D-477
17	D-478
18	D-479
19	D-481
20	D-482
21	D-483
22	DR-215
23	F75-20
24	F75-22
25	F75-24
26	F75-26
27	F75-28
28	F75-30
29	F75-32
30	F75-34
31	F75-36
32	F76-40A
33	F76-40B1
34	F76-40B2
35	F76-42A
36	F76-42B
37	F76-42C1
38	F-76-42C2
39	F75-45
40	F75-47
41	F75-49
42	F75-57
43	F75-59
44	F75-61
45	F75-63
46	F75-65
47	F75-67
48	F75-69
49	F75-71
50	F75-73
51	F75-75
52	F75-77
53	F75-79
54	F75-81
55	F75-83
56	F75-85
57	F76-38
58	F76-46
59	F76-51
60	F76-53
61	F76-55
62	F76-57
63	F76-59
64	F81-105
65	D-476B
66	F81-105-2.0
67	D79-10
68	D-449C
69	F76-16
70	F75-43
71	D-466

The list of the 71 seismic lines interpreted in this thesis.