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ORIGINAL ARTICLE

Geoconservation in Sicily (Italy): the Example of the Isola delle Femmine (Palermo)

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Abstract
The Regional Administration of Sicily recently erected Isola delle Femmine—a small island of the Tyrrhenian Sea, close to Palermo—as a geosite. A detailed geological survey has been carried out in order to define the most important geological features of the island together with the development of a new geological map based on topographic data and a digital model at 1:2.000 scale specially processed. Finally, a geological pathway through the island has been traced and illustrated. The geological substrate of Isola delle Femmine consists of a Mesozoic carbonate succession belonging to the Panormide Carbonate Platform. Two lithostratigraphic units have been differentiated. The lowest one consists of dolomitic limestones cropping out in the intermediate and northern part of the island. Despite the absence of biostratigraphic constrains, analogies with comparable deposits from the Palermo Mountains suggested to ascribe this unit to the Upper Triassic. The overlying unit consists of well-bedded rudist and stromatolitic limestones organized in peritidal cycles. The macro- and micro-facies analysis of these Cretaceous limestones allows to attribute this unit to the Lower Cretaceous (i.e., Aptian). Patches of upper Pleistocene skeletal calcarenites rich in benthic foraminifers and calcareous algae overlap the Mesozoic units. Spectacular speleothems such as stalagmites, ray crystals ("raggioni") of calcite, and mammillary calcite suggest a relative long-lasting exposure of the Mesozoic carbonate substrate to groundwater. This is not surprising since glacio-eustatic oscillations caused sea-level to fall up to 125 m during the Pleistocene thus exposing and linking to the mainland (Sicily) Isola delle Femmine and the surrounding area.

Keywords Geosites · Geological map · Carbonates · Speleothems · Cretaceous · Sicily

Introduction

In Italy, the management of the geological heritage is entrusted to ISPRA (Institute for Environmental Protection). However, several Italian regional administrations developed proper databases concerning the geosites. Since the early 1990s of the past century, the Regional Administration of Sicily set as an objective to identify the geological sites of greater value and scientific interest in its territory. Consequently, a regional law (L.R. n. 25, 11 April 2012) formalized the "Rules for the recognition, cataloging and protection of geosites in Sicily" to promote the establishment and management of geosites. The Regional Department for Land and Environment (ARTA Sicilia) has been charged with establishing a Regional Catalogue of Sicilian Geosites, based on the criteria and guidelines for the management and protection of geosites. The data analysis and definition of a single geosite are under the supervision of a Regional Committee on Geosites formed by delegates from the University, the Regional Administration, and the Regional Order of Geologists.

As first effect of the Regional Law n. 25/2012, about 80 natural reserves have been erected also as geosites on the base of geological peculiarities already described at the time of the legislative anactment. However, in some cases, these geosites lack careful and updated descriptions of the geological peculiarities present in their area.

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Taking into account the above considerations, the present contribution aims to describe and highlight the geological aspects of one of the natural reserves erected as a geosite, namely, Isola delle Femmine (IdF hereafter), a small island located along the Tyrrhenian coast of Sicily, not so far from Palermo.

Methods

A first step for the description of the geosite has been the achievement of a detailed geological map of Isola delle Femmine. The map was based on an original 1:2,000 topographic map, and a Digital Elevation Model processed thanks to a Trimble R10 GPS instrumentation.

The geological mapping has been integrated by the analysis of bed attitude and the sampling of about 30 selected sites to define lithology and areal distribution of the outcropping rock successions.

The carbonate facies analysis is based on the classifications proposed by Dunham (1962) and Embry and Klovan (1971) and performed both on the field and at the Laboratory of Stratigraphic Geology (Department of Earth and Marine Sciences, University of Palermo), where about 20 thin sections have been analyzed for microfacies characterization by means of a petrographic microscope Zeiss Laborlux associated to the Zen software for the acquisition of microphotographs.

The biostratigraphic analysis was based on the biozonal schemes proposed for the Cretaceous inner-carbonate platforms of the Western Tethys (Chiocchini et al. 2008 and references therein).

The Geosite of Isola delle Femmine

IdF is a small island located about 300 m N of the Tyrrhenian coastline between Capo Gallo and Punta Raisi in northwestern Sicily (Fig. 1). The island, also known as "Isola di Fuori" in some geographic maps, gave the name to the Municipality of Isola delle Femmine, located onshore facing the island.

This island has an oval shape (about 580 m long and 325 m wide) with a maximum elevation of 38 m a.s.l. Its topographic profile is asymmetric with a steep northern cliff and a gentle southern slope.

A tower dating back to the sixteenth century and known as *Torre di Fuori* dominates the island's highest point (Fig. 2). This tower was part of a system of watchtowers created by the Florentine architect Camillo Camilliani. All the Camilliani's watchtowers have the same structure with a squared base, few internal divisions, and a large tank to collect rainwater. Nowadays, it is possible to observe the northern side of the tower while the southern part is collapsed (Fig. 2).

In 1997, the Sicilian Region inserted IdF among the protected areas of Sicily (i.e., *Riserva Naturale Orientata Isola delle Femmine*) to safeguard the island as a whole and specifically the geological aspects, the floristic-vegetational heritage, and the local entomofauna. This natural reserve is entrusted to LIPU (Italian League for Bird Protection) and extends for about 15 hectares and includes a zone of integral protection which comprises the herbaceous and shrubby vegetation typical of the Mediterranean bush that consists of numerous habitats, from the garrigue to the steppe, from the grasslands to the rocky coasts.

In 2002, the marine area between Capo Gallo and Isola delle Femmine was erected as a marine protected area that

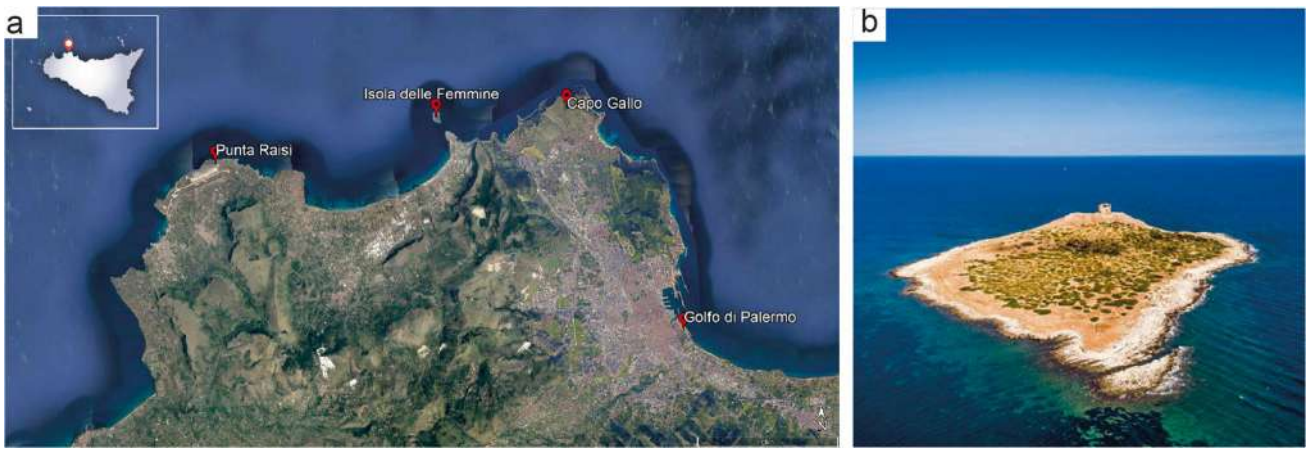

Fig. 1 **a** Location of Isola delle Femmine in a Google Earth satellite view of the Palermo area. **b** Aerial view (from south) of IdF (mod. from https://viaggi.corriere.it/)

Fig. 2 Two views of the watchtower *Torre di Fuori* from north (**a**) and south (**b**)

extends for 2173 hectares and is subdivided into three zones (i.e., A, B, and C) according to different protection levels (Fig. 3). The zone of integral protection (A) is located in the area comprising the north-western and north-eastern sectors of IdF and the western sector of Capo Gallo. The zone of the general reserve (B) surrounds the A zone. Finally, the zone of the partial reserve (C) covers the remaining part within the perimeter of the marine protected area (Fig. 3).

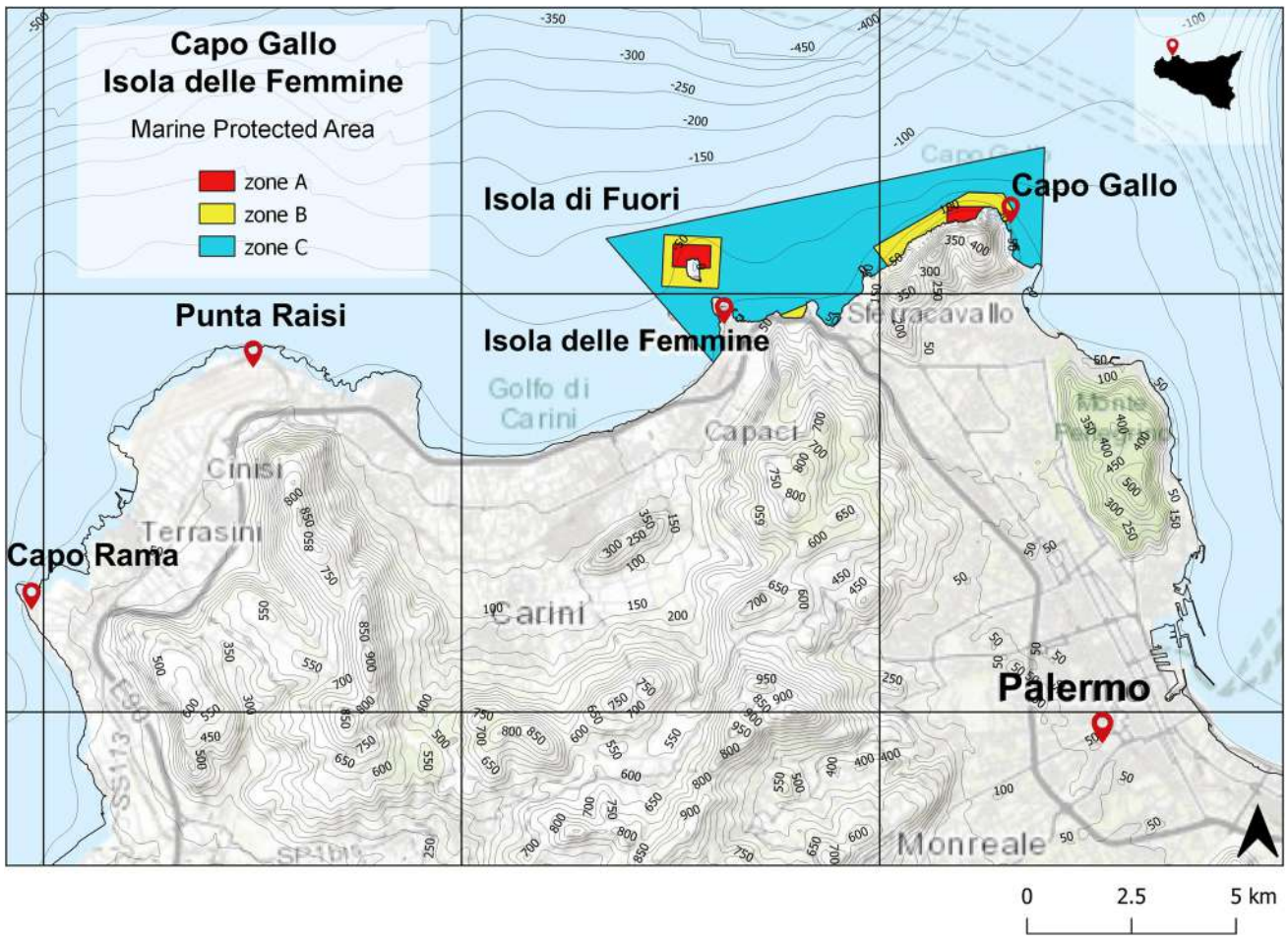

Fig. 3 Marine protected area between Capo Gallo and Isola di Fuori (mod. from official cartography of Marine Protected Areas, D.M. 24/07/2002)

Geological Setting

The geological setting of IdF is partly in accordance with the lithologies (mostly carbonates) and the geological structures cropping out in the larger area of the Palermo Mountains. This latter is part of the Apennine-Maghrebian chain and consists of south-verging thrust sheets of Mesozoic and Cenozoic sedimentary rocks piled up during Miocene times. The Mesozoic and Cenozoic carbonates are overlapped by Plio-Quaternary calcarenites and clays along a major erosional unconformity (Catalano et al. 1996 and references therein).

The tectonic units cropping out in the northern sector of the Palermo Mountains consist of thick (some thousand meters) successions of shallow-water limestones that were part of a large Mesozoic paleogeographic domain of the south-western Tethys known as Panormide Carbonate Platform (PCP hereafter) (Giunta and Liguori 1972; Catalano and D'Argenio 1982). In this paleogeographic domain, peritidal and reef carbonates were deposited in about 190 My ca., from the Late Triassic (Todaro et al. 2017, 2018; Todaro 2019) up to the Eocene. Sedimentation was influenced by severe extensional tectonic phases which affected the PCP during Jurassic (Zarcone and Di Stefano 2008) and Cretaceous times (Randazzo et al. 2020a, b).

Various reconstructions of the PCP have shown its development in a complex geodynamic area located during the Mesozoic between two oceans, the Ionian Tethys to the east and the Alpine Tethys to the west (Stampfli and Borel 2002; Rosenbaum et al. 2004). Despite the influence of long- and short-term sea-level fluctuations and palaeoceanographic perturbations, the repeated phases of uplift and erosion suffered by the PCP seem to be primarily associated with the geodynamic interaction of the two oceanic domains mentioned above (Zarcone and Di Stefano 2008; Capitanio et al. 2009; Zarcone et al. 2010; Frizon de Lamotte et al. 2011; Vitale et al. 2018; Randazzo et al. 2020b).

Based on the major occurrence of peritidal facies, the IdF area has been attributed to a tectonic unit that was part of the inner sector of the Mesozoic PCP. In particular, the presence of Upper Jurassic to Lower Cretaceous shallow-water carbonates was reported in previous contributions and geological maps concerning both the island and the facing coastal area (Bommarito 1982; Catalano et al. 2013). The Mesozoic carbonate succession of IdF was ascribed to one single formation (i.e., Calcari di Capo Gallo) in the recent 1:50.000 geological map (CARG Project, Sheet, 585–594 "Partinico—Mondello").

During the Plio-Pleistocene, the Palermo Mountains and the offshore sector including IdF were affected by strike-slip and extensional faults related to the evolution of the Tyrrhenian margin (Giunta et al. 2000b; Pepe et al. 2004). In particular, according to their observations, the complex fault grid consists of NW–SE– and E-W–oriented dextral strike-slip faults, and N-S– and NE-SW–oriented sinistral strike-slip faults (Giunta et al. 2000b).

Lithostratigraphy

Differently from previous studies, the new geological survey of the IdF reveals that the geological substrate of the island consists of two lithostratigraphic units of Mesozoic age (Units A and B, respectively) (Fig. 4). They are covered by thin levels of Upper Pleistocene calcarenites (Unit C), eluvial-colluvial detrital covers, and landslide deposits (Fig. 4).

Unit A–Dolostones and Dolomitized Limestones

This unit is exposed in the northern and central sector of the IdF and consists of whitish to gray massive dolostones and dolomitized limestones showing in places a brecciated, vacuolar texture (Fig. 5). The observed lithofacies are crystalline carbonates and the pervasive dolomitization hindered their biostratigraphic characterization and thus the chronostratigraphic attribution. However, some poorly preserved "ghost" structures observed in thin-section may suggest the presence of remnants of calcareous sponges and therefore a shallow-water depositional environment. The thickness of the outcropping part of this unit remains undetermined. Analogous deposits are well known in the Palermo Mountains area and, in particular, at the base of the Mt. Gallo succession, about 5 km east of IdF.

Unit B–Gray Limestones

Unit B consists of parallel-bedded gray, fossiliferous limestones cropping out in the southern part of the island. The bed attitude is almost constant, dipping 30–35° WNW, and the thickness of the outcropping succession is about 200 m. This unit allowed a detailed analysis of the carbonate macro-and-microfacies (see hereafter). On the base of the fossil content and, in particular, of the rudists, this unit can be subdivided in a lower part (Unit B1) that consists of Requienid limestones, well exposed in the south-eastern corner of the island, and in an upper part (Unit B2) made up by Caprotinid limestones occurring in the western sector of IdF.

Unit C–Pleistocene Calcarenites

This unit consists of thin patches of skeletal calcarenites with mollusks, echinoids, benthic foraminifera, and reddish algae. It lies with an angular unconformity above the

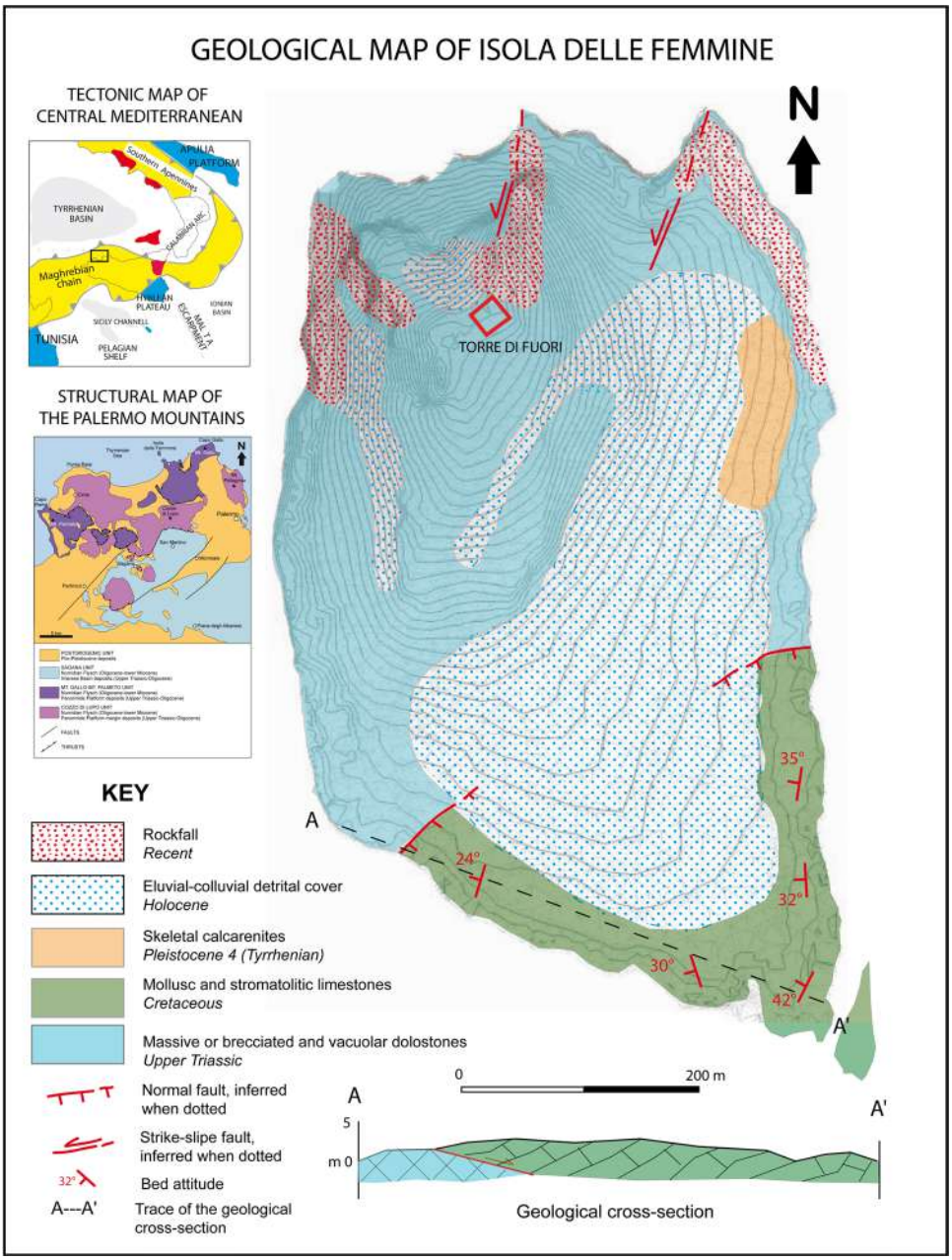

Fig. 4 Geological map of IdF

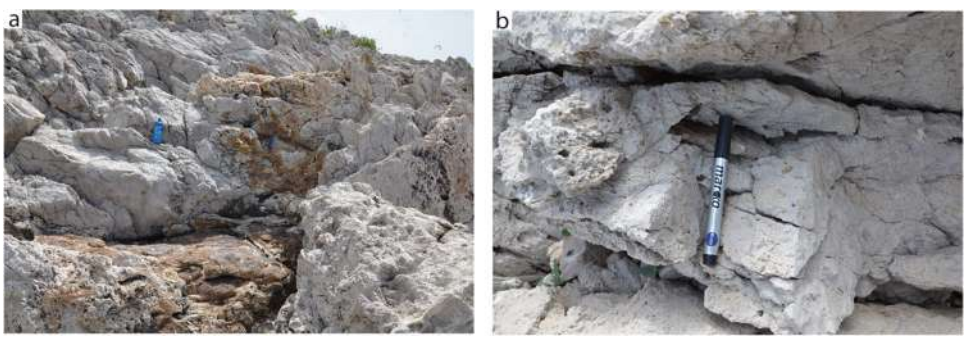

Fig. 5 **a** Outcrop view and a **b** detail of the whitish limestones

Mesozoic units. The unconformity is marked by a subaerial erosional surface associated to dissolution cavities and it is well exposed in the eastern margin of the island at an elevation of about 7 m a.s.l (Fig. 6a). Cavities and fractures are filled up by reddish to yellowish residual silt. The fossil association suggests an Upper Pleistocene age for this unit that is attributed to the Barcarello synthem (Di Maggio et al. 2009) (Fig. 6b). In particular, these deposits could probably correlate the MIS 5.5 highstand (Antonioli et al. 2006).

Eluvial–Colluvial and Rockfall Deposits

The eluvial-colluvial deposits consist of reddish calcareous siltstones and sands that show, in places, an early cementation. These deposits extend in the central and eastern part of the island, reaching a thickness of a couple meters. Several patches of dolomitic gravels also occur as results of some rock falls, mostly in the northern part of the island. They were already mapped in the regional database of the hydrogeological hazard (Regione Siciliana, 2006).

Tectonic Features

Among the tectonic features of IdF, worth of mention is the contact between Unit A and B, that is a low angle fault plane dipping about 15° to SE. This contact is observable both along the eastern and western coast (Fig. 7), while in the inner zone of the IdF, it is covered by eluvial-colluvial deposits. The well-bedded gray limestones of Cretaceous age (dipping about 24–35° NW) are abruptly truncated by this fault pane. A similar and peculiar contact is observed at Raffo Rosso, a cliff in the eastern sector of Mount Gallo, not far from IdF. Also, in this locality, it is possible to observe a low angle fault contact between Triassic dolostones and Cretaceous limestones. The occurrence of low

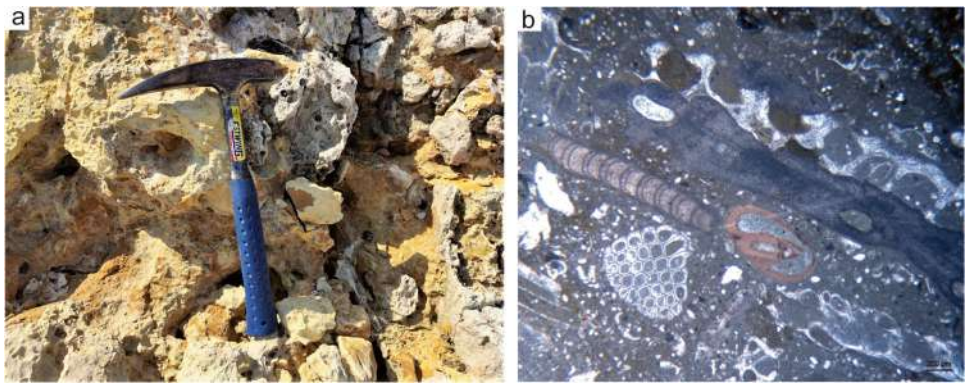

Fig. 6 Unit C, macro (**a**) and microfacies (**b**) of the Upper Pleistocene calcarenites. **a** The lower part of the calcarenites covers an irregular erosional surface on the dolostones of Unit A, filling also some fractures. **b** The most common microfacies are skeletal packstone/wakestone rich in red algae, bryozoans, and mollusks

Fig. 7 Tectonic contact between the whitish dolostones of Unit A (left) and the Cretaceous gray limestones (Unit B) along the south eastern margin of IdF. Consider that the parallel bedded gray limestones dip WNW about 35° and are sharply truncated by the low angle fault plane (see geological cross-section in Fig. 4)

angle normal faults (LANF) along the Apennine-Maghrebian chain is well known (Oldow et al. 1993; Collettini et al. 2006) and often related to the extension of the Tyrrhenian margin along the coast of Sicily (Nigro and Renda 2004).

In addition to the LANF between Unit A and B, two high-angle (50–70°), NNE-SSW–oriented faults crosscut Unit A. These faults are related to the extensional-transtensional system that from the Lower Pliocene onward dislocated the thrust system of the Sicilian-Maghrebian chain (Giunta et al. 2000a).

Facies Analysis of the Cretaceous Limestones

On the basis of its fossil content and stratigraphic position, Unit B can be subdivided in two subunits. The main facies types are listed in Table 1.

Unit B1–Requienid Limestones

This subunit crops out in the south-eastern sector of IdF and consists of well-stratified dark-gray limestones showing three main facies types, such as bindstones with *fenestrae* or bird's-eyes (F1), packstones/wackestones with benthic foraminifers and dasycladacaean algae (F2), and rudstones/floatstones with requienids (F3) (Fig. 8). These facies types are referable to intertidal (F1) and subtidal (F2, F3) environments, thus suggesting that Unit B was deposited in the innermost area of the PCP. F1 and F2 dominate this unit, while the occurrence of F3 is constrained to sporadic levels. The presence of abundant and often disarticulated rudist shells suggests that F3 was related to high-energy events, such as storms, carrying the bioclasts from the margin to the inner sector of the carbonate platform (Fig. 8c). The observed sedimentological features highlight a clear lateral continuity of the IdF succession with that exposed on the coast opposite to it (Nicchitta 1999). This is confirmed by the comparison between facies and biostratigraphic assemblage of samples collected from the onshore coast (samples N0-N6) and the IdF (samples F0-F7).

The assemblage in both samples mainly consists of benthic foraminifers *Pseudocyclammina* sp. (Fig. 9a), *Trochamminoides cf. coronus* LOEBLICH & TAPPAN, *Vercorsella arenata* ARNAUD VANNEAU (Fig. 9b), *Cuneolina camposaurii* (SARTONI E CRESCENTI), *C. laurentii* (SARTONI E CRESCENTI), *Cribellopsis* sp., *Praechrysalidina infracretacea* LUPERTO SINNI (Fig. 9c and d), *Pseudolituonella* sp., *Quinqueloculina* sp. and dasycladalean algae *Salpingoporella* sp. (Fig. 9e), and *Salpingoporella dinarica* RADOIČIĆ (Fig. 9f and g). Other shallow-water skeletal grains are echinoids (fragments and spines), ostracods, brachiopods, gastropods, and rudists mainly ascribed to the Requienidae. The assemblage shows in the whole good matches with the *Salpingoporella dinarica* taxon range zone by Chiocchini et al. (2008), thus suggesting an early Aptian age for Unit B1. Coeval taxa that are exclusive of backreef setting such as *Mesorbitolina texana* (ROEMER) and *Dictyoconus pachymarginalis* SCHROEDER (Chiocchini et al. 2008) lack in this assemblage. Furthermore, fragments of rudist shells have been observed just in few isolated beds interpreted as storm layers.

Unit B2–Caprotinid Limestones

Unit B2 is exposed in the southwestern sector of IdF and represents the stratigraphic prolongation of Unit B1. The facies observed in Unit B2 are laminated limestones (F1), packstones/wackestones with benthic foraminifers (F2), and skeletal rudstones rich in rudists, mainly caprotinids (F4) and ostreids (F5). F1 and F2 are the most common facies also here, speaking in favor of an inner platform depositional environment. As suggested by the occurrence of sporadic storm layers (F4, F5), the platform was still subject to high-energy events. Unit B1 and B2 thus share many sedimentological features, though caprotinids dominate the rudist assemblage of Unit B2. Furthermore, the

Table 1 Main facies types of the Cretaceous gray limestones (Unit B)

Facies	Texture	Main constituents	Depositional setting
Laminated limestones (F1)	Bindstone	Peloids, ostracod	Intertidal zone
Foraminiferal and algal limestones (F2)	Wackestone/packstone	Peloids, botryoidal lumps, ostracod, benthic foraminifers, dasycladalean algae, intraclasts	Low-energy subtidal zone
Requienid limestones (F3)	Rudstone/floatstone	Benthic foraminifers, gastropods, echinoderms, rudists (requienids)	Subtidal zone subject to storm events
Caprotinid limestones (F4))	Rudstone/floatstone	Benthic foraminifers, dasycladalean algae, echinoderms, rudists (caprotinid), brachioods, intraclasts	Subtidal zone subject to storm events
Ostreid limestones (F5)	Rudstone/floatstone	Ostreid shells	Subtidal zone subject to storm events

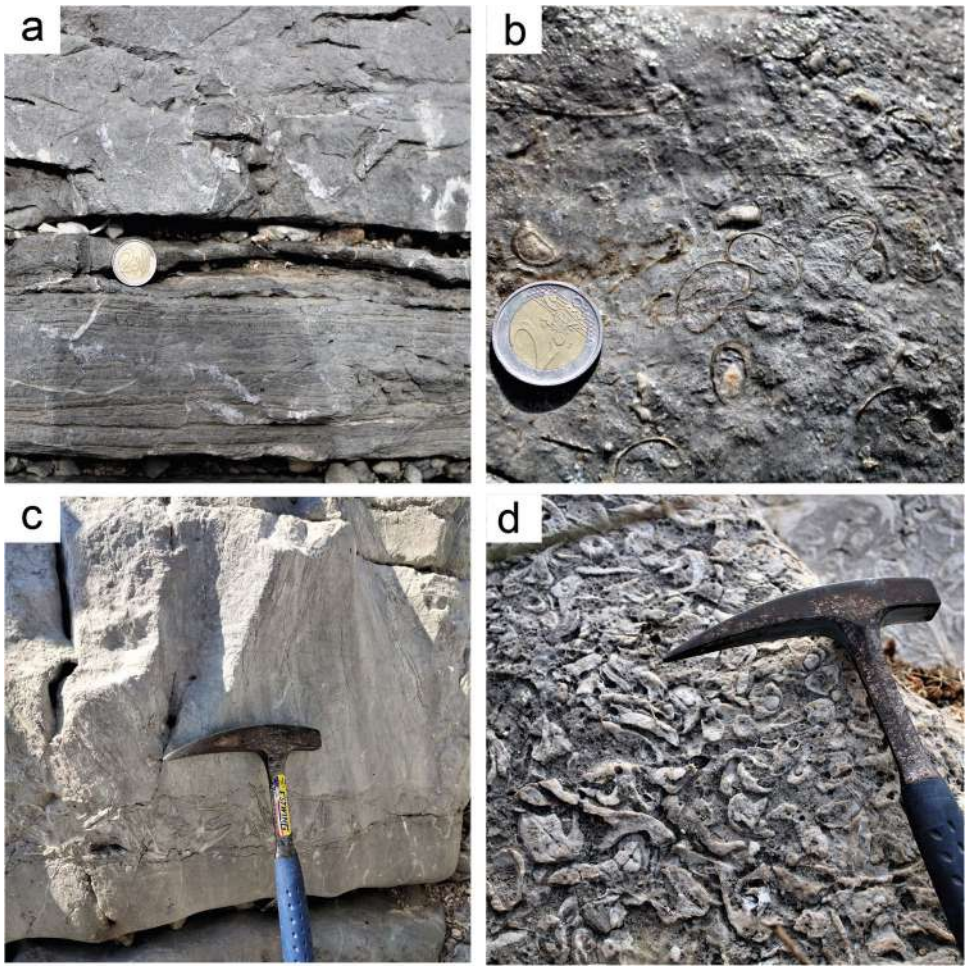

Fig. 8 Main facies types from Unit B: **a** Laminated limestones (F1) passing upward to foraminiferal and algal limestones (F2); **b** requienid limestones (F3); and **c** foraminiferal and algal limestones (F2) capped by an ostreid rud/floatstone (F5, storm layer) and, in turn, by foraminiferal and algal limestones (F2) and laminated limestones (F1). **d** Caprotinid rudstone (F4)

assemblage of Unit B2 (samples F16-F14) also differs from the preceding one as it lacks calcareous algae (e.g., *Salpingoporella dinarica*). *Vercorsella arenata*, *Cuneolina camposaurii*, *C. laurentii*, *Trochamminoides cf. coronus*, *Quinqueloculina* sp., and cfr. *Sabaudia* sp. continued from Unit B1, while large benthic foraminifers such as *Haplophragmoides* sp. (Fig. 9h), *Pseudonummoloculina* sp. (Fig. 9i–k), and *Archaealveolina reicheli* (DE CASTRO) (Fig. 9l–n) firstly occur. Echinoids (fragments and spines), ostracods, brachiopods, and gastropods complement the assemblage. The peritidal/inner platform depositional setting proposed for this section may be further confirmed by the abundance of *Archaealveolina reicheli*, which seldom occurs in backreef settings (Chiocchini et al. 2008). The observed assemblage is well comparable with the *Archaealveolina reicheli* taxon range zone (Chiocchini et al. 2008) since it records the first occurrence of the index form and the lack of *Salpingoporella dinarica*, thus suggesting a late Aptian age for Unit B2. On the whole, this succession is comparable to the lower part of the onshore succession well exposed at Pizzo Muletta, a locality about 4.5 km south of the IdF (Randazzo et al. 2021).

Facies Stacking

The facies described in Unit B are organized in aggrading peritidal cycles with an average thickness of about 35 cm (Fig. 10). The dominant facies are laminated limestones (F1) that alternate to foraminiferal and algal limestones (F2) and/or to mollusk rudstones/floatstones (F3, F4, F5) along the whole section. Supratidal facies (e.g., thin levels of green marls) were not observed, though they are common in the onshore succession (Nicchitta 1999). However, in the case of IdF, they have been likely obscured by the coastal erosion. The vertical stacking of the different facies appears very irregular, with symmetric and asymmetric cycles displaying either shallowing or deepening trends as already observed onshore in Lower Cretaceous successions (Nicchitta, 1999).

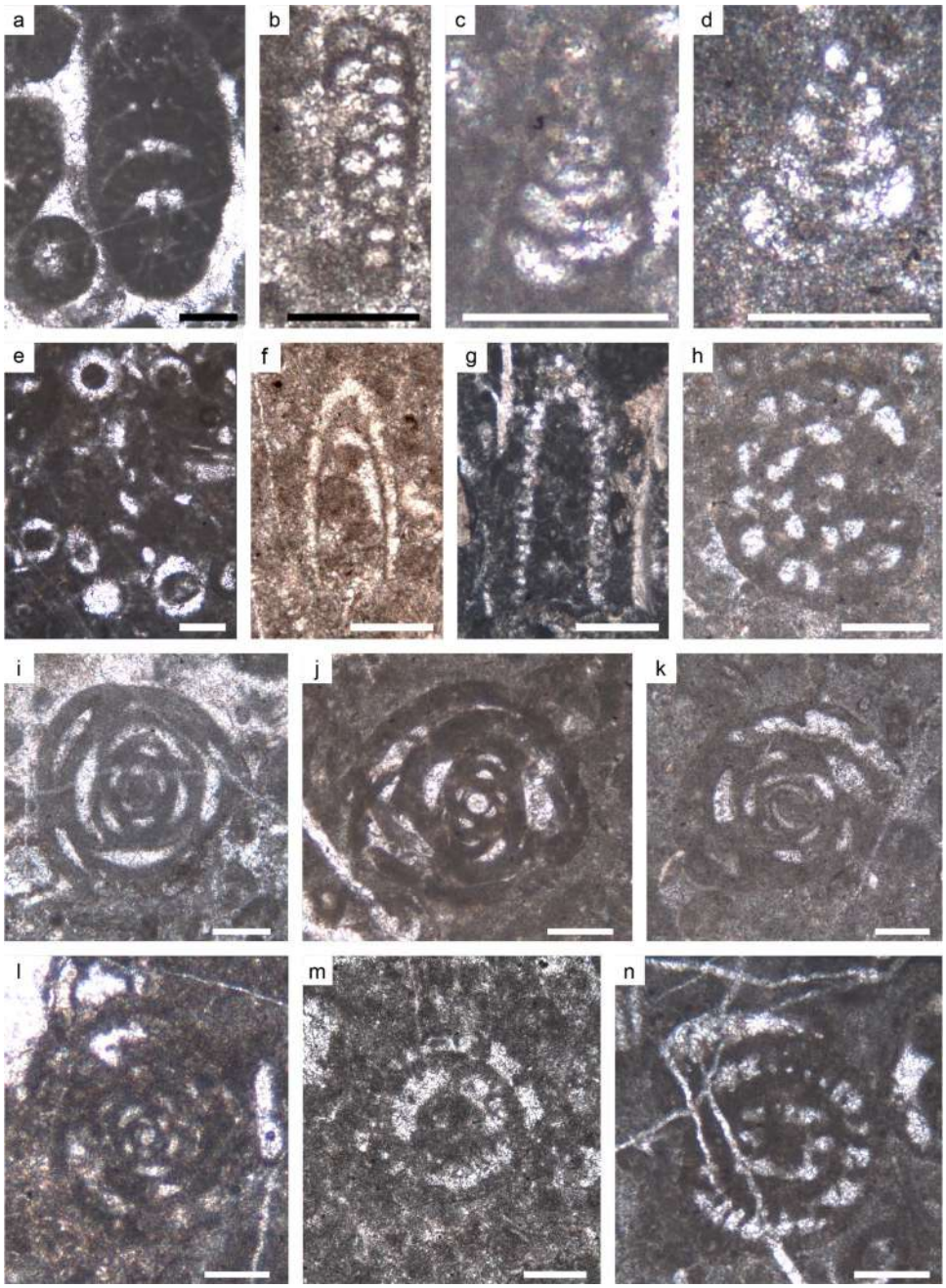

Fig. 9 Microfossil assemblage from Unit B: **a** *Pseudocyclammina* sp.; **b** *Vercorsella arenata* ARNAUD VANNEAU; **c**, **d** *Praechrysalidina infracretacea* LUPERTO SINNI; **e** *Salpingoporella* sp.; **f**, **g** *Salpingoporella dinarica* RADOIČIĆ; **h** *Haplophragmoides* sp; **i–k** *Pseudonummoloculina* sp.; **l–n** *Archaealveolina reicheli* (DE CASTRO)

Speleothems

Peculiar calcite/aragonite speleothems are widespread at IdF, both along the coast and in the innermost area of the island in Unit A and Unit B. They represent one of the most important geological features of the IdF. Besides some stalagmites, either individual (Fig. 11a) or coalescent (Fig. 11b, organized in organ pipe structures) and flowstones, the most beautiful and widespread speleothems are cm to dm raycrystals ("raggioni") (Assereto and Folk 1980). Part of these speleothems can be traced to a type of calcite known as mammillary calcite (vein calcite by Winograd et al. 1992). These bulbous bodies ("cave clouds") are generally white to yellowish and typically form on the roof of overhanging walls of the submerged embedded host rock (Fig. 11c, d) under phreatic conditions near the water table.

Other spheroidal calcitic bodies are described as shelfstones (Hill and Forti 1997, p. 96). These globular bodies, which may reach several decimeters, also form at the bottom of pools. The abundant presence of this type of calcite, together with other speleothems such as stalagmites and floatstones, suggests past existence of long-range groundwater flowpaths within the island. This is not surprising as the glacio-eustatic oscillations caused sea-level to fall up

Fig. 10 Peritidal cycles in Unit B that consist of laminated limestone (F1) and foraminiferal and algal limestones (F2)

to 125 m in the Pleistocene, thus subaerially exposing and linking to the mainland Sicily, IdF, and a large surrounding area during the glacial stages. Moreover, besides the karstic dissolution, the establishment of groundwater circuits could have been favored by the extensional tectonics (e.g. Riggs et al., 1994) related to the opening of the Tyrrhenian basin creating fracture networks and caves.

Vermetid Reef

Among the geological peculiarities of IdF, we consider the "worm trottoir" or "worm-shaped" shore-reef, an above-water bioconstruction produced by a family of mollusks, which follows the sinuosity of the shoreline by filling shallow cavities.

This bioconstruction is typical of the Mediterranean Sea, in many ways similar to coral reefs, and has been described for the first time as "worm trottoir" by Jean Louis Armand de Quatrefages 1854.

Such reefs are the products of the building action of two species: the vermetid gastropod mollusk *Dendropoma* (*Novastoa*) *petraeum* (Monterosato, 1982) and the encrusting Rhodophycea *Neogoniolithon brassica-florida* (Harvey) (Setchell and Mason 1943).

From the description of the Sicilian reefs and the data presented in the literature, it is possible to define a general structure model, along which the different components are distributed, according to a transverse transect from the coast towards the sea (Chemello et al. 1990; Chemello 2009):

(i) A "*proximal frame*," which is a few centimeters thick and considered an upper marker of the reef, formed by the encrustations of two rhodophyceous algae, *Neogoniolithon brassica-florida* and *Lithophyllum byssoides*. There is also an encrustation of *Dendropoma petraeum*, referred to as the "*inner rim*," several centimeters thick and from a few centimeters to less than half a meter wide, depending on exposure to hydrodynamics.

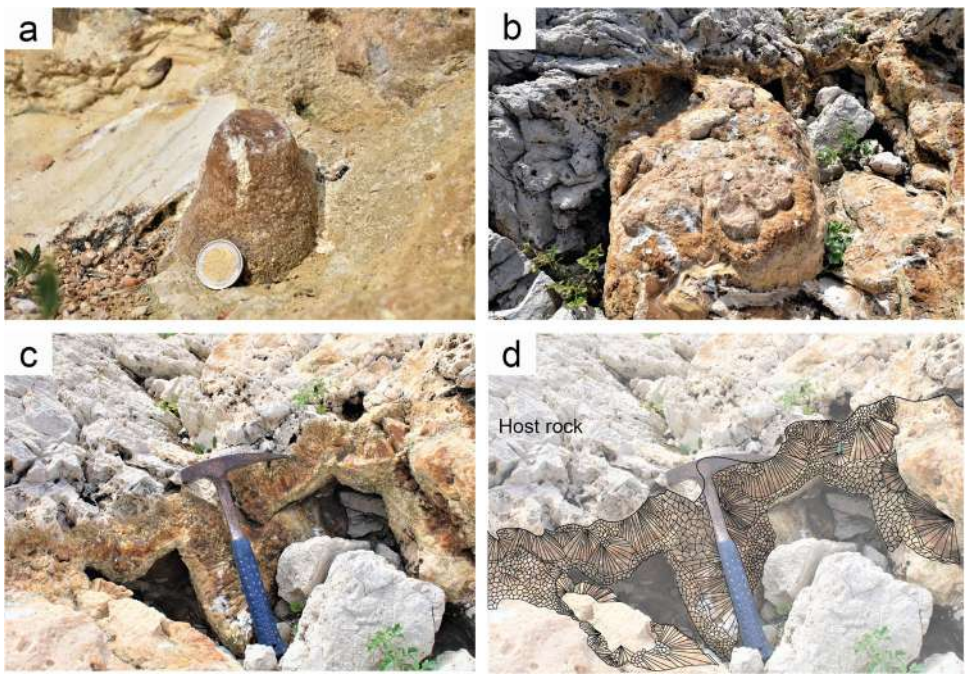

Fig. 11 Quaternary speleothems, one of the most peculiar geological aspects of the IdF: **a** part of a stalagmite surrounded by flowstones. **b** Coalescent stalagmites forming organ pipe structures; **c** mammillary calcite coating the roof of a cavity in the dolostones of Unit A. **d** Line drawning of the ray-crystals forming the mammillary structures in Fig. 11c

Fig. 12 Panoramic view of the "worm trottoir" along the eastern coast of IdF

(ii) One or more depressions in the platform, called "*cuvettes*," with a diameter varying from a few decimeters to over a meter and a depth generally less than 50 cm.

(iii) An "*outer edge*," consisting of a thick encrustation of *Dendropoma*, sometimes more than 40 cm wide and 50 cm thick, very articulated and fissured, which represents the actual active portion of the platform, expanding outward and upward.

(iv) An "*infralittoral belt*" of *Cystoseira amentaceous* var. *stricta*, placed inferior to the outer margin of the platform.

Therefore, a typical vermetid platform shows an articulated zonation between the lower mesolittoral and upper infralittoral planes (sensu Pérès and Picard 1964) and settles only on rocky coasts with increasingly less impressive formations depending on the rock substrate. They are in decreasing order of importance: calcarenites, limestones, dolomites, basalts, and flysch (Chemello 1989; Chemello et al. 1990). However, the presence of an abrasional platform is the fundamental prerequisite for the formation of a vermetid reef.

The vermetid reef observed at IdF runs mainly along the east coast and is only a few meters wide (Fig. 12). Components including the inner edge, couvette, and outer edge can be distinguished.

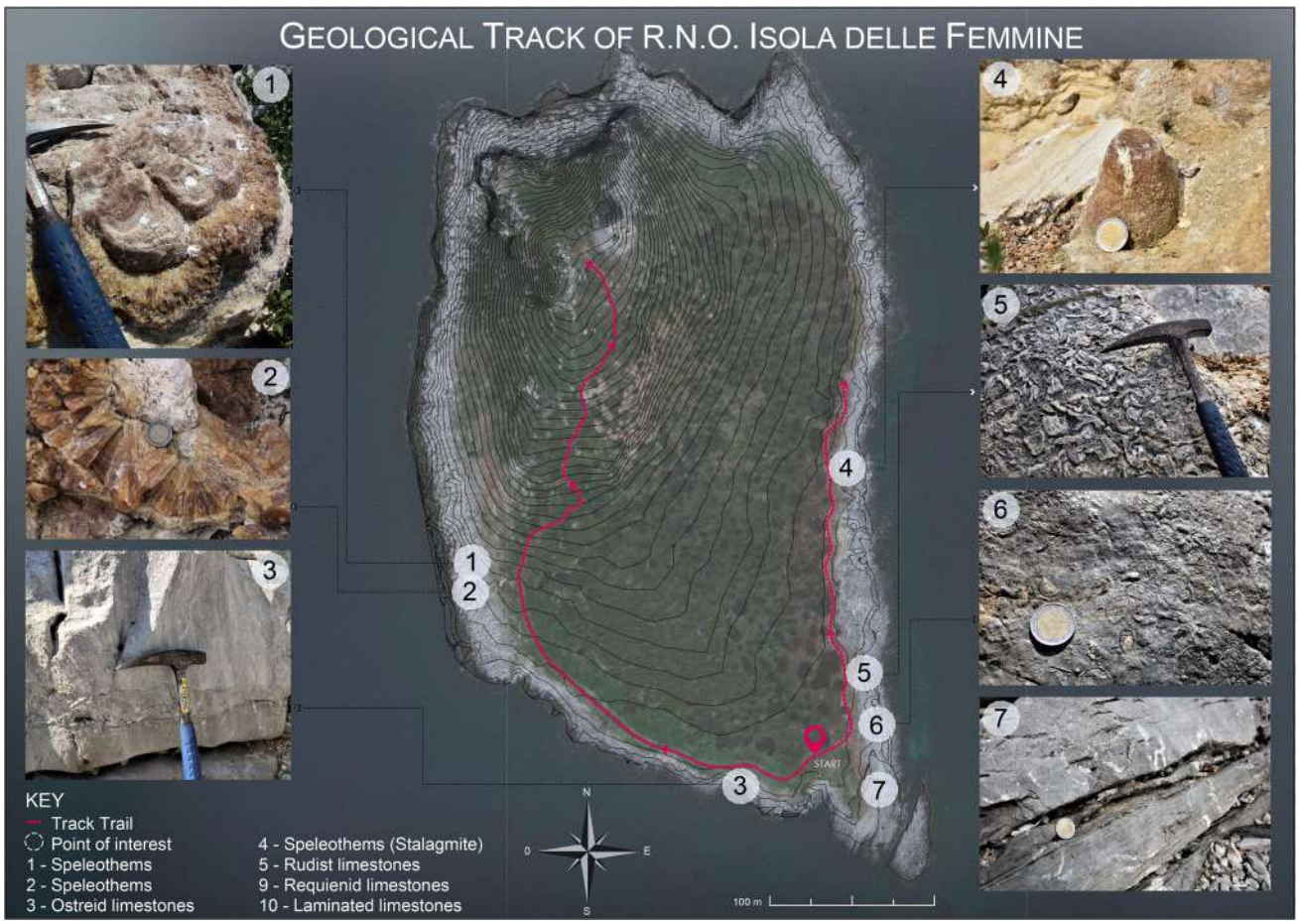

Fig. 13 Map of the Geological Peculiarities of the R.N.O. Isola delle Femmine that shows the itinerary of geological track and the position of the most noteworthy geological features

The Geological Track

The "Map of the Geological Peculiarities of the R.N.O. Isola delle Femmine" illustrates a geological track with the observation points of the geological features described above (Fig. 13).

Besides the geologic peculiarities, worth to mention are some anthropic structures such as the already described watchtower *Torre di Fuori* and the remains of seven *coccio-pesto* cisterns, dating back to the Hellenistic period. These tanks were used for the preparation of *garum*, a sought-after fish sauce traded in the Mediterranean. This trace of a plant for fish processing together with the discovery of ancient anchors and remains of Punic and Roman amphorae in the adjacent submerged areas makes the IdF geosite also important from an archeological perspective.

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Declarations

Ethics Approval The submitted work is original and has not been published elsewhere in any form or language.

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