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The palaeontological heritage of the Capo Vaticano – Monte Poro area (Vibo Valentia, Italy): research, protection, and management

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ABSTRACT
The Late Miocene successions of the Capo Vaticano-Monte Poro (Southern Italy) area, well exposed at Cessaniti – Cava Gentile, preserve a palaeontological record particularly relevant for phylogenetic studies and paleogeographic reconstructions as well as for the popular scientific divulgation and museology. The rich record of Sirenians highly contributed to the knowledge of phylogeny and intraspecific variability of *Metaxytherium serresii*. The exclusive terrestrial mammal association, having African and Greco-Iranian affinities, allows intriguing suggestions in the paleogeography of the Central Mediterranean. New taphonomic analyses on invertebrates and vertebrates, here presented, suggest that the good fossil preservation is due to the rapid burial of skeletons in a semipermeable mixture of sandy/muddy sediments which were quickly cemented. Late partial dissolution of the carbonate cement among particles made the fossils easy to extract from the sediment. The collaboration among palaeontology researchers, fossil collectors, and local administrators, under the direction of Superintendence and the control of Carabinieri Command for the Protection of Cultural Heritage, allowed the recovery, study, and promotion of this precious paleontological record. The area has a good flow of tourists for the pleasant seaside, and fossiliferous sites could attract cultural tourism, through educational trails and a museum network which valorize the palaeontological and archaeological heritage of the hinterland.

Section: RESEARCH PAPER

Keywords: Miocene; mammals; taphonomy; phylogeny; palaeogeography

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1. INTRODUCTION

In the popular tourist area of Capo Vaticano – Monte Poro (Vibo Valentia - VV, Calabria, southern Italy; Figure 1), the virtuous cooperation among researchers, palaeontology amateurs, and local administrations, under the supervision of the competent Superintendence of Cultural Heritage, is leading to the final step of promotion of the conspicuous palaeontological record [1]. This collaboration allowed the recovery, preservation, study and musealization of a huge palaeontological heritage found in this sector of the Calabria-Peloritani Arc, with an emphasis on mammals [1].

The area released an impressive abundance of fossil echinoids and other invertebrates [2], [3] associated with important remains of marine and terrestrial vertebrates, late Miocene in age [4]-[17]. The most representative site of the Capo Vaticano – Monte Poro area is Cava Gentile, a quarry located at Cessaniti (VV) [4]-[17]. For a long time, fossils of the area were subject to illegal trade or unauthorized exhibitions out of the Calabrian territory, breaking the Italian laws of protection of the Cultural Heritage [1], [18].

To contrast this negative trend, an association of palaeontology amateurs (*Gruppo Paleontologico Tropeano*; hereafter GPT) collected and stored fossils from the Capo Vaticano – Monte Poro area since 1995, correctly reporting the discoveries

Figure 1. Map showing the location of sites quoted in the text. Source: A.C.M.

to the Calabria Superintendence [1]. Although the GPT's members have not applied professional methodologies, they reported the location of many specimens [1]. Other fossils of the area were stored in institutional locations.

Among mammals, the considerable record of Sirenians first attracted researchers. In 1970, a Sirenian skeleton was collected at Santa Domenica di Ricàdi (VV) and later studied and attributed to *Metaxytherium medium* by Montcharmont Zei & Montcharmont [4]. In later studies, a large amount of Sirenian specimens recorded in younger rocks of the Monte Poro area has been attributed to the descendant species of *Metaxytherium medium*, *Metaxytherium serresii* [6], [8], [11]. The first scientific paper on terrestrial mammals, published in 2003 [5], reported the presence of *Stegotetrabelodon* cf. *syrticus*, a proboscidean of Afro-Arabian affinities.

A new impulse to studies on the mammal association started in 2008, under the permission of the Superintendence of Calabria and the scientific direction of one of the authors (A.C.M.), regulated by an agreement protocol. The study also involved researchers from other universities (Universities of Calabria, Firenze, Padova, Pisa, Barcelona, and New York) and the GPT [1].

Almost all mammals have been determined, described, and related to a new stratigraphical framework (Figure 2) [14]. The informally called "sabbie a *Clypeaster*" (from here on "*Clypeaster* sandstone") outcropping at the Cessaniti – Cava Gentile and nearby sites released not only abundant remains of the Sirenian *Metaxytherium serresii* and rare Cetaceans (Odontocetes: Physiteroidea indet.; Mysticetes: *Heterocetus* cf. *guiscardii*) but also a consistent record of terrestrial mammals (*Stegotetrabelodon syrticus*, *Bohlinia attica*, *Samotherium boissieri, Tragoportax cf. rugosifrons, 'Ceratotherium' advenientis,* an undetermined *Anthracotherid*) [5], [6], [8], [9], [11]-[16].

Other fossil vertebrates were found scattered in the deposits, mainly in the "*Clypeaster* sandstone": rays (*Myliobatis* sp.), sharks (*Carcharodon* sp., *Carcharhinus* sp.), and tetraodontiformes fishes [14].

Fossils from the area are stored at MuMe ("*Museo della Memoria*", Parghelia, VV; with the scientific supervision of the University of Messina), MuRi ("*Museo di Ricadi*", Ricadi, VV; with the scientific supervision of the University of Calabria), MuMaT at ("*Museo del Mare*", Tropea, VV), MuSNOB ("*Museo di Storia Naturale e Orto Botanico*", University of Calabria, Cosenza), MAUS (Museum of University of Salento, Lecce), MArRC (Museo Archeologico Nazionale della Magna Grecia, Reggio Calabria) and MuFE ("*Museo Civico*", Finale Emilia, Modena); (the abbreviations reported for each museum are used in the following paragraphs).

Besides the state of research and of museum valorisation of the fossils recovered in the late Miocene sedimentary successions of the Capo Vaticano - Monte Poro area, this paper presents new taphonomic analyses, regarding times and ways of fossilization. Notably, new micromorphological and geochemical data have been collected on different taxa (sirenians, echinoids, pectinids, and ostreids) to improve the knowledge of the diagenetic and preservation history of this unique fossil site.

A solid scientific knowledge is the basis for the musealization and management of the paleontological heritage, with the future perspective of new geosites and geoitineraries [19].

2. STRATIGRAPHIC FRAMEWORK

The Capo Vaticano – Monte Poro sedimentary succession and its fossiliferous contents belong to the Miocene onwards post-orogenic cover of the southern sector of the Calabria–Peloritani Arc [9], [17], [20].

At Cava Gentile (Cessaniti, VV, Figure 1) the stratigraphic succession is made up of four informal stratigraphic units that are, from base to top [3], [7], [14], (Figure 2):

i. "dark clayish sandstone with *Ostrea* and *Cerithium*", alternating with coarse sandstone, interpreted as deposited in lagoonal environment;
ii. "*Clypeaster* sandstone", interpreted as deposited in shallow marine environment;
iii. "*Heterostegina* yellow sandstone", interpreted as deposited in frankly marine conditions;
iv. "*Orbulina* marl", interpreted as deposited in a hemipelagic environment.

Soils and fluvial deposits in the "*Clypeaster* sandstone" (FL1 to FL3; Figure 2) were first recognised by Marra et al. [14]. They indicated temporary falls in sea level during the transgression, probably due to tectonic control (Figure 2). Moreover, the Authors dated the succession (from LG (Lagoonal deposits) to the top of SH4 (Shoreface deposits) between 8.1 and 7.2 Ma [14] (Figure 2).

Most of the fossil mammals come from the "*Clypeaster* sandstone". The stratigraphy at Cava Gentile is used as a reference to correlate the surrounding fossiliferous outcrops [7], [14].

The Capo Vaticano – Monte Poro sedimentary basin has a strategic role in deciphering the central Mediterranean complex palaeogeography, which underwent significant evolution during the late Miocene [17], [20], [22], [23].

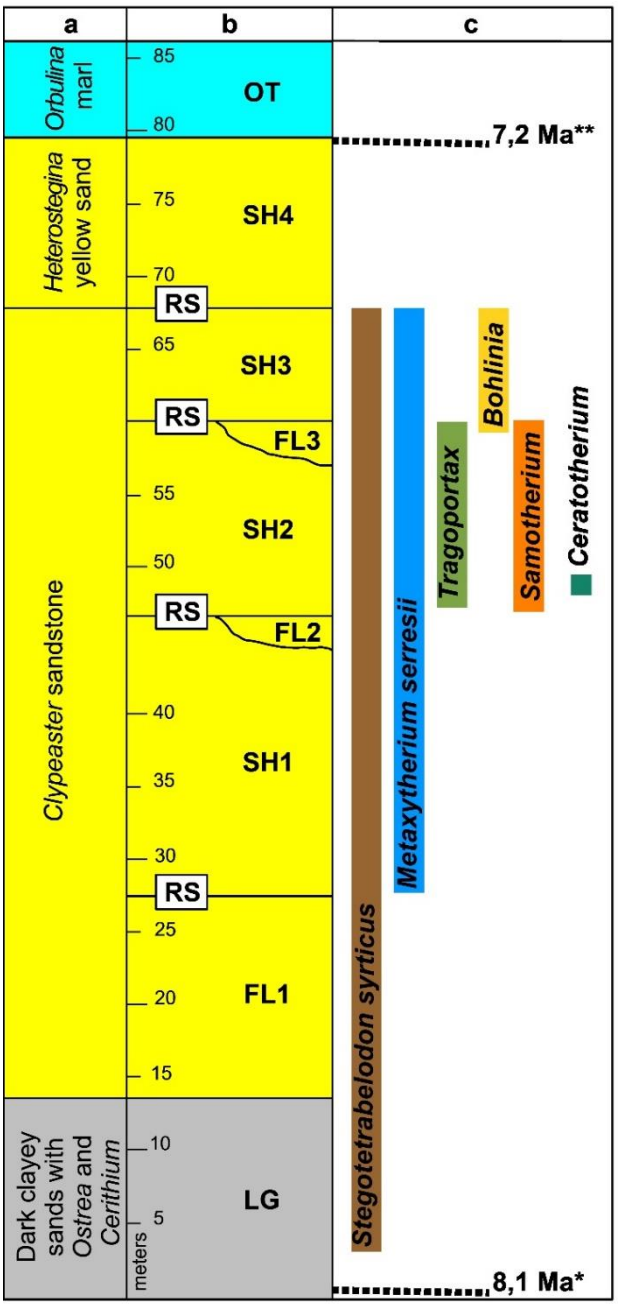

Figure 2. Stratigraphy of the Cava Gentile succession (Cessaniti, VV): a) informal stratigraphy; b) stratigraphy according to Marra et al. [14] (LG: Lagoonal deposits, FL: fluvial deposits, SH: shoreface deposits, OT: offshore transition; RS: Ravinement Surface); c) occurrences of mammal taxa. Legend: * dating for the attribution of LG to the Chron C4n; ** dating for the attribution of OT to the nannoplankton zone CNM17.

Sea level changes were responsible for the onset of continental environments with soils and fluvial phases recognized at Cava Gentile, where deposition from a near emerged land was recorded during the Tortonian [14], [24]. A transgressive phase followed more or less the modern coastline: whereas a lagoonal environment (in Figure 2) developed at Cessaniti, a shallow sea formed in the most southwestern area.

Gramigna et al. [7] provided a paleoenvironmental reconstruction of the different stages of marine transgression observable at Cava Gentile. In the first stage, the lagoonal environment (LG in Figure 2) was submerged by a shallow sea that deposited the "*Clypeaster* sandstone". The reconstructed palaeoenvironment was a marginal lagoon protected by a sandy barrier from the open sea. The transgression continued and was responsible for the landward shifting of the palaeo-coastline and deposition of frankly marine (SH4 in Figure 2) to deep sea (OT in Figure 2) sediments. The palaeoenvironment was truly marine.

3. ADVANCES IN RESEARCH ON FOSSIL MAMMALS (2003-2023)

3.1. The mammal assemblage

Marine mammals

Remains of the Sirenian *Metaxytherium serresii* abundantly occur in the "*Clypeaster* sandstone", often well preserved [2], [7], [10] (Repository: MuRi, MuSNOB, MuMaT). The sample provided valuable data to confirm the hypothesis that this species has a reduced body size, compared to the ancestor *Metaxytherium medium*, as a response to habitat variations due to the Tortonian crisis [6], [8], [11], [25]. The sample also reveals a broad intraspecific variability [6], [8], [11].

Cetaceans are represented by Odontocetes (Physiteroidea indet. and few remains indet.) and Mysticetes (few fossils of *Heterocetus* cf. *guiscardii*) [12] (Repository: MuMaT).

Terrestrial mammals

In the last years, the sample of the first-recorded terrestrial mammal, *Stegotetrabelodon syrticus* [5], was enhanced with new findings [13]. The presence of the species in the "*Clypeaster* sandstone" and in the lagoonal deposits (LG in Figure 2) [13], testifies to a more extended time persistence than other mammals (Repository: MuRi and MuFE). The record of *Stegotetrabelodon syrticus* in Calabria represents the first finding out of Africa and Arabia. In Libya, at the site of As Sahabi, a significative record of the species has been recovered and dated about 6.7 Ma; *Stegotetrabelodon syrticus* is also present in different sites of the Baynunah Formation (Abu Dhabi, United Arab Emirates), dated from 8.2 to 5.3 Ma [5], [13], [34], [35], [36], [37], [38].

Two almost complete forelimbs of *Samotherium boissieri* (Figure 7) have been recorded at Contrada Malopara (Zungri, VV) in layers correlatable with the upper part of the "*Clypeaster* sandstone", while other postcranial bones attributable to the same species come from Cava Gentile (SH1-3 units [9]; Repository: MuRi and MuSNOB).

The sample of *Bohlinia* cf. *attica* consists of an upper toothrow and postcranial elements recovered at the Cava Gentile SH3 unit (Repository: MuSNOB; [9])

Bohlinia attica and *Samotherium boissieri* were species common in the Pikermian biome, recorded in several sites of the Greco-Iranian bioprovince [39]. The occurrence of *Samotherium boissieri* in the Capo Vaticano – Monte Poro area could confirm the westward expansion of its areal [40], also indicated by the presence in some African sites (As Sahabi in Libya, Bou Hanifia in Algeria, and Nakali in Kenya [41]-[43]). *Bohlinia attica* is known from the Tortonian to the Messinian in the western regions of the Greco-Iranian bioprovince [41], [43], while its presence in Africa is uncertain [41].

A hemimandible and postcranial bones attributable to the medium-sized bovid *Tragoportax* cf. *rugosifrons* (Figure 8) [15] come from SH2–FL3 units of Cava Gentile (Repository: MuRi). The occurrence of *Tragoportax* at Cessaniti is accordingly to the presence of the taxa with African and/or Greco-Iranian affinity in the site [15], being the genus *Tragoportax* widespread in Eurasia [37], [43], [44] and signaled in Africa and Arabia [36].

Other fossils from Cava Gentile (SH2 and SH3), attributable to a small-sized bovid, are insufficient for reliable taxonomic classifications [15] (Repository: MuRi). Rhinocerontidae remains (a partial skull, a fragment of an upper tooth, and few postcranial elements; Repository MuRi and MAUS) have peculiar characteristics that allow the institution of the new species *'Ceratotherium' advenientis*, related to the African genera *Diceros* and *Ceratotherium*, clearly differing from European species [16]. Isolated limb bones seem attributable to an Antracotherid and are still under study [14] (Repository: MuRi; MArRC).

The overall data suggest that the Capo Vaticano-Monte Poro mammal fauna is indicative of a new peculiar bioprovince, characterized by the coexistence of species coming from Africa and Eastern Europe [14], [17].

The assemblage has no similarities with other Italian bioprovinces, characterised by marked insularity and Western Eurasian affinities (Tusco-Sardinian bioprovince: [28]-[33]; Apulo-Abruzzi bioprovince: [31], [32], [33]), and is earlier than the assemblage of Gravitelli, in Sicily, having African affinities [17], [26]-[29].

The biodiversity of the assemblage and the stratigraphic constraints led to assume the existence of an extended land in the Capo Vaticano - Monte Poro area with connections to North Africa [31], [14].

4. TAPHONOMICAL ANALYSES

4.1. Collecting methods

The study of the stages occurring from the death of the organism to its recovery as fossil remains usually follows scientific protocols, adequate to reconstruct the taphonomical constraints. In the case presented here, fossils have been collected thanks to the constant activity of the GPT's members on the territory. They collected emerging fossils during stops in the quarrying works at Cava Gentile and the surrounding area, mainly after rains, reporting the site and the altitude of each recovery but not always following an accurate scientific protocol.

The collectors used the informal stratigraphy of Nicotera [3] (column "a" in Figure 2) as a reference and annotated some peculiar conditions. In this way, they collected many fossils that otherwise would be destroyed and that, in any case, would not be systematically excavated due to their low concentration in the sediment.

While this collection method allowed for the recovery of an extensive fossil record, it partially compromised the taphonomic analysis.

4.2. State of preservation

The fossils are preserved in calcarenites which nowadays are loose through diagenetic processes. This makes fossil extraction quite easy due to the low degree of cementation. The good preservation state allowed the study of a very rich and differentiated invertebrate fossil assemblage [7]. Among the skeletal specimens, the most famous, common, and best-preserved fauna belongs to Echinoids, represented mainly by the genera *Clypeaster* and *Echinolampas*. Bivalves are also present with the genera *Amusium*, *Pecten*, *Chlamys*, *Glycymeris*, etc. Gastropods are less frequent and restricted to particular beds; among them have been recognized specimens belonging to the genera *Cerithium*, *Conus*, *Buccinum* and *Ancilla*, the last three preserved as moulds. In the upper part of the succession Brachiopods, mainly *Terebratula*, are relatively common and well-preserved and form decimetre-thick beds. Additionally, benthic Foraminifera are widely represented in the "*Heterostegina* yellow sand" unit, where banks constituted only by *Heterostegina papyracea* are present. The variability of the fossil invertebrates corresponds also to a high variability of skeletal structures and microstructures, characterized by different chemical compositions. This variability involves different reactions and transformation of fossils towards diagenetic fluids and, in general, this translates into different degrees of preservation between groups of different organisms. However, apart from a few Gastropods that have undergone evident dissolution processes, the fossils from Cessaniti appear well preserved on macro-scale observations. Only microscopic and geochemical analyses can highlight any alterations of the original structures.

As already said, among the vertebrate fauna, numerous fossils of marine and terrestrial mammals have been recovered [5], [9], [13], [15]-[17]. Unlike the marine invertebrates, the terrestrial and marine vertebrates suffered more severe disarticulation and maceration processes, leading to the preservation of only the most massive skeletal parts. However, these are well cemented and show no traces of bioerosion or incrustation.

The bones of the Sirenian *Metaxytherium serresii*, ribs in particular, are the most abundant and the best preserved among the mammal record, to the point of not being quantifiable [6], [11]. Cetacean remains are the worst preserved in the Cessaniti sample, except for teeth [12].

4.3. Quantitative analyses

Terrestrial mammal bones are represented by prevailing postcranial elements quite well preserved, often fragmented (Figure 3). The representation of the abundances of the skeletal elements of the terrestrial mammals found at Cessaniti (Figure 3), due to the prevalence of sturdy limb bones, can be indicative of transport and deposition in fluvial or subaerial continental environments.

Fossil collectors did not recognize the fluvial and soil nature of the deposits, later identified by Marra et al. [14]. However, in the pedogenised shore sands are present shells of *Clypeaster* replaced by clay minerals, called by the quarrymen "*Clypeaster* shadows" (Figure 4).

GPT members reported mammal fossils from layers with "*Clypeaster* shadows", presumably deriving from the soil and fluvial deposits (G. Carone, personal communication). These reports are consistent with the transport of mammal remains in the shallow sea by fluvial systems flowing from a near mainland, as indicated by the skeletal part representation (Figure 3) and the fragmentations.

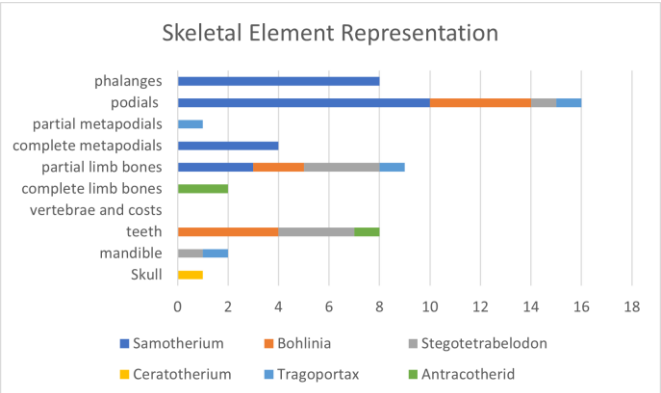

Figure 3. Skeletal element representation of the terrestrial mammals found at Cessaniti (method according to Klein and Cruz-Uribe [45]).

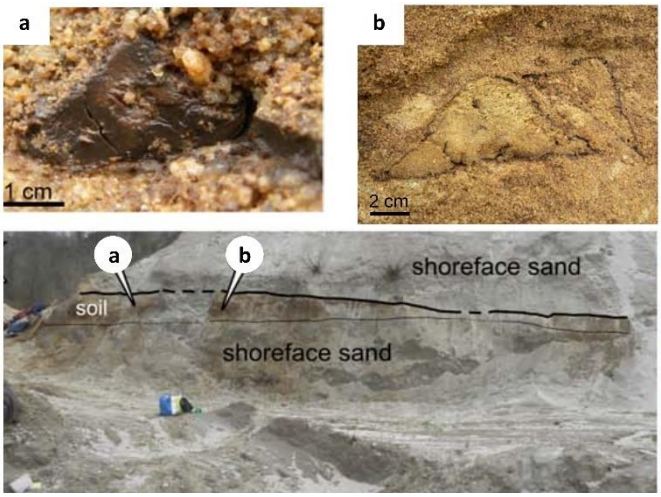

Figure 4. "*Clypeaster* shadows" in the soil represented by pedogenised shore sands (FL2 in Figure 2) at Cava Gentile: a. detail of the replacement of a *Clypeaster* shell by clay minerals; b. *Clypeaster* shells were replaced by clay minerals (modified after Marra et al. [14]).

4.4. Instrumental analyses

Fossils of Sirenian ribs, Echinoids, Pectinids, and Ostreids shells have been analysed and described in this paper to better constrain the diagenetic and preservation history of the Cessaniti site.

Materials and Methods

The fossils have been investigated using optical microscopy (Zeiss Axioplan Imaginin II) at different magnifications (2.5x, 5x, 10x, 20x, 40x) for the description of the microstructures. Incident light, emitted by Hg high-pressure vapour bulb, attached to an Axioplan Imaging II microscope (Zeiss), with high-performance wide bandpass filters, was used as a parameter of fluorescence intensity (band-pass filter 436/10 nm/long-pass filter 470 nm, no 488006, for the green light; and band-pass filter 450–490 nm/long-pass filter 515 nm, no. 488009, for the yellow light). UV-epifluorescence allowed to discriminate the presence and distribution of organic compounds and was useful for recognizing biotic and abiotic fractions.

Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) were utilized for targeted analysis of the sample surfaces. For this purpose, the samples are carbon-coated. The SEM apparatus utilized is Ultra High-Resolution SEM (UHR-SEM) – ZEISS CrossBeam 350 with these conditions: resolution 123 eV, high voltage 10 keV, probe current 100 pA and working distance 11 mm. Mineralogical and chemical compositions were detected using the following conditions: voltage 15 keV, probe current 60 μm, working distance 12 mm, take-off angle 40°, live time 30 sec.

Results

New diagenetic data have been collected on Ostreids from the lagoonal clays, and Sirenian ribs, Pectinids and Echinoids shells from the marine sandstones, to evaluate the general preservation state of this unique fossiliferous site.

The analysed Ostreid shell belongs to the species *Crassostrea gryphoides*. The thin section shows the typical microstructure of ostreids consisting of two textures (Figure 5 A, B): thin but densely spaced foliate layers separated by thick layers of light-weight chalky material. The fast-growing structure is interpreted to be a major adaptive advantage of *Crassostrea* to avoid drilling predation and to prevent it from sinking in the soft bottom [46], [47], [48], [49], [50]. In fossil shells, as in the analysed sample, the chalky layer is generally recrystallized and has the same density as the foliate layer. Nevertheless, it is optically easily recognized by its lighter colour and nearly opaque appearance. The SEM-EDS microanalyses and elemental maps showed the discrete preservation of the original crystals forming the foliate layers and a homogeneous low-Mg calcite (average wt%: 98.7 Ca; 0.4 Mg) composition of the two structures (Figure 6 A, B). The preservation of the ultrastructures and the epifluorescence under UV light suggest a good preservation degree of the fossils present in the lagoonal sediments. The analyses on ribs of *Metaxytherium* sp. confirm the biostratinomic processes evidenced by Guido et al. [10]. The bones show typically pachyosteosclerotic structures and lack medullar cavities (Figure 5 C, D). Macro- and microscopic analyses revealed that the external layer is missing or thinned and strongly micritized, while the rest of the bone is well preserved. These data and the absence of traces of encrustation or boring by epibionts are consistent with a relatively rapid burial. The bone canals and the micro-fractures are usually empty, rarely filled by thin siliciclastic sediments. Organic matter is preserved inside the palaeohistological structure, as revealed by bright epifluorescence under UV excitation. The SEM–EDS analyses and elemental maps detected well-preserved crystals of francolite (carbonate fluorapatite) (Figure 7 C, D). F content of ca. 1.42 wt% is according to low carbonate fluorapatite minerals. Processes of dissolution and/or recrystallization are absent or minimal. These data are consistent with very slight diagenetic processes.

The thin section of a shell of *Pecten* sp. shows the typical structure of bivalves (Figure 5 G, H). The crossed lamellar and underlying nacreous or foliated layers are well preserved, while as temperature or pH. The specimen selected for this study is composed of low-Mg calcite (average wt% of the elements: 98.4 Ca, 1.4 Mg) (Figure 6 C, D).

The decrease in the Mg content may be due to an initial phase of recrystallization which led the unstable high-Mg calcite phase to transform into the more stable low-Mg calcite phase. The few amounts of Si (average 0.2 wt%) derive from fine siliciclastic minerals deposited in the skeleton pore spaces. The growth of syntaxial calcite in these spaces (originally filled by organic matter), together with the sand cementation, made the the periostracum is missing. Remain of the original acicular crystals forming these layers are observable. The EDS microanalyses (spot and areas) and maps show the presence of few amounts of Strontium (average 0.6 wt%), denoting the original aragonitic composition of the skeletons (Figure 7 A, B). This data, associated with the small amount of magnesium (average 0.2 wt%) and the discrete epifluorescence under UV excitation, suggests that the pectinid suffered only at the beginning of the first stage of neomorphic transformation, notably the inversion process which transforms the metastable aragonite phase in the most stable low-Mg calcite phase.

The diagenetic study of a skeleton of *Clypeaster* sp. allowed us to confirm the good preservation state of the fossil assemblage of the site deducted from the study of the other fossils. The SEM observations show the preservation of the echinoid stereo, characterized by variable-oriented trabecular architecture (Figure 5 E, F), i.e., struts, made of biocalcite. The skeletons are generally considered a high-magnesium calcitic structure, although their magnesium content can vary significantly according to species and specific skeletal parts, as well as, environmental factors such as temperature or pH. The specimen

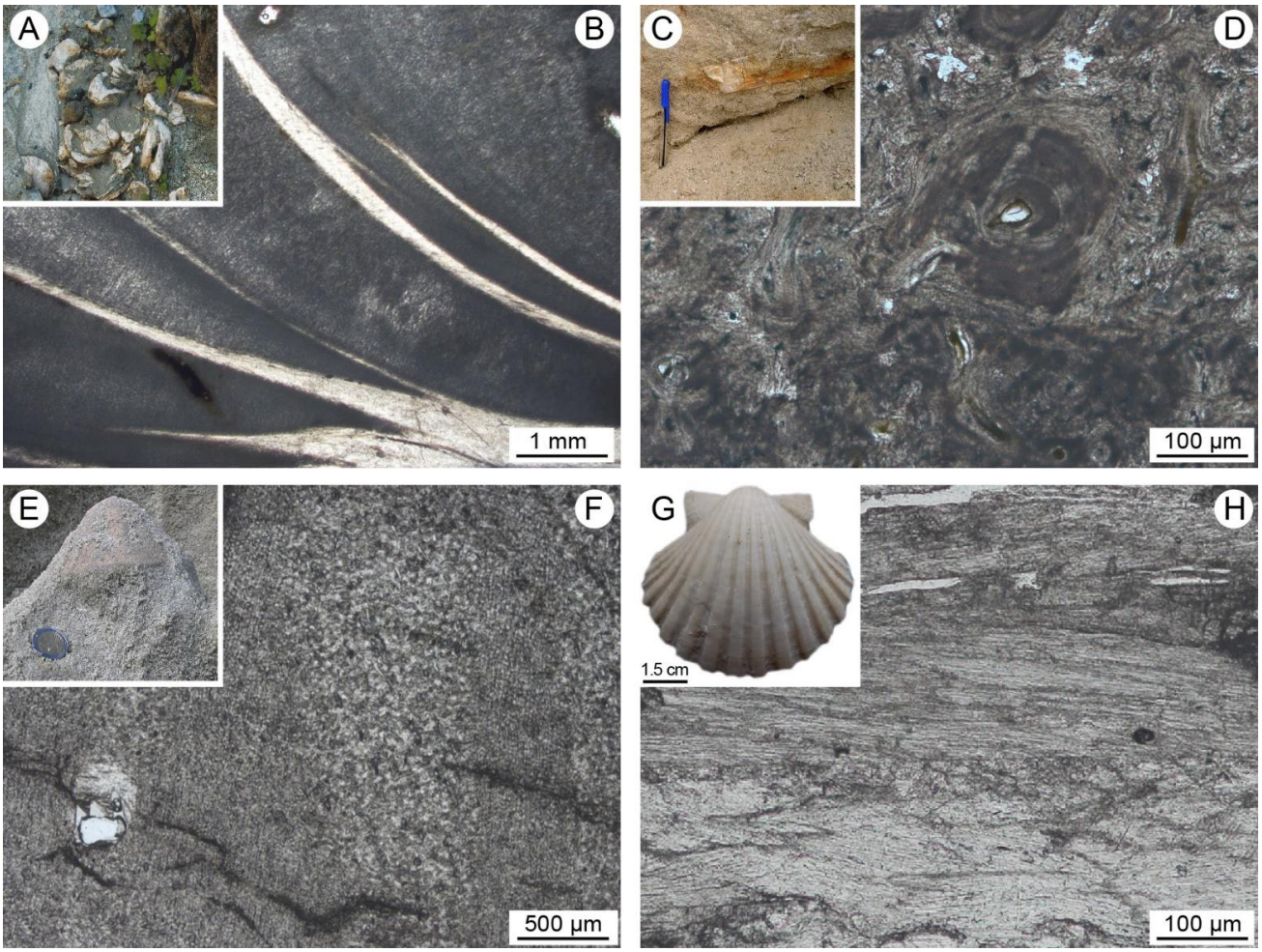

Figure 5. A) Crassostrea gryphoides in the clay of the lagoonal sediments and (B) a thin section showing the microstructure of the wall (B). C) A Metaxytherium sp. rib engulfed in the "Clypeaster sandstone", and (D) a thin section showing the well-preserved paleohistological bone structure. E) Clypeaster sp. in the x"Heterostegina yellow sandstone", and (F) thin section showing the preserved trabecular architecture of the skeleton. G) Pecten sp. from the Clypeaster sandstone, and (H) thin section showing the crossed lamellar and underlying nacreous layers.

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5. PROTECTION AND MANAGEMENT

The palaeontological heritage of the Capo Vaticano – Monte Poro area is protected by the Superintendence. Most of the fossils are exhibited in a museum network in the province of Vibo Valentia, where MuRi (Santa Domenica di Ricadi), MuMaT (Tropea), and MuMe (Parghelia) are a few km away from each other. Some specimens are located at the MuSNOB (Cosenza) and MarRC (Reggio Calabria), in Calabria. Only some specimens are hosted out of Calabria: a mandible of *Stegotetrabelodon syrticus* at Finale Emilia; and the skull of *Ceratotherium adveniensis* at Lecce.

The projects for the exhibitions are coordinated and approved by the Superintendence of the Cultural Heritage of Calabria and completed after the final permissions by the Italian Ministry of Culture. The museums also provide the storage of fossils not included in the exhibition. Cultural contents are provided by the scientific papers, adapted to a general public.

MuRi and MuMaT are open to the public, while the museum set-up of the MuMe is in progress. At the MuRi Museum, the palaeontological section opens with an introduction to the site of Cessaniti, presenting stratigraphy and palaeoenvironmental reconstructions. The rest of the museum itinerary displays terrestrial mammals.

The palaeontological section of the MuMaT is devoted to marine mammals and invertebrates. Part of the exhibition will show in the next future the evolution of the Sirenian genus *Metaxytherium*, well documented in the Capo Vaticano – Monte Poro area, where two evolutionary steps are represented by *Metaxytherium medium* (ancestor) and *Metaxytherium serresii* (descendant).

The MuMe will include a palaeontological section devoted to the memory of Mario Bagnato, one of the GPT's founders, who was also engaged in educational activities for local schools. With this purpose, he curated the first exhibition of fossils of the area, hosted in the association's headquarters. The same exhibition hall, made available by the Municipality of Parghelia, will be part of the MuMe. The original educational vocation will be respected, and the hall will be restaged as a didactic space addressed to school children and tourists.

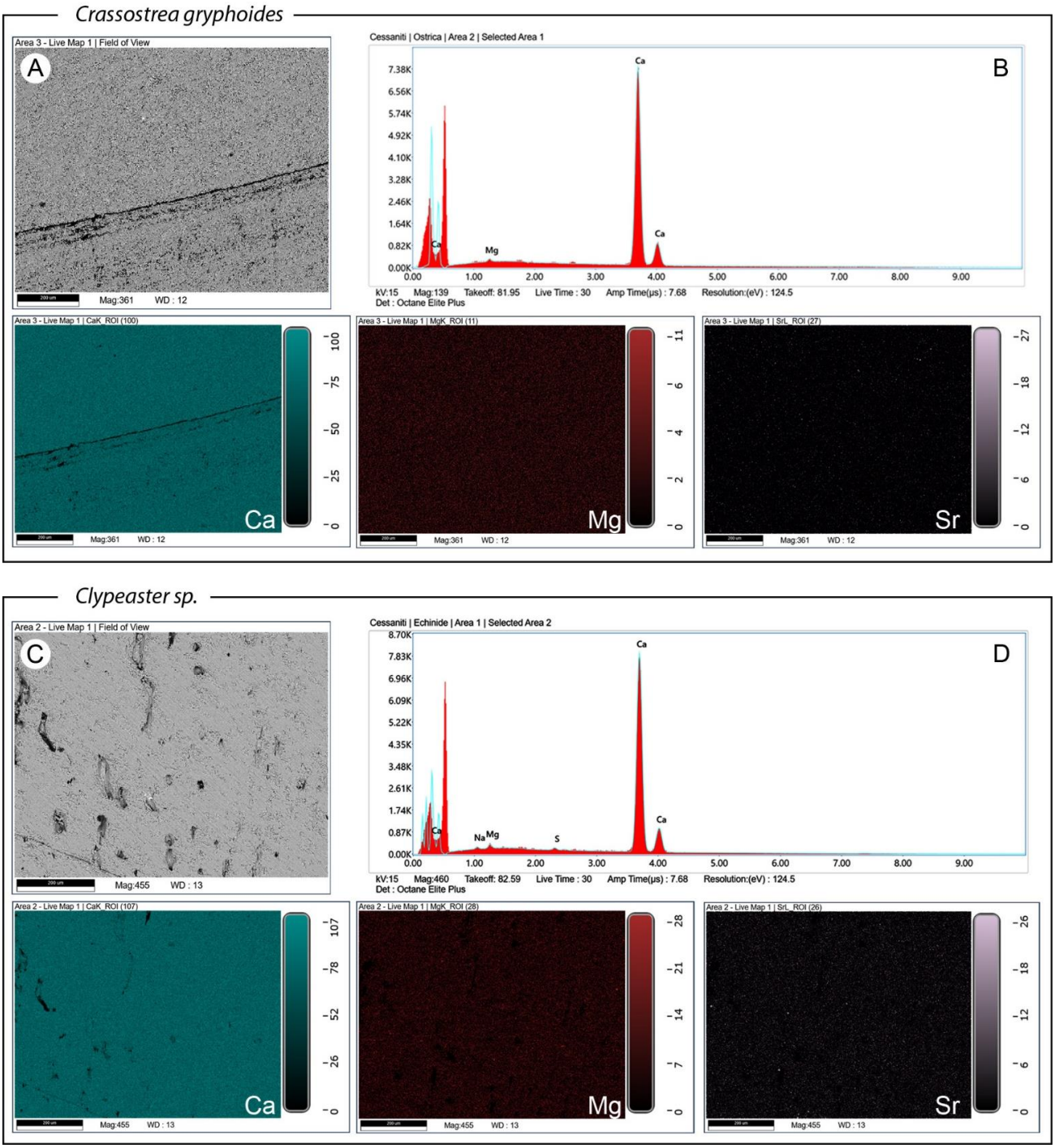

Figure 6. A) SEM image of the area for collecting the map of the main elements constituting the *Crassostrea gryphoides* skeleton, and b) EDS spectrum. C) SEM image of the area for collecting the map of the main elements constituting the *Clypeaster* sp. skeleton, and b) EDS spectrum. Ca: Calcium; Mg: Magnesium; Sr: Strontium.

Some mammal specimens and a conspicuous collection of invertebrates are exposed at the Section of Palaeontology of the MuSNOB, at the University of Calabria, where are located also collections derived from the activities of the Command of Carabinieri for the Protection of Cultural Heritage. MuRi, MuMaT, and MuMe are located in touristic areas, characterized by a high number of visitors, especially during the spring/summer. This makes the role of these structures highly important in terms of monitoring, protection, and valorisation of the palaeontological heritage of the Capo Vaticano – Monte Poro area, and they can represent a driving force for the development of cultural tourism and education of citizens.

The role of the Superintendence of Cultural Heritage and the Command of Carabinieri for the Protection of Cultural Heritage was crucial for primarily protecting and secondarily promoting this palaeontological heritage, hosted in buildings made available by local administrations. The consistency and relevance of the palaeontological heritage have been revealed by the scientific studies and related papers.

The management of the palaeontological heritage through museum exhibitions is the culmination of the scientific work carried out in the area until now, but this may not be the ultimate initiative, considering that the area has a network of trails also connected to the rock settlements of Zungri. The "Sbariati" cave

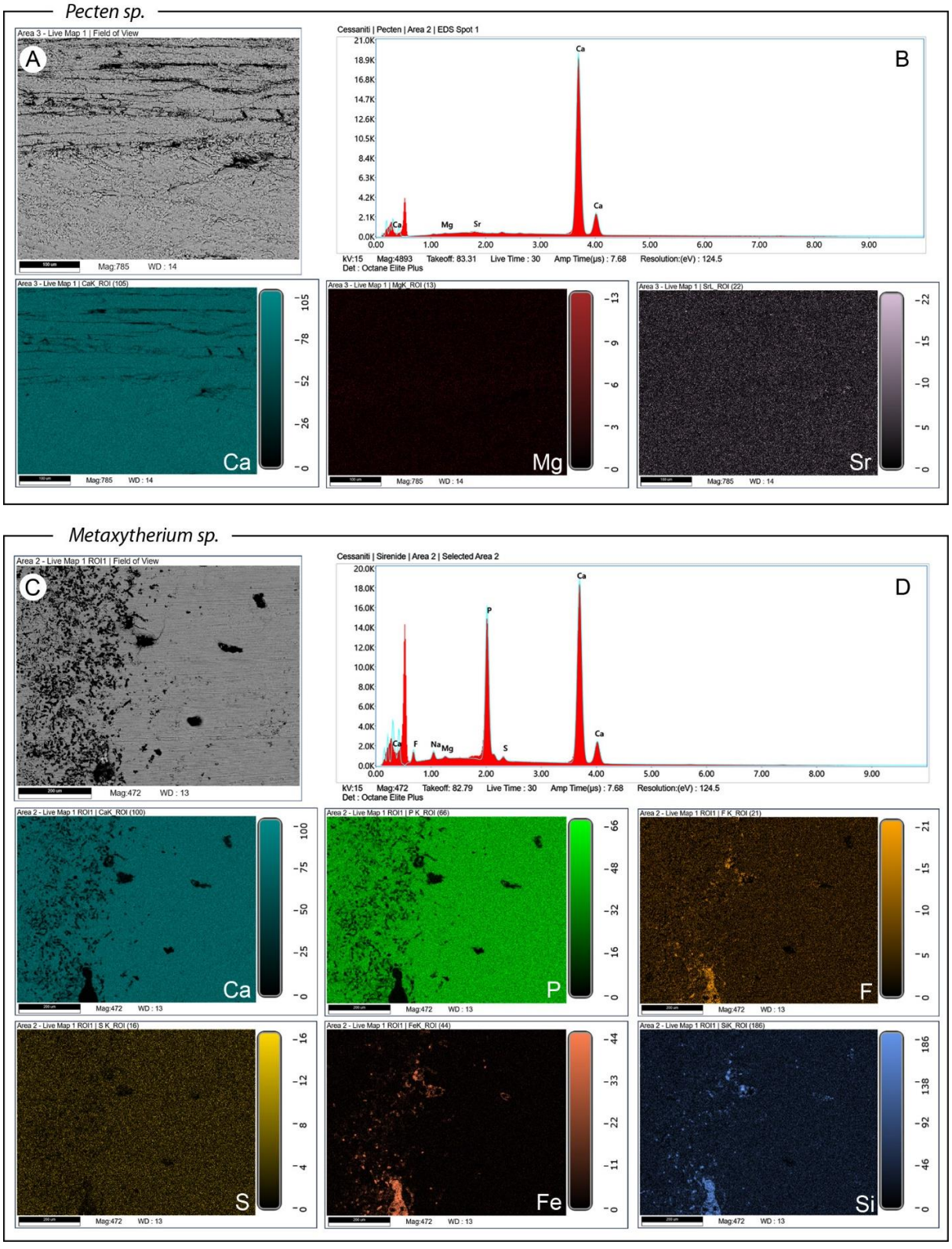

Figure 7. A) SEM image of the area for collecting the map of the main elements constituting the *Pecten* sp. skeleton, and b) EDS spectrum. C) SEM image of the area for collecting the map of the main elements constituting the *Metaxytherium* sp. rib, and D) EDS spectrum. Ca: Calcium; Mg: Magnesium; Sr: Strontium; P: Phosphorous; F: Fluorine; S: Sulfur; Fe: Iron; Si: Silicon. Note the preservation in the aragonite phase of the *Pecten* sp. skeleton, and carbonate fluorapatite of the Sirenian rib. Iron and Silicon are concentrated along the deeply micritized external part of the rib.

houses (Zungri) date from IX to XIV century D.C. and are attributed to the settlements of Basilian monks. Geopalaeontological sites could be added to the itineraries.

The most representative site of the area, Cava Gentile, is a private quarry but deserves to be considered as a geosite for its exceptional scientific relevance, as well as educational and touristic values [51]. The geosites in the Capo Vaticano area are at present only two: "Lateral expansions of Capo Vaticano" (Tropea) and the "Pleistocene cliff of Vibo Valentia" [52], [53].

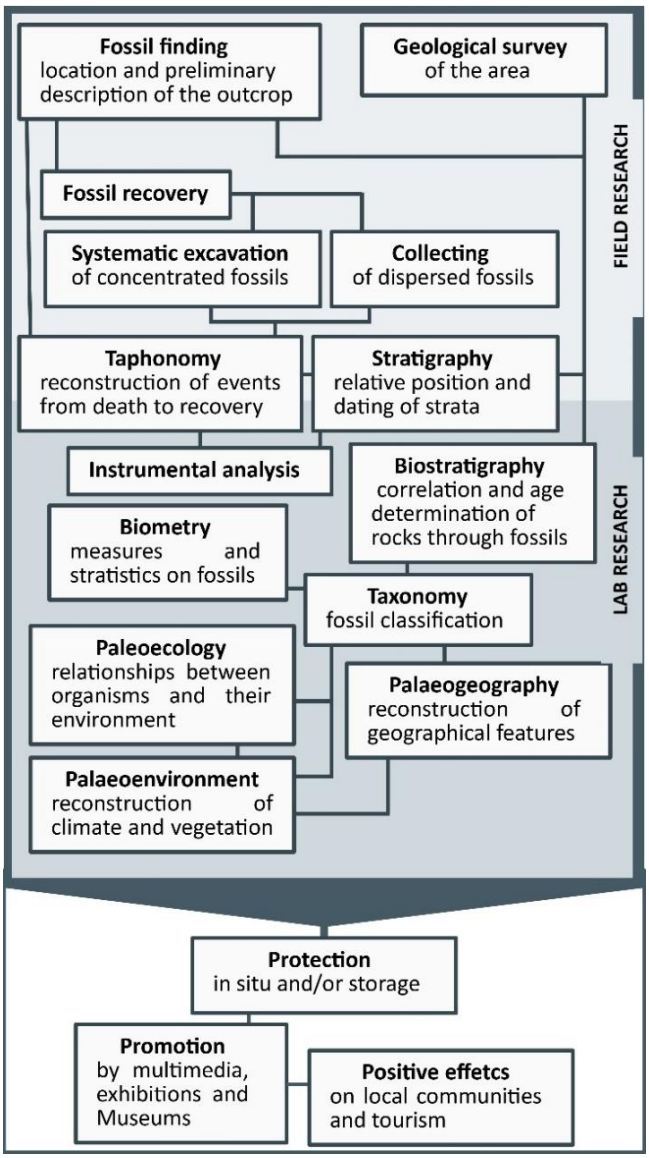

Figure 8. Scheme of the steps and related subdisciplines in studying the palaeontological heritage of the area. Source: A.C.M.

6. CONCLUSIONS

The palaeontological site of the Capo Vaticano – Monte Poro area represents an open window on a very diversified fauna populating the Calabria region 7 million years ago. The fossil assemblages are rich, differentiated, and well-preserved thanks to their peculiar diagenetic history. The most famous and best-preserved fossils of the area are Echinoids, represented mainly by the genera *Clypeaster*. Together with Echinoids the marine fauna is very rich in Bivalves, Gastropods, Brachiopods, Foraminifers, Balanids, Corals, Bryozoans, Polychaete, and other taxa. Fossils of terrestrial and marine mammals, together with tropical marine fishes and sharks also occur.

New data on the taphonomic constraints are here presented. The data allowed us to delineate the diagenetic history of the sedimentary succession of the Cessaniti site. It can be summarized as follows: a) death of organisms and burial of their skeletons in a semipermeable mixture of sandy/muddy sediments; b) fast burial and cementation together with the abundance of organic matter in the skeletons allowing the good preservation of microstructure and original mineralogy; c) late partial dissolution of the calcite filling the pores and the carbonate cement among particles making the fossils easily removable from the sediment. The dissolution processes are still working as testified by the complete dissolution of many Gastropods which are preserved only as internal models. In summary, this sequence of diagenetic events makes the Cessaniti – Cava Gentile site an open-space laboratory for palaeontological studies and palaeoenvironmental reconstructions. The good preservation of bones encourages the possibility that research be directed towards the accurate studies of fossil organic molecules [54].

Palaeontological research in the Capo Vaticano – Monte Poro area is in continuous progress, almost all the recovered mammals were studied and referred to a clear stratigraphical framework [5]-[17]. The studies on terrestrial mammals increased morphometric data for the referred species and also gave a consistent contribution to palaeogeography, for their affinities with African and Pikermian faunas. Moreover, Sirenian fossils enhanced the knowledge of the monophyletic evolution of the genus *Metaxytherium*, revealing also possible ecophenotypic adaptation to the late Tortonian ecological crisis.

These and most other scientific studies carried out in the field and the laboratory involved different sub-branches of palaeontology and gave the basis of knowledge to the museum exhibition of fossils (Figure 8).

In the area of Capo Vaticano – Monte Poro, a virtuous cooperation among amateur palaeontologists, universities, Superintendence, Carabinieri and local administrations led to relevant results in recovering, studying, and promoting the huge palaeontological heritage recorded in the upper Miocene sedimentary successions [1].

The palaeontological Museums of the area represent a net, each one complementary to the others, and are located along the "Costa degli Dei" (Coast of Gods), a popular tourist destination. However, despite the seaside tourist vocation, the hinterland also offers hiking and cultural destinations, in which the geo-palaeontological heritage has to be taken into account.

The institution of new geosites referred to in the evidence here presented could represent an auspicious opportunity for cultural and touristic development.

New field and laboratory research as well as promotion of museums and palaeontological sites are the next objectives to be achieved in an area that has already revealed a huge and significant palaeontological record.

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