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INVENTORY OF THE GEOPALAEONTOLOGICAL HERITAGE IN PROTECTED AREAS OF THE CAMPANIA APENNINES

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ABSTRACT: D. Ruberti *et al*., *Inventory of the geopalaeontological heritage in protected areas of the Campania Apennines.* (IT ISSN 0394-3356, 2005).
Goal of the present paper is to select important geopaleontological sites in protected areas of the Campania Apennines by constructing a geosites database.
In particular, following research activities focused on Cretaceous rudist benthic communities, areas where fossiliferous horizons occur rich in rudists have been selected. These organisms were widespread in shallow marine settings during the Cretaceous time and become extinct at the end of that period. The wide distribution of the rudists during the Cretaceous makes them an usefull key to evaluate the paleoecological and sedimentary conditions of the environments they colonized. Their study may provide interesting qualitative insight in palaeoecological dynamics of carbonate platforms.
Geopalaeontological sites from protected areas of the Campania Apennines have been recognized and listed in order to promote the knowledge of the geological history of these regions not only among specialists.
A computerised database of the selected geopaleontological sites has been created on the base of the Italian Geological Survey indications. Tabeled data have been imported in a GIS project that also contain the administrative boundaries and the limits of Regional/National Parks and Protected Areas. Other tematic database can be linked to the GIS project.
Such a recognition and inventory may offer a way to make use of such an heritage through naturalistic routes that evidence the geological history of a region.

RIASSUNTO: D. Ruberti et al., Censimento del Patrimonio geopaleontologico nelle aree protette dell'Appennino Campano*. (IT ISSN 0394-3356, 2005).*
Scopo del presente lavoro è quello di selezionare importanti siti geopaleontologici in aree protette degli Appennini Campani attraverso la costruzione di un database dei geositi.
In particolare sono state selezionate, sulla base delle attività di ricerca sulle comunità bentoniche delle rudiste del Cretaceo, aree con orizzonti fossiliferi ricchi in rudiste. Questi organismi erano abbandonati nei fondali marini bassi durante il Cretaceo e si estinsero alla fine di questo periodo. L'ampia distribuzione di rudiste durante il Cretaceo le rende un utile strumento per valutare le condizioni paleoecologiche e sedimentarie degli ambienti che hanno colonizzato. Il loro studio può fornire interessanti indicazioni delle dinamiche paleoecologiche delle piattaforme carbonatiche.
Sono stati riconosciuti ed elencati siti geopaleontologici di aree protette dell'Appennino Campano con lo scopo di diffondere la conoscenza della storia geologica di queste regioni anche in un pubblico di non specialisti.
Sulla base delle indicazioni del Servizio Geologico Nazionale si poi è proceduto alla creazione di un database dei siti geopaleontologici selezionati. I dati raccolti nel database sono stati inseriti in un GIS, contente anche i confini amministrativi e i confini dei Parchi Nazionali, Regionali e delle Aree Protette. Altri database tematici possono essere collegati al GIS. Questo censimento può rappresentare un valido strumento di valorizzazione di questo ricco patrimonio attraverso sentieri naturalistici che mettano in evidenza la storia geologica della regione.

Keywords: Geopalaeontological sites; Cretaceous; Rudists; Southern Apennines.

Parole chiave: Siti geopaleontologici, Cretaceo, Rudiste, Appennino meridionale.

1. INTRODUCTION

Carbonate deposits, that form most of the central-southern Apennines, testify to a long and complex geological history. Moreover, since carbonates are the direct result of biosphere metabolism, it is important to understand the role played by the biosphere in controlling sedimentation and evolution of carbonate bodies. The genesis and evolution of the latter thus represent the key to recognize changes in climate, oceanic circulation, relative sea level changes, etc., that have affected the development of depositional systems and the delicate biological equilibria of benthic communities, considered as primary carbonate sediment-producers.

Cretaceous deposits, widespread in the central-southern Apennines, are particularly interesting. In general, they appear to have originated in shallow water marine environments in which benthic communities (mostly composed by molluscs – bivalves and gastropods – benthic foraminifers, bryozoans and red algae) settled. Their study has been fundamental in reconstructing short- and long-term environmental changes (cf. Carannante *et al*., 1995; 1997; 1999; Ruberti, 1997; Simone *et al*., 2003, and references therein) and still involves international research groups.

Among the benthic communities, in particular, rudists (a group of invertebrate metazoa) represent an interesting and complex case history. These organisms, which appeared at the end of the Jurassic and lived till the end of the Cretaceous, were found throughout the shallow water environments of the old Tethys ocean, from its inner shelf to marginal environments. Their rapid evolution, as well as their great species diversity, makes them good stratigraphic markers for the Cretaceous and a valuable tool to evaluate the paleoecological and sedimentary conditions of the environments they colonized and the factors that controlled their evolution and extinction.

At this regard, within the International Union on Geological Sciences (IUGS), the Cretaceous Research Working Group 4 (CRER WG4) and the International Research Group on Rudists have promoted interesting international activities (conferences, scientific volumes, field seminars) focused on Cretaceous bioconstructions through time and space (Simo *et al*., 1993; Cestari & Sartorio, 1995; Masse et al., 1995; Proceedings of the 2nd, 3rd, 4th, 5th, 6th Intern. Conference on Rudists) in order to provide qualitative insight in palaeoecological dynamics of carbonate platforms.

This kind of study has highlighted very descriptive, spectacular, well exposed outcrops, which are well-suited to becoming geopalaeontological sites of natural interest.

In recent years, national institutions (i.e. National Geological Survey, ENEA), local administrations, international associations (IUGS, ProGEO) and Earth Science Societies have started to promote geological culture outside the usual specialists. A proposal of a geosite inventory has been proposed to the international Earth Science communities, especially since the birth of ProGEO Italia, with a view to selecting an international list of the most important sites for geological sciences and identifying what is special and representative in the geology of each country (cf. Praturlon, 1996; Wimbledon *et al*., 1996; Brancucci *et al*., 1999; Wimbledon, 1999; D'Andrea, 2000).

It is thus particularly important that public administration converges with the world of geological and environmental research to ensure an increasingly attentive approach to renewable and non-renewable natural resource management. The latter may also be achieved by protecting sites of particular geo-palaeontological interest in the regions concerned.

The aim of the present paper is to select the most important geopalaeontological sites in protected areas of the Campania Apennines by constructing a geosites database. Such a recognition and inventory may open up the possibility of exploiting such resources sustainably by mapping out trails that highlight the geological history of the region.

2. RUDISTS

Rudists are Bivalves with more or less modified shells. They can be divided into two groups: those attached by the right valve (*Monopleura*, *Caprina*, *Hippurites*, *Radiolites* genera, among others) and those attached by the left valve (*Requienia*, *Toucasia* genera). During their evolution, rudists were subjected to major changes as a response to ecological factors (Fig. 1; based on Sirna & Laviano, 1989; Sirna, unpublished data; see also Cestari & Sartorio, 1995).

The earliest rudists (Diceratidae) were only slightly inequivalve genera, the latter characteristic becoming increasingly pronounced. Requieniidae evolved at the beginning of the Cretaceous from the Diceratiidae and were characterized by an inequivalve left valve, attached to the substratum. The right valve was smaller, opercular. The presence of an external ligament caused an accentuated tangential shell growth and the consequent spirogyrate shell-shape (Cestari & Sartorio, 1995). The ligament invagination produced the uncoiling and rising from the substratum of the shell, as can be observed in the Caprotinidae and Caprinidae. The latter had an inequivalve shell that reached also wide dimensions. The right fixed valve was small and conical while the left free one was more developed and markedly spirogyrate.

The shells of Radiolitidae and Hippuritidae changed their architecture gradually, achieving a pipe-like shape with an opercular upper valve. In evolutionary terms, Radiolitidae are older than Hippuritidae; both reached their peak expansion with marked endemism during the Late Cretaceous. Similarly to other important organisms, these bivalves did not survive the great mass extinction that occurred at the end of the Cretaceous.

2.1 Palaeoecological aspects

Among the Cretaceous sediment producer organisms, rudists play an important role because they occurred in different depositional environments of the Tethys ocean. They spread over the carbonate shelves, from the innermost settings to the outermost sectors of the shelf. Their rapid evolution and large number of species make rudists good stratigraphic markers in the whole Carribean and Mediterranean region (cf. Pons & Sirna, 1992; Cestari & Sartorio, 1995; Sirna & Paris, 1999; Proceedings of the 2nd, 3rd, 4th, 5th, 6th Intern. Conference on Rudists; among others). They are known from the Gulf of Mexico, Iberian Peninsula, southern France, the Italian Apennines, Apulia, the Dinarides, Romania, Hungary, Poland, Greece, Turkey, Syria, the Lebanon, and north Africa.

During the Cretaceous, rudists inhabited tropical and subtropical belts of the Tethys, including those between North and South America and the Indo-Pacific. A few highly specialized taxa (mostly Radiolitidae), settled in the temperate zones of southern Canada and the British Isles. As already stated, rudists preferred the neritic realm, adapting to different kinds of sea bottoms: some genera colonized sandy bottoms, others preferred silty-sandy ones, at least the terrigenous ones. Nevertheless, as a rule rudists preferentially inhabited carbonate environments.

More generally, the main observation is that from the Middle-Upper Cretaceous, rudists spread over all shelf sectors, from more open and external areas to more internal ones, occupying different substrata and furnishing the bulk of the skeletal component by means of bioerosion processes. They colonized mobile sediments giving rise to complex bodies with peculiar cha-

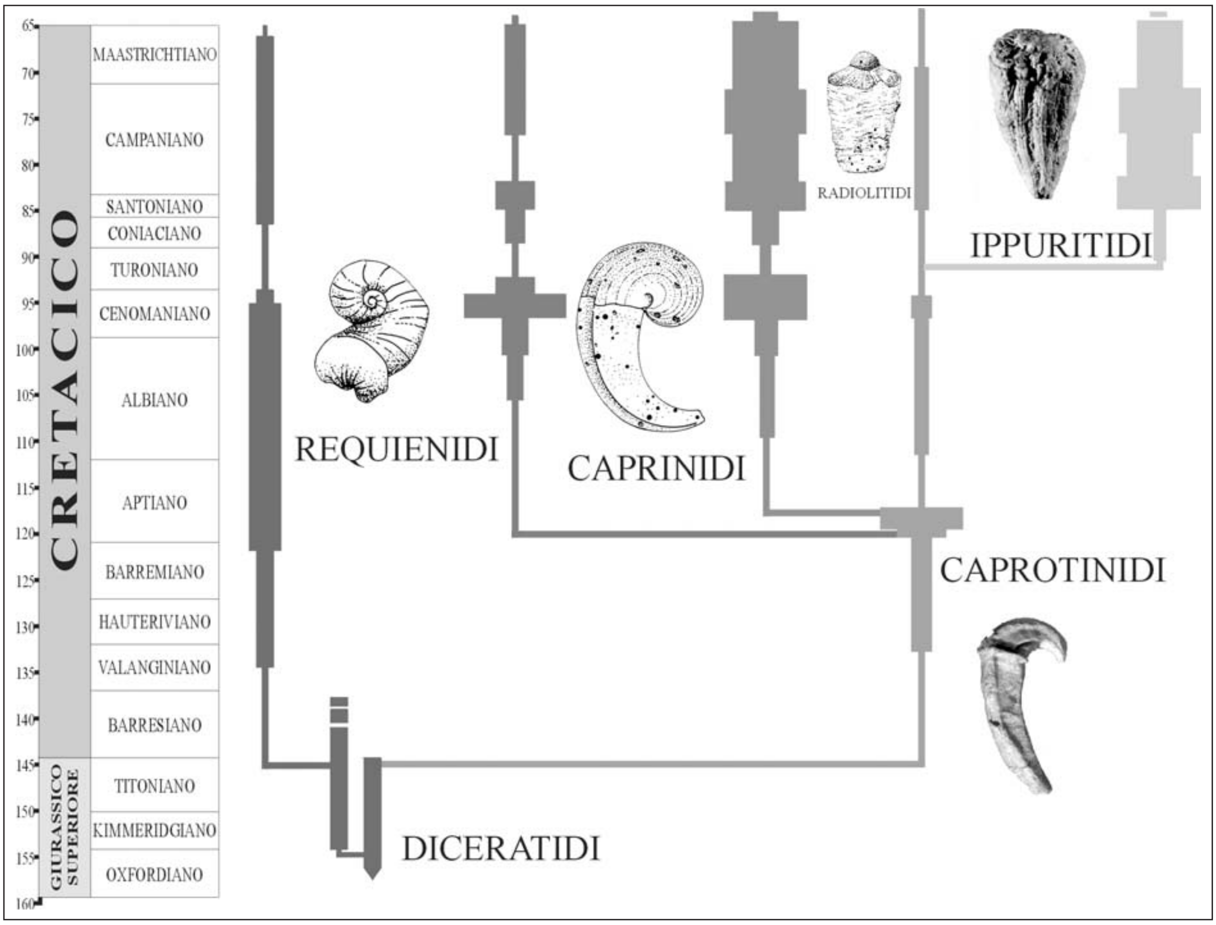

Fig. 1 – Evolution of the main rudist families and their distribution in time (based on Cestari & Sartorio, 1995, and Bosellini, 1991). See text for explanations.

Evoluzione delle principali famiglie di rudiste e relativa distribuzione nel tempo (modificato da Cestari & Sartorio, 1995, Bosellini, 1991). Per ulteriori spiegazioni si veda il testo.

racteristics related to the environmental parameters of the different sectors of the shelf (cf. Carannante *et al*., 2001; Simone *et al*., 2003).

2.2 Rudists of the southern Apennines

During the Lower Cretaceous, the Requienidae and Caprotinidae are the best represented. The former preferred sheltered environments, characterized by fine-grained, mainly muddy substrata, such as protected lagoons, and only occasionally they can be found associated with silty-sandy sediments. Caprotinidae and Caprinidae assemblages are common in higher energy environments, such as open shelves (well known in the Matese, southern Fucino Campoli Appennino and Monti d'Ocre successions).

Nevertheless, owing to vast and complex geologic events occurred in the Late Aptian-Early Senonian time (e.g. changes in climate, oceanographic circulation, sea level, tectonic and volcanic activity), the Cretaceous carbonate platforms modified the organization of their depositional system resulting in a drastic facies variation.

In particular, during Cenomanian time, the eustatic oscillations and tectonic events that interested the Periadriatic Region induced localized emersions and strong physiographic alterations of the carbonate platforms. Even the carbonate platforms of central-southern Italy were affected by these events. In their evolution it is possible to recognize crisis period in rudist evolution that started during the Albian and that was characterized by a decrease of species, genera and family number.

An abrupt inversion of tendence is recorded in the lowermost Cenomanian through an adaptative radiation of forms and an increase of the biological diversity mainly in the high energy and/or marginal open areas of the shelf. In the Cenomanian time carbonate shelves became more articulated, owing to the complex tectonic and eustatic events that characterized the periadriatic region. In this interval several genera of Caprinidae developed, in association with Radiolitidae and a few corals, especially in the outermost sectors of the shelf. In more protected settings Gastropods (Nerineids) and radiolitid assemblages flourished togheter with Oysters (*Chondrodonta*) and Benthic Foraminifers.

At the end of the Cenomanian, in correspondence of the Turonian boundary, a new important crisis phase took place in all shallow-water environments. This one knocked mainly the caprinids, among the rudists, but also nerineans, and only few species of them survived.

During the Upper Turonian-Senonian interval, rudists spread over all the shelf sectors, from more open and external areas to more internal ones, occupying different substrata and furnishing the bulk of the skeletal component. Rudists grew in loose sediments giving rise to limited and scattered rudist-rich bodies. Storm- and wind-induced currents and waves repeatedly mobilized the rudist-supporting loose sediments; as a consequence toppled shells are very abundant and only in the more internal and protected shelf sectors, the growth-related arrangement of the rudist-shells can be easily observed (cf. Carannante *et al*., 1993; 1997; Simone *et al*., 2003).

3. INVENTORY OF THE GEOPALAEONTOLOGICAL HERITAGE

3.1 Identification and inventory of sites of palaeontological importance

Rudist-bearing Cretaceous successions cropping out in the southern Apennines have been intensively studied in recent years (cf. § 1) on the basis of research projects dealing with the environmental reconstruction of the Cretaceous carbonate platforms and the recognition of the factors influencing growth and development of the biotic communities, primary sediment producers (cf. Simone *et al.*, 2003, for a review).

Particularly interesting, spectacular geopalaeontological sites have been recognized, that can be proposed for preservation. Some sites lie within protected areas of Campania.

Two sites are illustrated herein, located in the widest protected areas of the Campania Region: the Matese and Cilento Mountains (Fig. 2). The main purpose is to evidence the geopalaeontological aspects of international importance and make them known through a computerized inventory in order to include the sites along specific nature trails.

3.1.1 Regional Park of Matese

The Matese Mountains represent the eastern part of the southern Apennines and straddle the provinces of Benevento, Isernia, Campobasso and Caserta. The Matese Mountain Range morphologically forms one of the main axial culminations of the southern Apennines (Fraissinet & La Valva, 2001). It derives from the deformation of a palaeogeographic domain characterized by a carbonate sedimentation from the Triassic to the lower Miocene, with local and sometimes large stratigraphic gaps. The sedimentary model for the Mesozoic is a carbonate platform with scarps of variable inclination and height that came into existence in the upper Trias and was deformed by the Late Miocene tectogenetic events and dissected by Plio-Pleistocene tectonics.

The main outcrops concern the Mesozoic-Cenozoic shallow water-to-slope carbonate platform domain pertaining to the southern Tethys. The outcrops relative to transitional facies between these two domains are poorly defined, with no physical continuity and are strongly tectonized.

Rich and interesting fossiliferous "horizons" are found throughout the mountains, culminating in the real "subaerial museum" of Pietraroia. They offer an interesting record of the Meso-Cenozoic marine life and environments.

Cretaceous deposits appear particularly interesting: they record the events that characterized the Periadriatic region in that period (D'Argenio, 1974; Channel *et al*., 1979; D'Argenio *et al.*, 1980; Radoicic, 1987; Accordi & Carbone, 1988; Cocco & D'Argenio, 1988; Carannante *et al*., 1991; D'Argenio & Mindszenty, 1992; Carannante et al., 1994) and show remarkable facies differences in various Matese sectors. Shallow water deposits characterize the whole Cretaceous eastern Matese successions, while in the western area late Cretaceous margin-to-slope bioclastic limestones

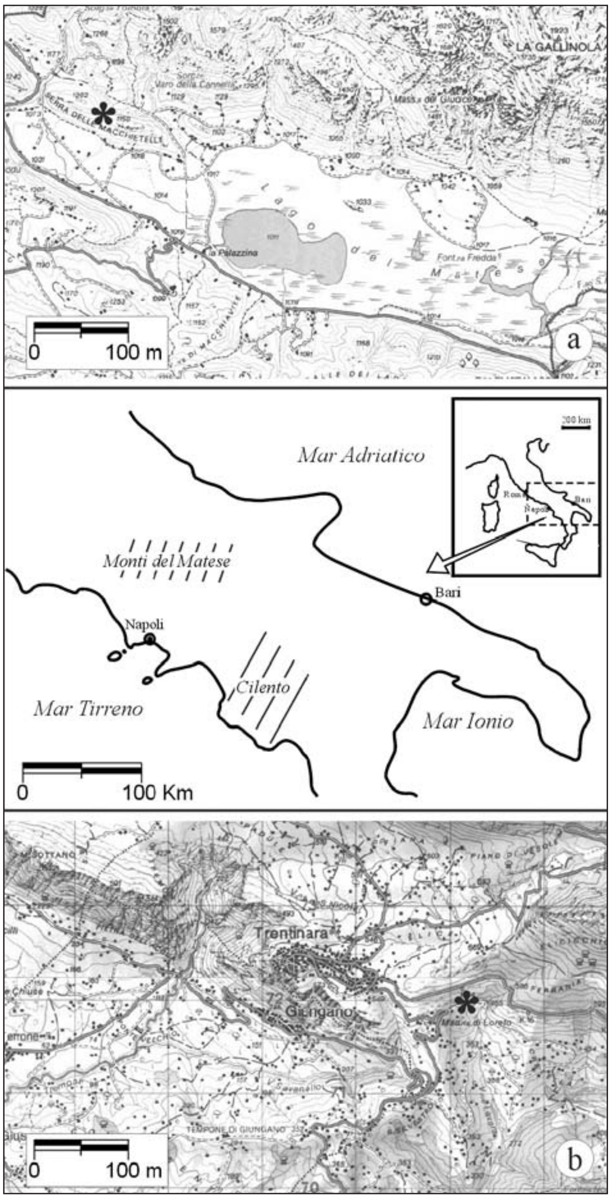

Fig. 2 – Location map of the proposed gepaleontological sites. a) Serra delle Macchietelle hill, in the Regional Park of the Matese Mounts. b) Trentinara outcrop in the National Park of Cilento and Vallo di Diano. IGM Topographic map 1:50000, Sheet 405, 487, 503.

Ubicazione dei siti geopaleontologici proposti per la tutela. a) Dorsale di Serra delle Macchietelle, nel Parco Regionale del Matese. b) Affioramento di Trentinara, nel Parco Nazionale del Cilento e Vallo di Diano. Basi topografiche IGM, in scala 1:50000, Fogli 405, 487, 503.

(better known in the literature as "Calcari Pseudo-saccaroidi bianchi" or "Calcari Cristallini" - Selli, 1958; Pescatore, 1964; 1965; Ietto, 1970; Accordi *et al*., 1982) can be recognized resting on Triassic-Jurassic shallow water limestones. Stratigraphic analysis carried out in this region led to identify in the eastern area the source of sediments accumulating in the western area.

The sector proposed for protection comprises the central part of the Matese Mounts, around the Lake of Matese, on the southern flanks of M. Miletto. This area is characterized by Mesozoic shallow-water limestones. Cretaceous limestones are well exposed, characterized by large occurrence of rudist facies that represent highly didactic successions, both for scientific and naturalistic/touristic purpose (Accordi *at al*., 1990; Ruberti, 1991; Carannante *et al*., 1993; 1997).

3.1.2 National Park of Cilento and Vallo di Diano

The National Park of Cilento and Vallo di Diano is the second largest national park in Italy (181,048 ha) and represents one of the largest biogeographic complexes in southern Italy. Its geographical position, the coasts, the rivers, and the mountains have resulted in a variety of environments. Geologically, the area is characterized by limestone mountains in the eastern part, with the Alburni range and Mt. Cervati, and arenaceous reliefs in the western part (Mt. Stella, Mt. Sacro, Mt. Centaurino); the southwestern part is once again limestone (Mt. Bulgheria). By a geomorphological point of view, the Cilento Park consists of both smooth hills and high mountains. Long, deep valleys cut the mountain flanks; the rivers running over them gave rise to wide and smooth alluvial areas. Moreover the Cilento has the most extensive karstic system in the southern Apennines.

By a geopalaeontological point of view, the limestones cropping out in this area offer rich and interesting fossiliferous “horizons” that document Meso-Cenozoic marine and fresh-water life and environments.

The sector proposed for protection comprises the Mt. Soprano-Mt. Vesole structures and the Monti Alburni. This area has outcrops of great importance for geopalaeontological studies, which testify to the geological history of the region. The Mt. Soprano-Mt. Sottano Ridge is a 20 Km NW-SE belt that crops out south of the Sele Plain and represents the northern margin of the Cilento Mountains (Cestari, 1971; Sgrosso, 1968). This structure may be considered part of a wide anticline pertaining to the stratigraphic-structural unit of Alburno-Cervati (Scandone, 1967; Sgrosso, 1968; D’Argenio *et al*., 1973).

Mesozoic lithologies cropping out in the studied area mainly consist of carbonate platform limestones and, subordinately, dolostones pertaining to the Campano-Lucanian Carbonate Platform succession (Scandone, 1972; D’Argenio *et al*., 1973) of the Upper Triassic-to-Senonian age. A transgressive Palaeocene-Miocene succession overlies in paraconformity the Upper Cretaceous successions.

The Cretaceous sediments, in particular, were deposited in shallow-water environments that show a change from restricted circulation and tidal settings during the Early Cretaceous to more open marine conditions in the Late Cretaceous (Cestari, 1971). Previous stratigraphic studies have been carried out by Sartoni & Crescenti (1963), Scorziello & Sgrosso (1965), Sgrosso (1968) and Cestari (1971).

3.2 Inventory of geopalaeontological data

The data were catalogued through computerized inventory tables, created on the basis of the Italian Geological Survey indications (cf. Praturlon, 1996; Wimbledon *et al*., 1996; Brancucci *et al*., 1999; Wimbledon, 1999; D’Andrea, 2000). The Microsoft ACCESS 97 database was developed with several tables bearing homogeneous information (Fig. 3):

- geosite identification data (e.g.: country, town, province, locality, UTM coordinates, height above sea level, etc.)
- geosite quality (scientific importance, interest, state of preservation, etc.)
- geological data (e.g.: lithology, age, age of the substratum, etc.)
- palaeontological data (e.g.: biotic remains, icnite, etc.)
- accessory data (degree of knowledge, presence of areal constraints, etc.)
- selected references

Each table is related to the others through a common field (“Num. Progressivo”; Fig. 4) which allow the unique identification of the geosite through simple *queries*. Each table corresponds to a mask (Fig. 5) created with the purpose of reducing data entry mistakes, displaying all the indications to fill in the tables, and showing indicative schemes and pictures.

These tables represent a database that can be read in MS ACCESS environment and imported in a GIS project. A GIS prototype was created; the geopalaeontological sites are located as spots on a georeferenced topographic map (Sheet 1:50.000 IGM, 50/L Series, 3 colors), in raster format (Fig. 6). The project also contains the administrative boundaries and the limits of Regional/National Parks and Protected Areas, as indicated under Law 394 of 6.12.1991 and Regional Law 33 of. 1.9.1993. In particular, for the proposed sites, the zones of integral reserve (zone A), general reserve (zone B) and controlled reserve (zone C) are delimited.

The project was set up with GeoMedia Pro of Intergraph Corporation and published on the web site of the Dipartimento di Scienze Ambientali of the Seconda Università degli Studi di Napoli (www.sa.unina2.it).

4. DESCRIPTION OF THE PROPOSED SITES

As an example, one site was selected from the National Park of Cilento and Vallo di Diano and one from the Regional Park of Matese.

4.1 Regional Park of Matese: the Serra delle Macchietelle outcrop

The proposed site is represented by the Serra delle Macchietelle hill, located at the northwestern end of the Matese Lake (Fig. 2). Serra delle Macchietelle is a NW-SE hill rising from the lake up to 1202 m above sea level. It is mainly made up of NE dipping limestones, well exposed along the southern flank road cut, from NW toward SE (Ruberti, 1991, 1992; Carannante *et al.*,

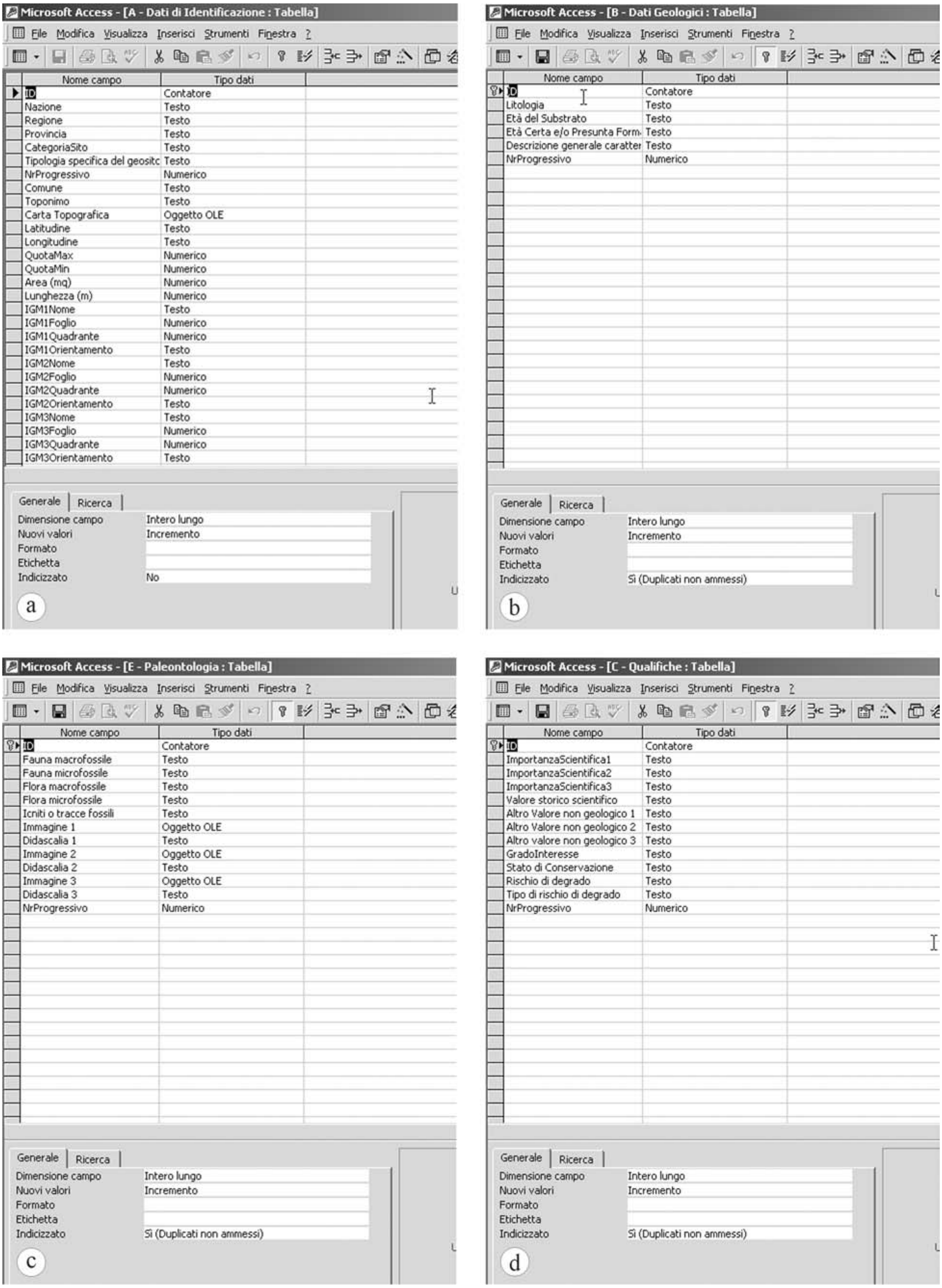

Fig. 3 – Tables from the MS ACCESS 97 database concerning identification data, geological data, paleontology, geosite quality.

Esempi di tabelle relative al database creato in MS ACCESS 97, riferite ai dati identificativi, geologici, paleontologici e alle qualifiche del sito.

1993).

Early Cretaceous deposits are rich in bivalves (among which Requienidae and Oysters), Gastropods (mostly Nerineids), giving rise to thick beds cyclically alternating with loferitic and stromatolitic limestones (Fig. 7a, c). Up in the sequence, thanatocoenosis rich in Radiolitidae and Caprinidae constitute small congregations (*sensu* Gili & Skelton, 2000; see also Ruberti & Toscano, 2002) associated with Oysters and Gastropods (Fig. 7b).

The Upper Cretaceous is characterized by widespread distribution of Radiolitidae, locally forming well preserved assemblages supported by bioclastic sands (Fig. 7d). The related lithosomes result to be delimitated and often eroded by coarse sandy deposits in which it is possible to recognize transported organisms which are often still undamaged.

These lithofacies (mollusc rudstones-floatstones in a matrix of silty packstones) are generally found in more or less silt-rich lens-shaped bodies, which contain a great abundance of poorly sorted bioclastic material. The resulting rudist-rich bodies, that may be 3-10 m thick and for a few tens of meters in diameter, laterally blend into bioclastic talus in which it is common to find cross-lamination, graded beds, isorientation and imbrication of the grains. Many bioclastic episodes clearly appear to have originated from storms, on the basis of associated sedimentary structures; others represent the normal breakdown of the organisms which grew developing limited positive structures, with more or less intensive reworking of the grains. Deposition, therefore, took place on shelf areas on relatively shallow sea floors which might be periodically exposed, thereby undergoing dissolution phenomena.

4.2 National Park of Cilento and Vallo di Diano: the Trentinara outcrop

The proposed site is located in the northern margin of the Cilento, nearby the village of Trentinara (Fig. 2). The road cut along the southern flank of Mt. Vesole, starting from the Madonna di Loreto Sanctuary, shows fine outcrops characterized by subhorizontal calcareous strata in which well-preserved rudist-beds offer a bidimensional picture of Cretaceous sea beds.

Detailed taphonomic studies (Ruberti & Toscano, 2002; Carannante *et al.*, 2003) have shown the species distribution in the various fossiliferous beds and the different spatial arrangement of the sedimentary bodies that range from monospecific biostromes to subtidal channelized bodies in which rudists have been found to colonize channel levees. Taphonomic characterization enabled hydrodynamic control on lithosome evolution, geometry and spatial distribution to be recognized.

The rudist shell beds are characterized by low species diversity, with slight differences in the abundance of a few species belonging to the *Durania*, *Bournonia*, *Sauvagesia*, *Gorjanovicia* and *Biradiolites* genera, that usually form oligo- or monospecific con-

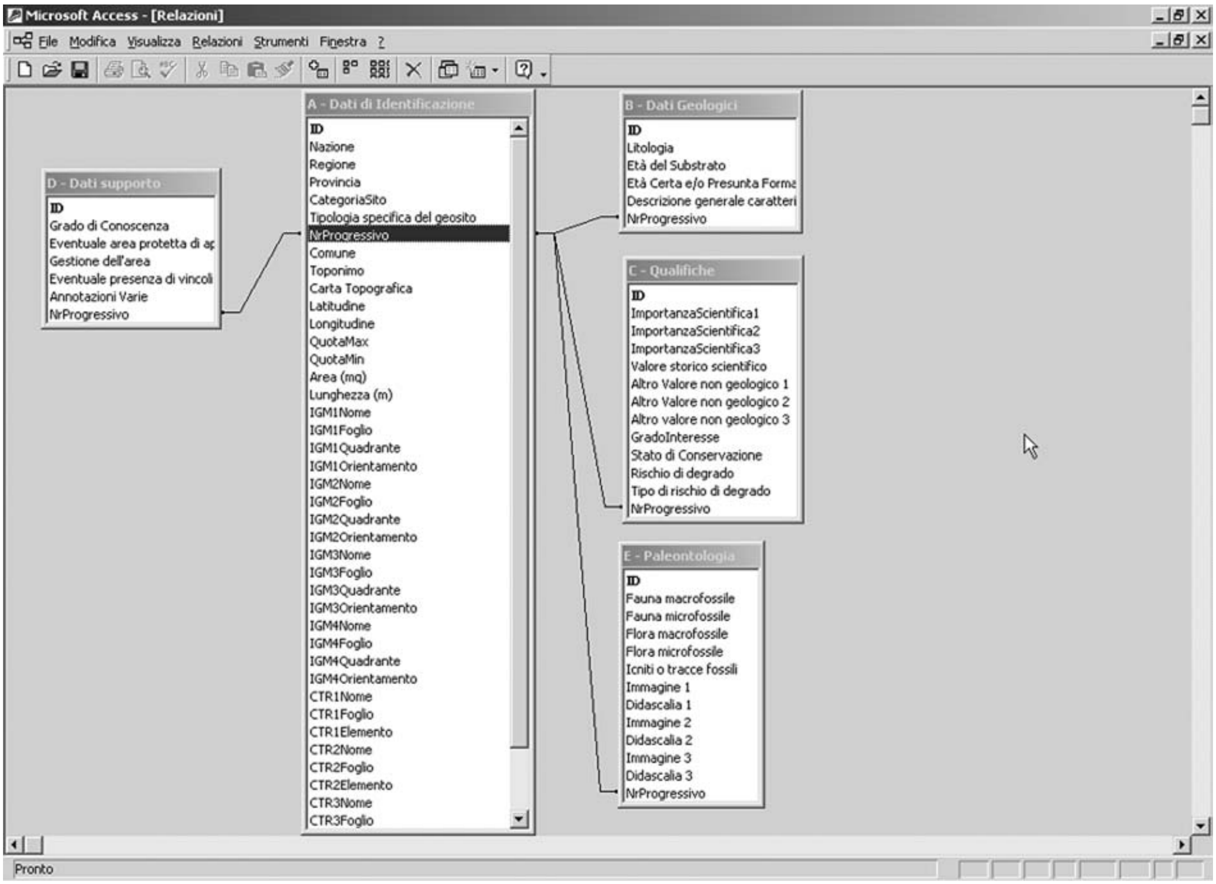

Fig. 4 – Relationships among tables in the database.

Esempio di relazioni tra tabelle nel database relazionale creato.

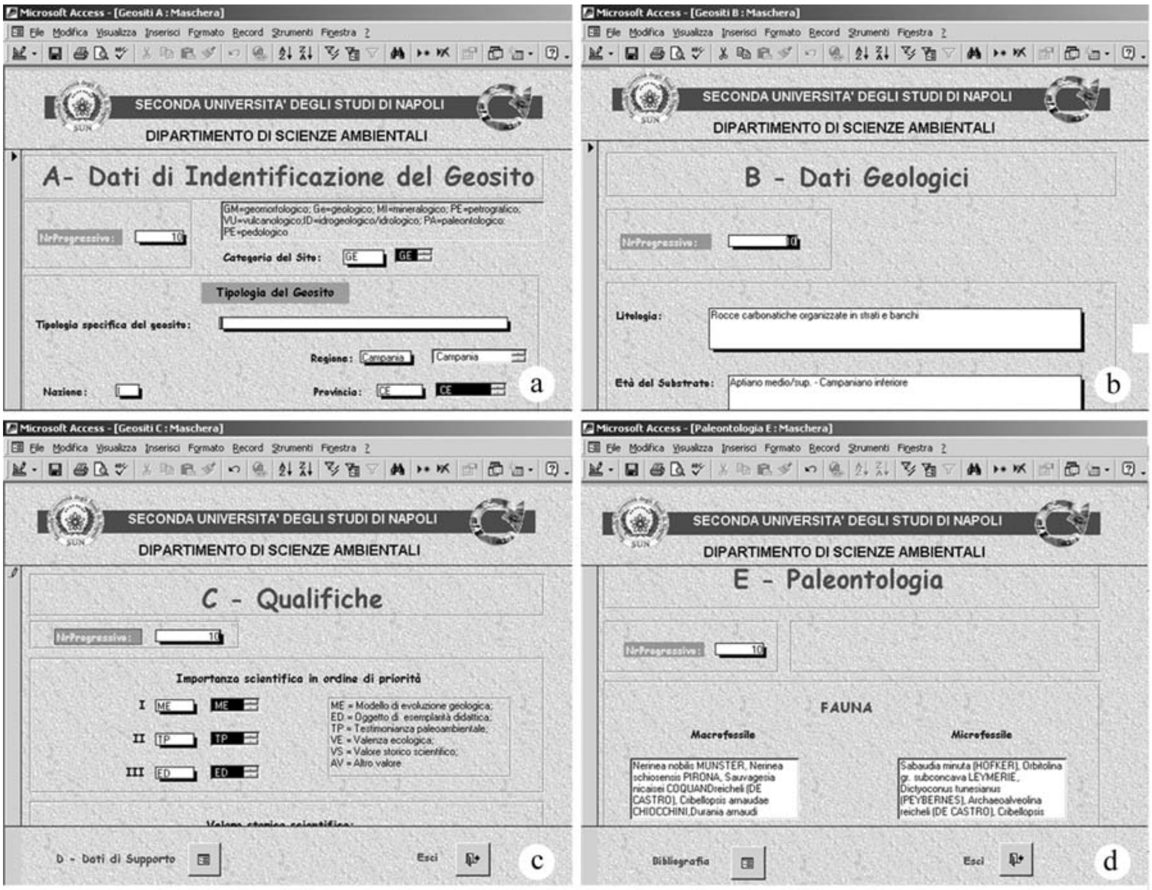

Fig. 5 – Examples of masks supporting the tables in the database.

Esempio di maschere create per l'inserimento dati nel database realizzato.

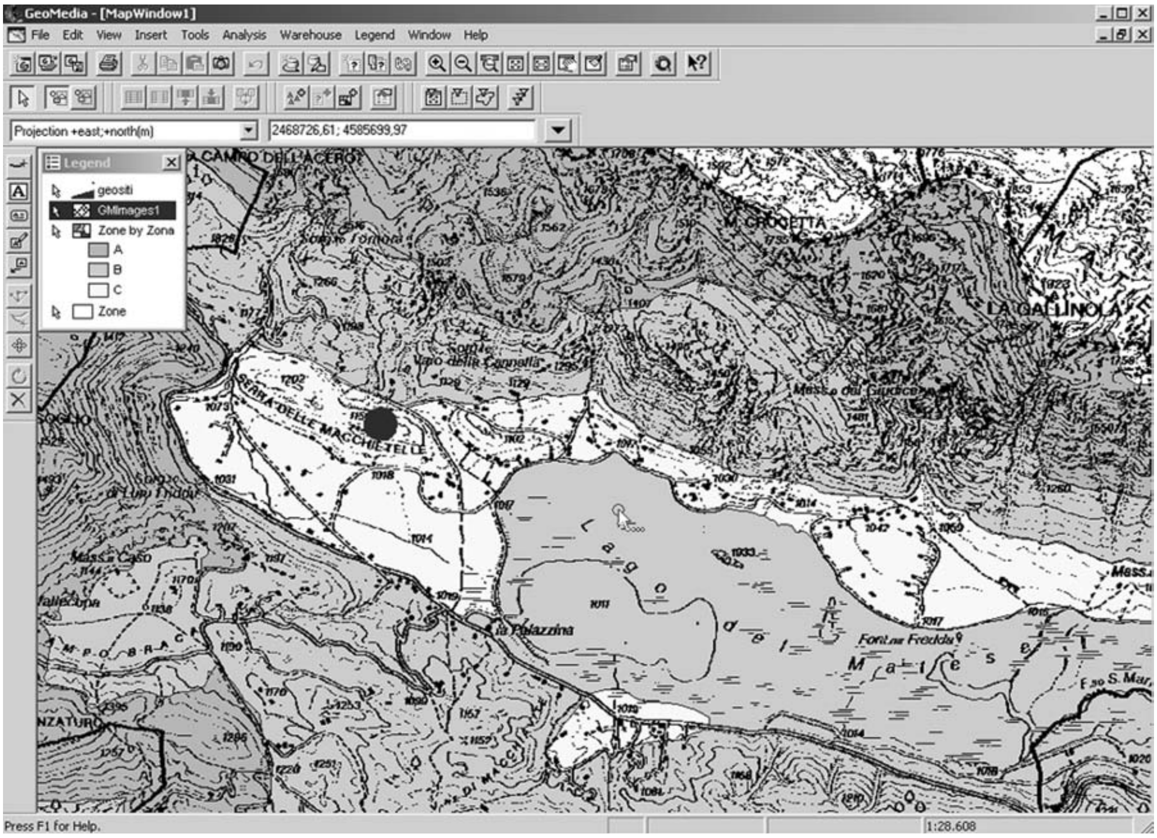

Fig. 6 – Screenshot of the GIS prototipe created with GeoMedia 4.0 Pro (Intergraph) to read the database on the georeferred map.

Cattura a video del progetto GIS realizzato con GeoMedia 4.0 Pro *(Intergraph) per la visualizzazione su basi cartografiche georiferite delle banche dati relative ai geositi.*

gregations (Fig. 8). The characteristics of the shell beds show, in the first instance, that the recognized rudist species settled and thrived in relation to the grain size and the hydrodynamics, giving rise to different lithosome composition and geometry. The taphonomic attributes of macrofossil associations were broadly categorized on the basis of Carannante *et al.* (1998; 2000) and Ruberti & Toscano (2002). The internal fabric of these levels (i.e. orientation, arrangement, packing and sorting of the skeletal elements; internal microstratigraphy) allowed two broad shell bed categories to be distinguished: a) shell beds considered as "Primary Shell Concentration" in which the shell concentration is essentially created by the behaviour of local shell producers, preserved *in situ* and in growth position; b) shell beds considered as "Hydraulic Shell Concentration", that were deposited under the influence of hydraulic processes and/or input of surrounding bioclastic sediments.

All the aspects described, in terms of lithofacies associations, taphonomic aspects of the rudist congregations and their role in the depositional cycles, testify to open shelf settings periodically disturbed by higher-energy events. The latter might have resuspended fine-grained sediments and caused the benthos to become unstable, though the fine fractions settled down *in situ*.

The depositional sites were characterized by a large-scale facies polarity. Under closer examination, a patchy distribution of the latter appears, often related to channelized systems or current pathways through rudist settlement areas.

5. CONCLUDING REMARKS

Knowledge and the subsequent census of the geological heritage of a region undoubtedly constitute very important elements for local administration (Gisotti & Massoli-Novelli, 1997; Zarlenga, 1996; D'Andrea & Di Leginio, 2002), even if the motivation behind them may be simply knowledge-oriented. The value of such heritage can be enhanced by creating itineraries that highlight the geological history and dynamics of the region. Indeed all regional protected areas have a large potential for tourism which has to be organised intelligently. The key to such tourist development is diversification which allows, amongst other things, a broader year-round distribution of tourist flows. Hence the importance of targeting school tourism and cultural tourism in general, which is particularly busy in autumn and spring, creating a network of footpaths that allows direct observation of the area's geological and palaeon-

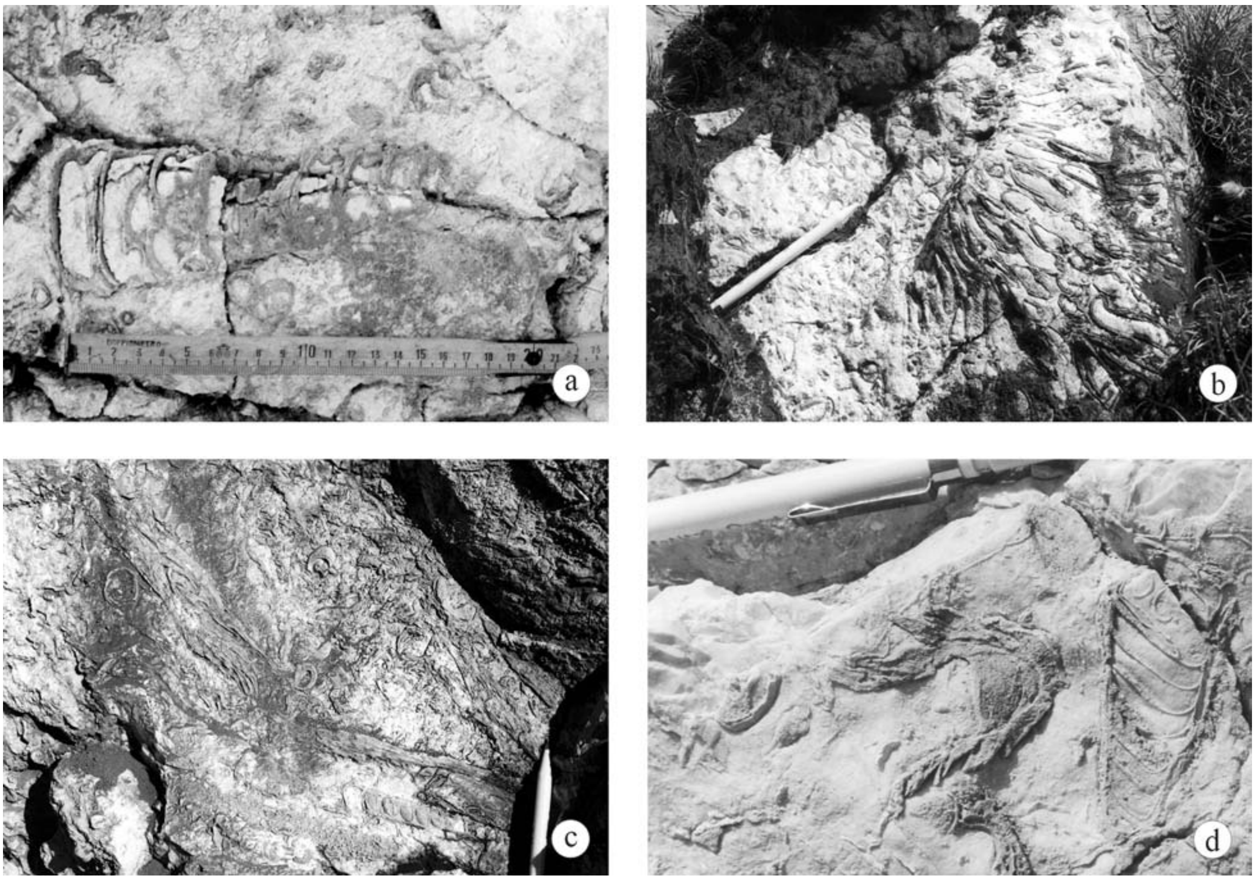

Fig. 7 – Serra delle Macchietelle outcrop. a) Close-up of a Nerineid specimen. b) Thicket formed by Caprotinidae, closely-spaces in an upright growth position. c) Floatstone rich in *Chondrodonta* sp. and Gastropods (among with Acteonids and Nerineids). d) Radiolitid limestones.

Affioramento di Serra delle Macchietelle. a) Dettaglio di un esemplare di Nerineide. b) Thicket formato da Caprotinidi, addensate e in posizione di crescita. c) Floatstone ricco in Chondrodonta sp. e Gasteropodi (tra cui Acteonidi e Nerineidi). d) Calcari a Radiolitidi.

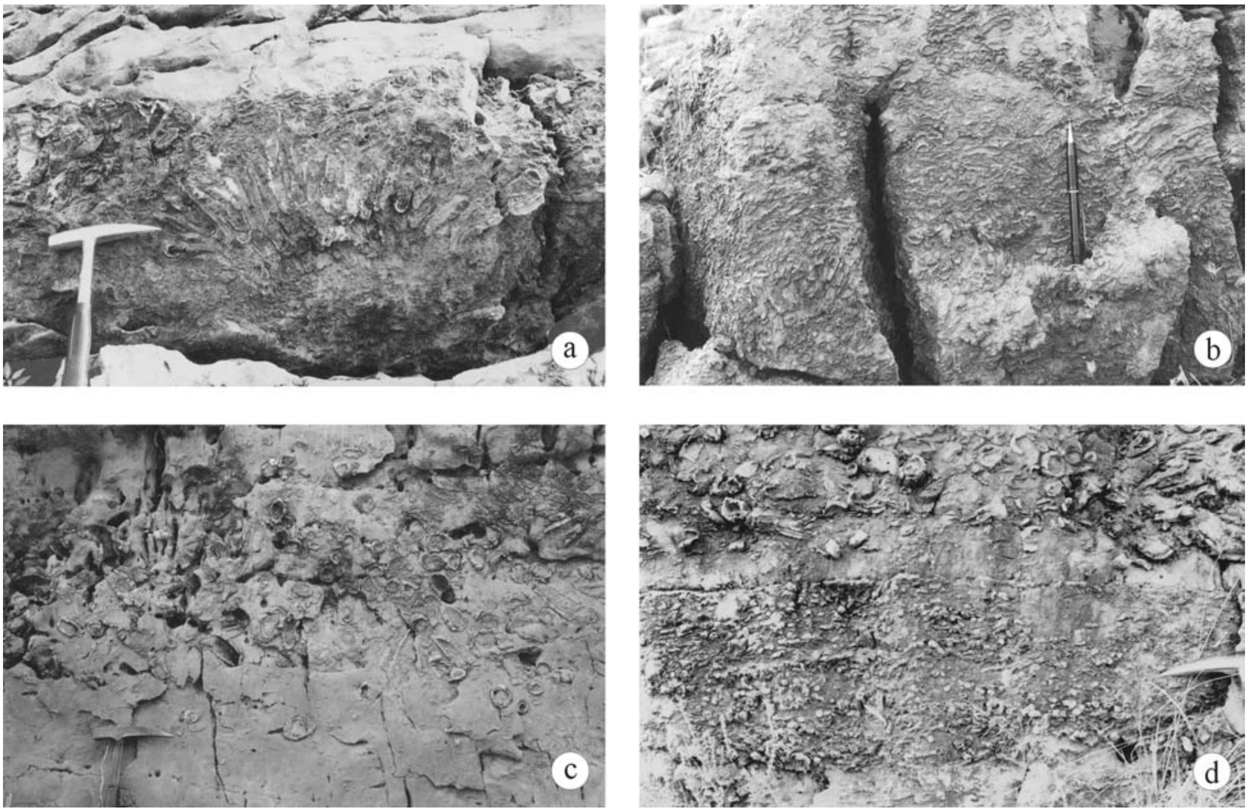

Fig. 8 – Trentinara outcrop. Rudist rich limestones. Note the close-spacing of the individuals in the monospecific congregations in a), b) and d). More complex, with moderately higher diversity, rudist beds are represented in c).

Affioramento di Trentinara. Calcari ricchi in rudiste. Si noti l'addensamento dei gusci nelle associazioni monospecifiche (a, b, d). In c) è rappresentato un livello a rudiste caratterizzato da una moderatamente più elevata diversità specifica e da un organizzazione spaziale degli individui più articolata.

tological heritage is effective way to conserve and protect its cultural and natural assets.

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