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CARBONATE FACIES ZONATION OF THE UPPER JURASSIC-LOWER CRETACEOUS APULIA PLATFORM MARGIN (GARGANO PROMONTORY, SOUTHERN ITALY)

MICHELE MORSILLI & ALFONSO BOSELLINI

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Riassunto. Il margine giurassico-eocretacico della Piattaforma Apula è ben esposto in terraferma nel Promontorio del Gargano dove, recentemente, è stata riscontrata la presenza di una *drowning unconformity* di età Valanginiana. Questo permette di raggruppare tutte le unità affioranti al di sotto di tale inconformità all'interno di una nuova sequenza deposizionale, denominata Sequenza di Monte Sacro. Nel presente lavoro viene presentata una zonazione di facies delle unità appartenenti a tale sequenza. Sono state distinte otto associazioni di facies corrispondenti a vari ambienti deposizionali. Nelle aree interne del Gargano affiorano tipiche successioni con cicli peritidali, interessati localmente da temporanee emersioni e da tempeste (F1); queste facies passano esternamente a calcareniti oolitiche e oncolitiche con strutture trattive e da onda a varia scala (F2), interpretate come barre e dune subacquee. Una fascia, in parte discontinua, con abbondanti calcareniti bioclastiche e piccoli *patch-reefs* (F3), è presente alle spalle di facies massive con organismi costruttori e incrostanti (F4); queste due associazioni vengono interpretate rispettivamente come un *reef-flat* e un *reef-front*. Esternamente è presente una facies massiva con *Ellipsactinie* e stromatoporoidi (F5) di margine esterno, che passa in modo graduale a delle brecce con frammenti centimetrici, bioclastici e litoclastici (F6), di scarpata prossimale. Brecce con clasti decimetrici e calcitorbiditi (F7) intercalate a micriti pelagiche con selce (F 8) rappresentano la scarpata distale e la transizione al bacino.

L'organizzazione areale di tali facies permette di ricostruire per la Sequenza di Monte Sacro una architettura deposizionale abbastanza complessa, anche se discontinua. Il profilo deposizionale della piattaforma è tipico delle piattaforme giurassico-cretacee tetidee, con pendenze massime del pendio sull'ordine dei 25°-28°. Il fatto che la piattaforma avesse una progradazione accentuata nel tratto nord del Gargano (area di M. d'Elio) e fosse quasi stabile verso sud-est (area di Mattinata) indicherebbe una posizione sopravento in questo secondo tratto e sottovento in quello settentrionale.

Abstract. The Late Jurassic-Early Cretaceous Apulia platform margin and the transition to adjacent basinal deposits (inner platform to basin) are well exposed in the Gargano Promontory. Detailed field work has allowed to recognize eight main facies associations which reflect various depositional environments, and which document a differentiated zonation, from the inner platform to the basin. A shallow lagoon existed in the internal part of the Gargano Promontory with a transition to tidal flat areas (F1). Oolitic shoals (F2) bordered this internal peritidal area passing seaward to a reef-flat with abundant corals (F3). A reef-front, associated with a coral rubble zone, has been found in some areas (F4). In the external margin zone, massive wackestones with *Ellipsactinia* occur (F5) and pass gradually to a rudstone facies on the proximal slope (F6). The base-of-slope facies association consists of pelagic sediments interbedded with gravity-displaced deposits (F7 and F8).

The depositional profile of the Apulia Platform is typical of the Tethyan Jurassic-Early Cretaceous platforms, with slope declivities in the order of 25°-28°. The remarkable progradation of the platform in the northern tract of the Gargano (Lesina and Varano lakes area) and its substantial stability east- and southwards (Mattinata area) suggest a possible windward position of the margin in this latter portion and, in contrast, a leeward position of the northern portion.

Introduction.

The Gargano Promontory is almost entirely constituted by a thick pile of various carbonate rocks, spanning in age from the Late Jurassic to the Pliocene with several hiatuses. It belongs to the external Apulia Platform (Mostardini & Merlini, 1988), which is part of the weakly deformed foreland of the Southern Apennine thrust belt (Finetti, 1982; Moretti & Royden, 1988). Furthermore, the Gargano is the area where the transition from the Apulia carbonate platform to the Ionian Basin is exposed on land (Fig. 1) (Bernoulli, 1972; D'Argenio, 1976; Zappaterra, 1990; Bosellini & Morsilli, 1997).

While the slope and inner platform successions of the Gargano, of Hauterivian to Eocene age, have recently been studied in great detail by many authors (Luperto Sinni & Masse, 1986, 1987; Masse & Borgomano, 1987; Bosellini & Ferioli, 1988; Borgomano & Philip, 1989; Masse & Luperto Sinni, 1989; Bosellini & Neri, 1993, 1995; Neri, 1993; Bosellini et al., 1993a, 1993b, 1994; Graziano, 1992; Bosellini & Morsilli, 1994, 1997; Luciani & Cobianchi, 1994; Neri & Luciani, 1994; Claps et al., 1996), the Upper Jurassic-Lower Cretaceous

Dipartimento di Scienze Geologiche e Paleontologiche, Università di Ferrara, Corso Ercole I d'Este, 32, 44100 Ferrara (E-mail, Michele Morsilli: morsilli@gst.it; Alfonso Bosellini: bos@ifeuniv.unife.it).

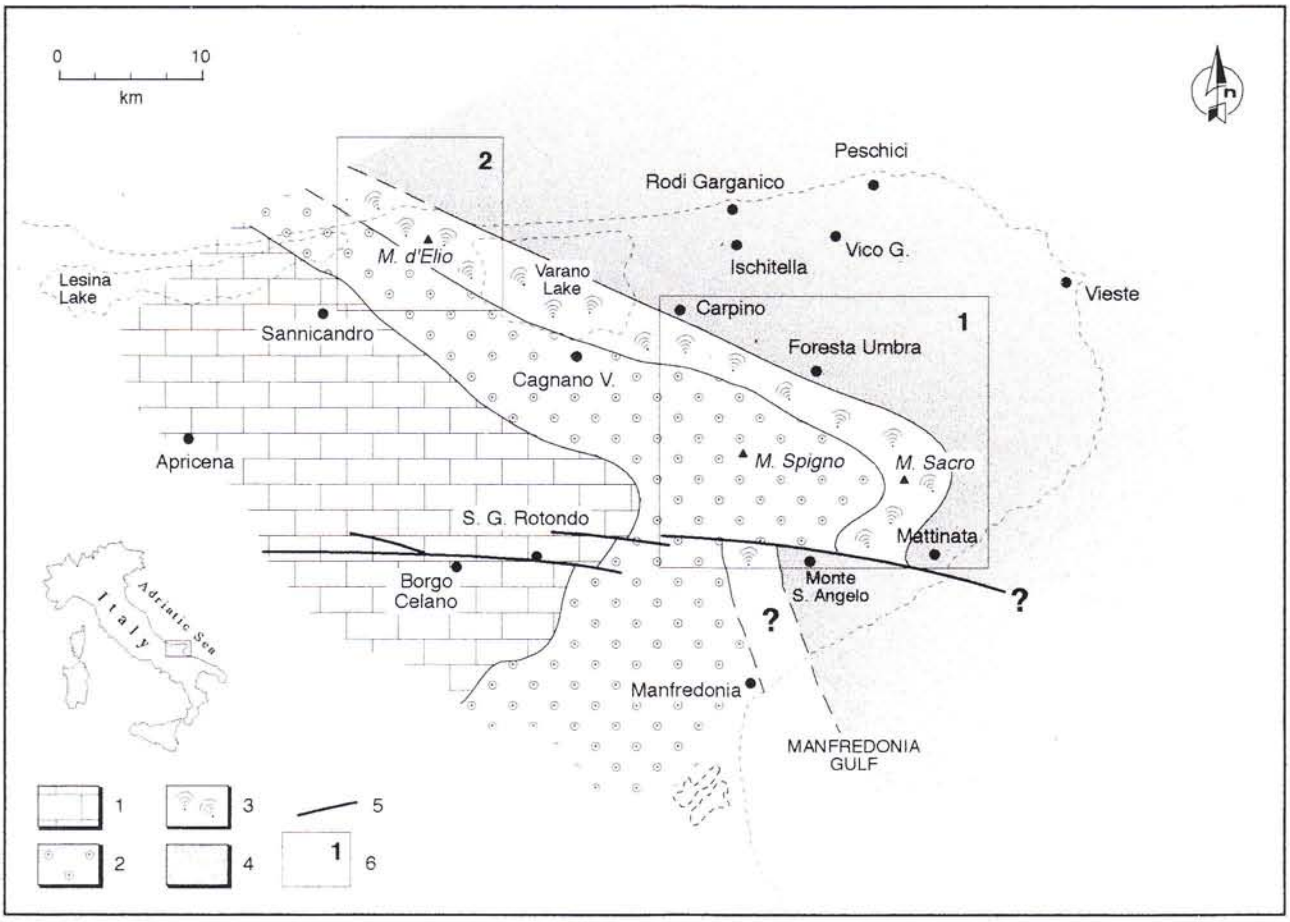

Fig. 1 - Palaeogeographic map of the Gargano Promontory for the Late Jurassic-Early Cretaceous. 1, inner platform (Sannicandro Formation); 2, internal margin (Monte Spigno Formation); 3, external margin (Monte Sacro Limestone); 4, slope and basinal deposits (Casa Varfone Formation and Maiolica); 5, Fault of regional importance (Mattinata Fault); 6, location of the study areas (slightly modified from Bosellini and Morsilli, 1997).

platform margin has received little attention from a sedimentological point of view.

The presence of Jurassic rocks in the Gargano yielding *Ellipsactinia* and corals has been known since the last century as a result of the pioneering work of Cortese & Canavari (1884) and Viola & Cassetti (1893). After a long break, in the mid 1960's AGIP geologists (Mattavelli & Pavan, 1965; Pavan & Pirini, 1966; Martinis & Pavan, 1967) recognized the presence of a shallow water carbonate succession in the south-western part of the promontory and of a slope to basin transition in the north-eastern area. These two areas were connected during the Late Jurassic by what they called a "bank-reef" margin (Monte Sacro Limestone) which separated a back-reef zone (Coppa Guardiola oolitic limestones) from a fore-reef zone (M. Iacotenente limestones, Maiolica). The same interpretation was accepted by Cremonini et al. (1971) who, furthermore, introduced many new formation names and created some confusion in the Gargano stratigraphy.

Coeval platform margin facies, with the same or similar biota, are widespread in the Tethyan realm. In Europe they have been found in Serbia, the Carpathians, Montenegro, Croatia (Grubic, 1967), Slovenia (Turnšek, 1981) and Portugal (Leinfelder et al., 1994; 1996). In Italy they have been described from the eastern Alps to Sicily (see references in De Castro, 1987), particularly in the Terratta Formation of the Abruzzi Region (Marsica Mountains, Maiella) (Colacicchi & Praturlon, 1965; Colacicchi, 1967; Crescenti et al., 1969; Catenacci, 1974; Colacicchi et al., 1978; Chiocchini, 1987). The upper part of the Terratta Formation was correlated with the Gargano Monte Sacro Limestone by Crescenti et al. (1969). The same correlation has been suggested with the island of Capri (*Ellipsactinia* limestones) (Barattolo & Pugliese, 1987; Chiocchini, 1987).

Current knowledge about the Upper Jurassic-Lower Cretaceous Gargano marginal facies composition and distribution is limited to a broad reconstruction which was proposed recently (Bosellini & Morsilli, 1994, 1997) (Fig. 1). The aim of this paper is to present a more detailed account of the facies distribution of the platform margin during the Late Jurassic-Early Cretaceous, based on detailed field work and on a new stratigraphic subdivision of the Gargano succession (see Bosellini & Morsilli, 1997). Hopefully, our work will be

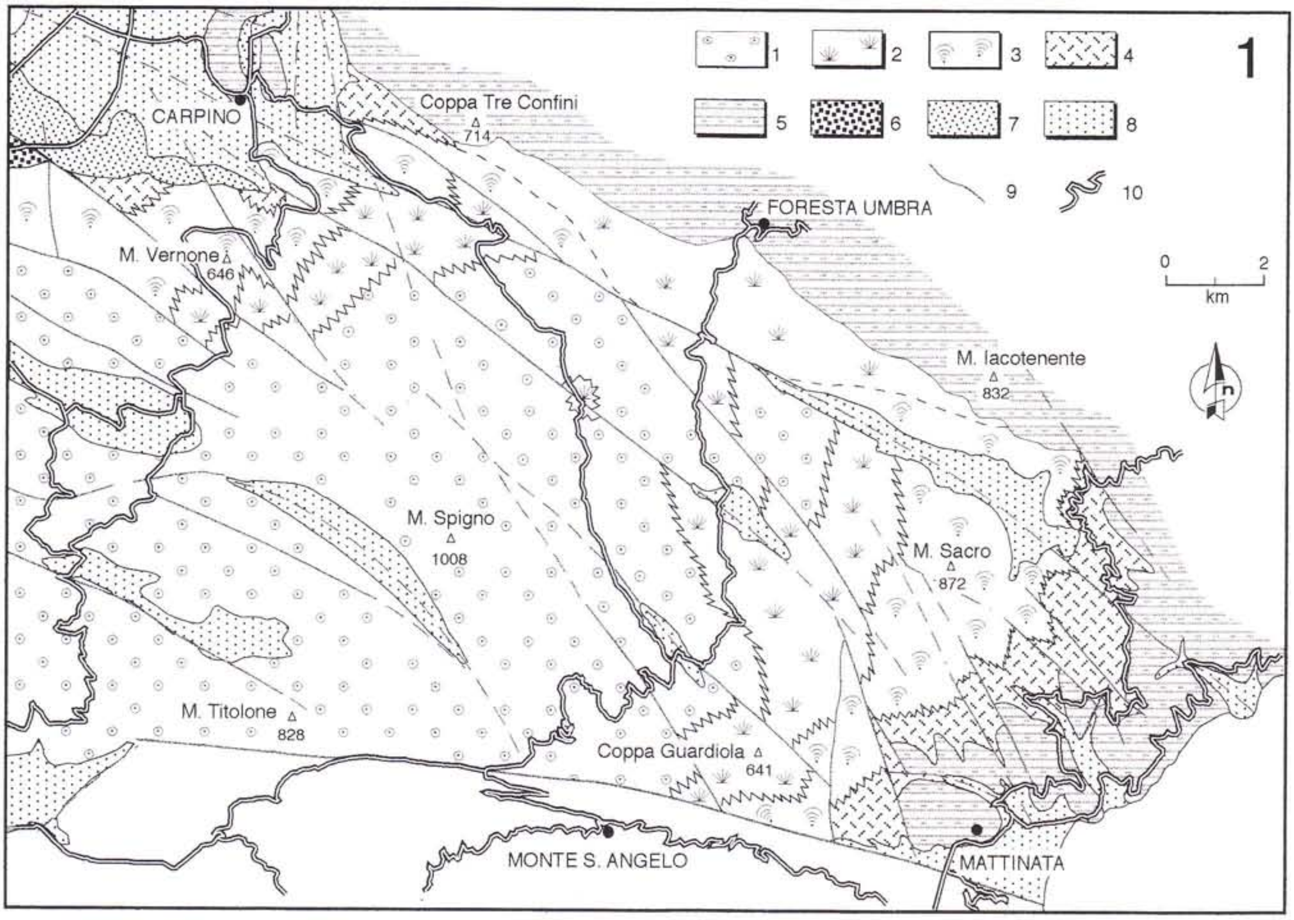

Fig. 2 - Simplified geological map of the area between Mattinata and Carpino (see Fig. 1, study area n. 1). 1, oolitic and micritic limestones (Monte Spigno Formation p.p. and Sannicandro Formation p.p.) (Facies associations 1 and 2); 2, calcarenites with corals (Monte Spigno Formation p.p.) (Facies associations 3 and 4); 3, Ellipsactinia wackestones (M. Sacro Limestone) (Facies associations 5 and 6); 4, stromatoporoid breccia and bioclastic calcarenites (Casa Varfone Formation and Maiolica p.p.) (Facies associations 7 and 8); 5, pelagic mudstones, graded calcarenites and breccias (Maiolica p.p. and Mattinata Formation, upper Valanginian-lower Aptian); 6, Cagnano breccia (Cenomanian?); 7, Miocene and Pliocene calcarenites; 8, Quaternary deposits; 9, main faults; 10, main roads.

useful for the interpretation of the stratigraphy of the Apulia platform margin both in regions less exposed than the Gargano, and in offshore seismic reflection profiles or in subthrust investigations.

Lithostratigraphy of the margin.

The platform margin crops out in two separate areas (Fig. 1). The first is the long arcuate segment between Mattinata and Carpino, where the marginal facies are well exposed (especially near Mattinata, along the main road S.S. n° 89). The exposure is however very poor in the "Foresta Umbra" owing to the extensive vegetation cover (Fig. 2). The second area is located between M. d'Elio and S. Nicola Varano (Fig. 3).

According to Bosellini & Morsilli (1997) the Late Jurassic-Early Cretaceous Apulia Platform was halted in its evolution by a drowning event of Valanginian age, which is well documented in other parts of the world (Simo et al., 1994). In the Gargano, pelagic sediments (Maiolica p.p.) of Valanginian-Hauterivian age onlap the platform flank: this stratigraphic relationship has been interpreted as a drowning unconformity (*sensu* Schlager, 1989) by Bosellini & Morsilli (1997). In a sequence stratigraphy context, the occurrence of a drowning unconformity allowed a new sequence to be identified, denominated here the "Monte Sacro Sequence" (Fig. 4), which broadens the sequential subdivision of the Gargano successions proposed by Bosellini et al. (1993, 1994).

The Monte Sacro Sequence is composed of five lithostratigraphic units (Fig. 4); from the inner platform to the basin these are as follows:

1 - Sannicandro Formation: this unit outcrops in the western sector (Fig. 1); the base is unknown in outcrop, and it is overlain by the San Giovanni Rotondo Limestone (Claps et al., 1996). Its lateral eastern boundary is difficult to map, since it passes very gradually into the Monte Spigno Formation; to the west the unit is buried below Tertiary sediments of the Apennine foreland basin. This formation is constituted by an alternation of dm-to-m-bedded lime mudstones-wackestone, decimetric to metric in thickness, frequently bioturbated. At the top of each cycles a cap of laminated stromatolite or oolitic packstones-grainstones occurs. The exposed thickness can be estimated to be about 200-250 ? m.

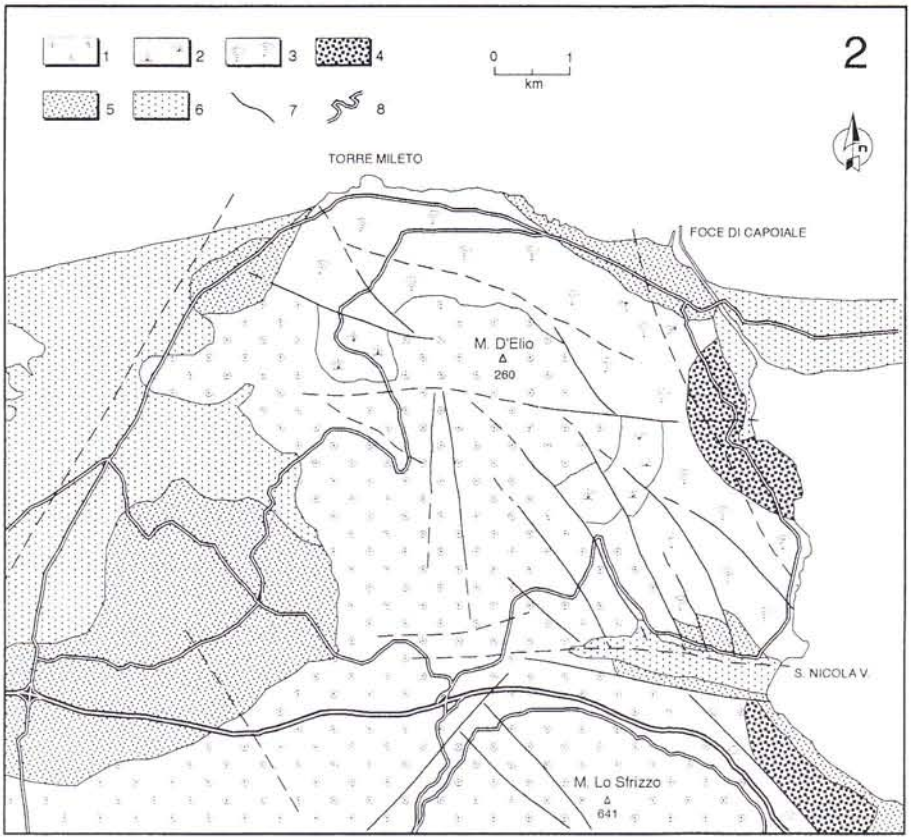

Fig. 3 - Simplified geological map of the area between Torre Mileto and S. Nicola Varano (see Fig. 1, study area n. 2). 1, oolitic and micritic limestones (Monte Spigno Formation p.p. and Sannicandro Formation p.p.) (Facies associations 1 and 2); 2, calcarenites with corals (Monte Spigno Formation p.p.) (Facies associations 3 and 4); 3, *Ellipsactinia* wackestones (M. Sacro Limestone) (Facies associations 5 and 6); 4, Cagnano breccia (Cenomanian?); 5, Miocene and Pliocene calcarenites; 6, Quaternary deposits; 7, main faults; 8, main roads.

The Sannicandro Formation is poorly known with respect to the other units since previous works included this formation in the S. Giovanni Rotondo Limestone (Mattavelli & Pavan, 1965; Pavan & Pirini, 1966; Cremonini et al., 1971).

More recent authors (Luperto Sinni & Masse, 1987; Claps et al., 1996) investigated only the Lower Cretaceous succession of the internal platform facies. Recently, Luperto Sinni & Masse (1994) proposed that the Sannicandro Formation should be confined to the inner platform facies of Jurassic age. On the basis of the occurrence of a Valanginian drowning unconformity (Bosellini & Morsilli, 1997), we suggest that the Sannicandro Formation should be extended to include the Berriasian-Valanginian p.p. interval.

2 - **Monte Spigno Formation**: this unit crops out along the central area of the Gargano promontory (Fig. 1) and is equivalent to the Coppa Guardiola Oolitic Limestones (*sensu* Mattavelli & Pavan, 1965; Martinis & Pavan, 1967). The lateral boundaries with the Sannicandro Formation and the Monte Sacro Limestone are very gradual, with some evidence of progradation over the latter (at M. d'Elio for example). The upper boundary is unknown because it has been eroded. The main lithofacies are oolitic and oncolitic grainstones, with parallel and oblique lamination (ripples and megaripples, small dunes), and frequent bioturbated lime mudstones-packstones. This formation consists of several facies and facies associations that reflect a broad range of depositional environments, suggesting depositional settings which shifting rapidly with time (see later). The true thickness is unknown since the base is buried, and Neogene extensional tectonics complicate the reconstruction of the succession; however, it is estimated to be about 300-400 m thick.

3 - **Monte Sacro Limestone**: this unit crops out in a narrow and arcuate belt from M. d'Elio to Mattinata (Fig. 1, 2 and 3). The continuity of outcrops is interrupted in the Varano Lake area, where the amphitheatre-like bay has been interpreted as a Cretaceous platform margin scallop (Bosellini & Morsilli, 1994). The lateral boundaries with both the Monte Spigno Formation and the Casa Varfone Formation are gradual; in contrast the upper boundary is abrupt and corresponds to the previously cited drowning unconformity: the Maiolica Formation onlaps and overlays the platform sediments. The base is not exposed. The outcropping thickness can be estimated to be about 300 m. This unit consists of massive wackestones with *Ellipsactinia*, *Sphaeractinia* and stromatoporoids; stromatactis, i.e. internal marine cements, occurs in some intervals. This formation has been referred to a "bank reef" (Mattavelli & Pavan, 1965; Martinis & Pavan, 1967; Cremonini et al., 1971). The same facies has been interpreted as an "external margin" on the island of Capri (Barattolo & Pugliese, 1987) and as representing a "slope environment" in the Marsica area (Colacicchi & Praturlon, 1965; Colacicchi, 1967).

4 - **Casa Varfone Formation**: this unit, informally proposed by Bosellini & Morsilli (1994), crops out near Carpino and Mattinata (Fig. 2 and 3). Upslope it passes into the M. Sacro Limestone and downslope into the Maiolica p.p.. Like the M. Sacro Limestone, it is onlapped by the Maiolica of late Valanginian-early Hauterivian age. The exposed thickness can be estimated to be about 150 m. The lithofacies consists of well bedded bioclastic calcarenites and stromatoporoid breccias interfingering with cherty lime mudstones.

5 - **Maiolica p.p.**: the Late Jurassic-Berriasian interval of this unit is poorly exposed, except for the strata interfingering with the Casa Varfone Formation and for a small outcrop described by Zamparelli (1964), where a few meters of Scisti ad Aptici and basal Maiolica formations occur. This interval has been encountered, also, in the AGIP well "Peschici 1" (Martinis & Pavan, 1967). In contrast, the upper interval (upper Valanginian-lower Aptian) is well exposed in the north-eastern Gargano, with some spectacular outcrops along the sea cliffs from Mattinata to Vieste. The Maiolica is a well known basinal facies of the Mediterranean region, and consists of thin bedded, intensily slumped, cherty micritic limestones.

Margin zonation: facies and environments.

The various units of the M. Sacro Sequence described above can be grouped into eight main facies associations. The terms facies and facies association are used here according to their definitions given by Mutti (in Bosellini et al., 1989). Each facies association corresponds to a depositional environment in a broad sense (lagoon, tidal-flat, beach, sandy shoal, reef, slope, basin) and is usually composed of typical facies, i.e. groups of strata or lithologies which reflect specific subenvironments and/or particular sedimentary processes. The eight facies associations recognized in the Monte Sacro Sequence were deposited in various depositional environments and sub-environments from the inner platform to the basin. Their zonation along the depositional profile is schematically shown in Figure 5.

Facies association 1 (lagoon-tidal flat). It is still poorly investigated, and the data mainly come from facies interfingered with Facies association 2. Highly variable facies have been recognized in the transitional area with F2, while in the internal zone of the Gargano Promontory Facies association 1 is more monotonous with a well defined peritidal cyclicity. The facies association consists of five lithofacies.

F1A: medium to thick-bedded (0.3-1.2 m) bioturbated lime mudstone-wackestone with fragments of dasycladacean algae and ostracods, large gastropods (*Nerinea* sp.) and oncoids are common in these beds. The tops of the beds are frequently characterized by birdseye structures or layers of oolitic-peloidal packstone. *F1B:* medium bedded (30-50 cm) packstone-grainstone with micritic ooids and pellets; bioclasts are fragments of gastropod, benthic foraminifers and echinoderms. In some beds layers of radial ooids and intraclasts, composed of peloids and ooids, are present. *F1C:* medium beds (30-50 cm) of peloidal packstone with well sorted oncoids (1-3 cm) at the top. *F1D:* thin to medium beds (10-30 cm) of planar stromatolites; small micritic intraclasts are present within the fine lamination frequently associated with irregular fenestral fabrics. *F1E:* thin beds (15-30 cm) of flat pebble intraformational breccia (Fig. 6) with packstone-grainstone clasts of 2-5 cm in lenght constituted of micritic ooids and peloids (F1B).

Interpretation. This facies association represents a typical lagoon environment grading into a tidal flat. The features described indicate subtidal (F1A), intertidal (F1D) and supratidal (F1E) facies. In the internal zone peritidal cycles have been recognized; the basal unit is represented by a subtidal facies (F1A), which is followed upwards by the intertidal and supratidal facies (F1D). In some cases thin beds (10-30 cm) of oolitic grainstones (F1A) are interbedded in these cycles; they probably represent washover-fan deposits, like those recently described in the Lower Cretaceous of the S. Giovanni Rotondo Limestone (Claps et al., 1996). Facies association 1 is represented in parts of the M. Spigno and Sannicandro Formations.

Facies association 2 (oolitic shoals). This association is more variable in comparision with the Facies association 1 because there are numerous and frequent vertical and lateral facies changes. This reflects quite a variety of sub-environments. Seven main lithofacies have been recognized.

F2A: massive or thinly-bedded (20-40 cm) oolitic grainstone. Ooids are characterised by thick concentric laminations, in some cases with a radial fabric. The nucleus is frequently a bioclast (small gastropod fragments or benthic foraminifers) or a broken ooid. Mollusk shell fragments and echinoderm spicules are also present. Radial ooids and intraclasts connected by meniscus cement are visible in thin section. Sedimentary structures observed include current and wave ripples (Fig. 7) and low angle planar-lamination (dune scale). *F2B:* poorly stratified or thick-bedded (1-2 m) grainstone with micritic ooids; no matrix is present (well washed grainstone). *F2C:* well bedded (20-50 cm) grainstone with coarse concentric ooids and pisoids, sparse intraclasts and fragments of gastropods. These beds are frequently graded

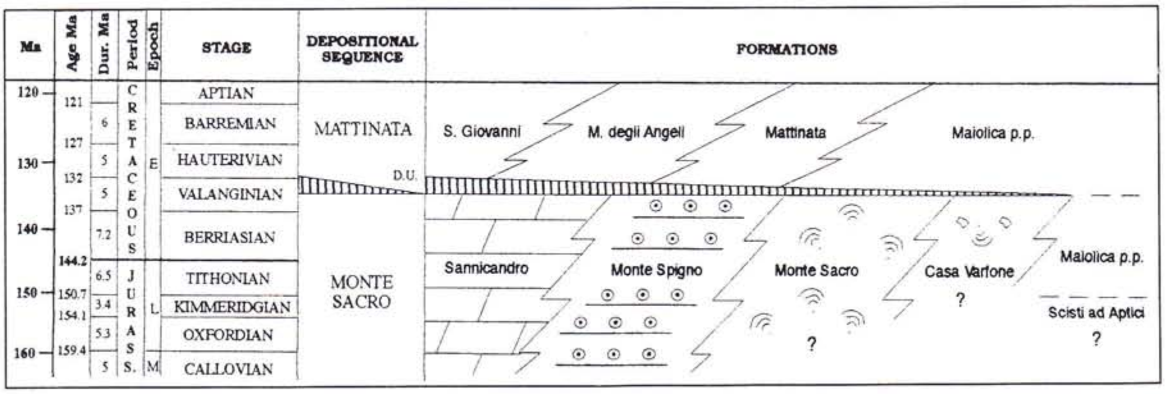

Fig. 4 - Chronostratigraphic chart showing the Upper Jurassic-Lower Cretaceous formations of the Gargano Promontory. The succession discussed in the present report is the Monte Sacro Sequence. Time scale after Gradstein et al. (1995).

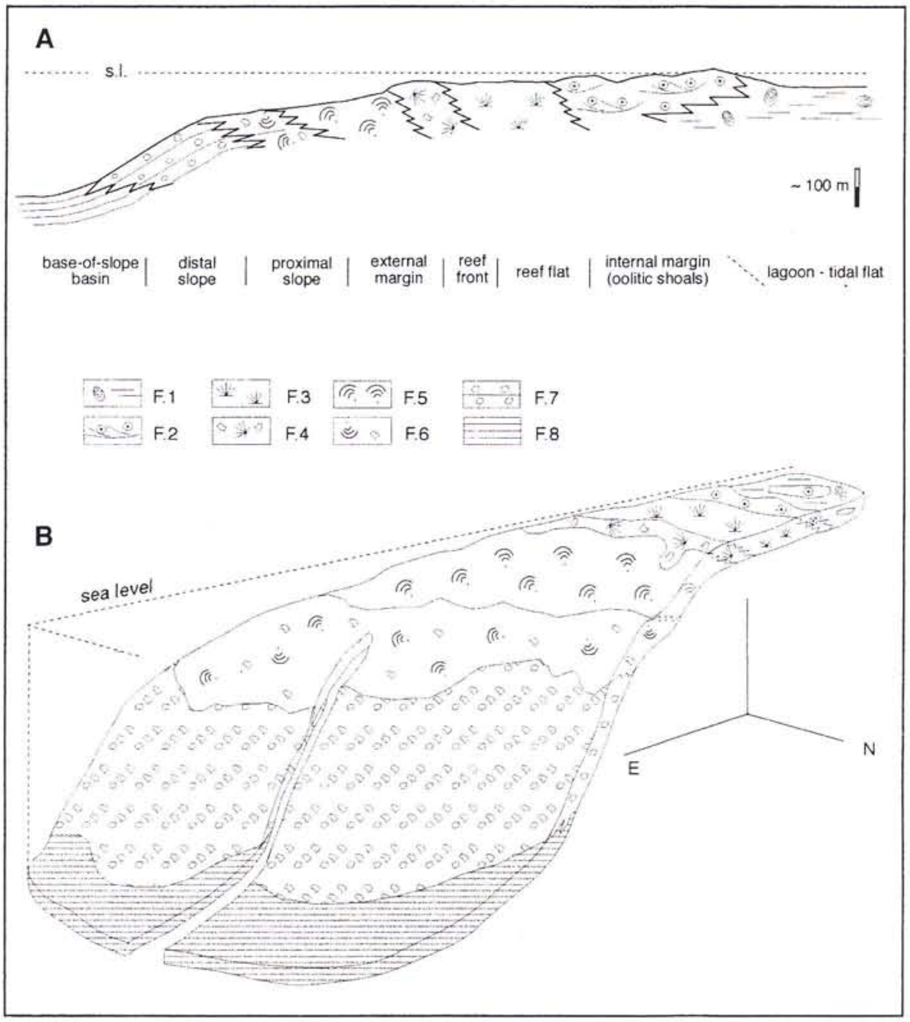

Fig. 5 - A) Schematic depositional profile and facies belts. Numbers refer to facies association described in the text. B) Schematic 3-D reconstruction of the Gargano margin during the Late Jurassic-Early Cretaceous.

and well sorted. Keystone vugs are visible in some cases at their top. *F2D:* thinly-bedded (10-20 cm) wackestone-packstone with micritic ooids, pellets and some grapestones. *F2E:* massive (2-4? m) skeletal grainstone with abundant gastropods. Small oncoids and lenses (20-30 cm) of graded packstone also occur. *F2F:* medium to thick beds (40-90 cm) of skeletal grainstone frequently even laminated with variable sorting, and sometimes containing single corals. *F2G:* thick beds of oolitic and bioclastic grainstone with small black pebbles (diameter 0.5-2 cm). This lithofacies has only been found near M. Vernone (Fig. 2).

Interpretation. This facies association is representative of various sub-environments, developed in a shallow-water high energy setting passing into a lagoonal environment (Facies association 1). These facies are indicative of oolitic shoals with local zones of emersion (small islands with beach and beach-rocks) (F2A). Facies association 2 corresponds to part of the M. Spigno Formation.

Facies association 3 (reef-flat). This association consists of four main lithofacies with a variable areal distribution.

F3A: thin to medium thick beds (10-50 cm) of grainstone with skeletal debris and micritic ooids; branching corals in life position are very abundant. *F3B:* thin beds (20-30) composed of large coated grains with a thick calcitic envelope. A skeletal fragment often forms the nucleus. *F3C:* skeletal grainstone lenses (few meters in length) with large fragments of gastropods and corals associated with F3B. *F3D:* massive bodies (3-6 m thick and 15-20 m long) of grainstone-packstone with branching corals. Poorly stratified beds of skeletal or oolitic grainstone are present along the flank of these bodies. They seem to onlap their surface. This facies is well developed in the Foresta Umbra area.

Interpretation. The abundance of branching corals in life position and the occurrence of slightly elevated massive bodies with corals, associated with skeletal sands, allows this facies association to be interpreted as a typical reef-flat with small patch-reefs. Facies association 3 corresponds to part of the M. Spigno Formation.

Facies association 4 (reef-front). This association consists of three main lithofacies with a variable areal distribution.

Fig. 6 - Flat pebble breccia in the inner peritidal succession (F1E). Note the small tepee structure at the top of the breccia layer (Folcara zone, road Cagnano-S. Giovanni Rotondo).

F4A: thick beds of massive skeletal grainstone with fragments of stromatoporoid, sponges and numerous corals. Sometimes micritic ooids and large gastropod fragments are recognizable. *F4B:* boundstone with various branching and single corals, *Tubiphytes*, sponges, large echinoid spines, some gastropods and stromatactis. In places, the rock is spotted with small cavities (5-10 cm) filled with carbonate silt (intra-reef cavities) *F4C:* rudstone with stromatactis, echinoids and corals in massive and thick beds (0.8-1 m), strongly bioturbated.

Interpretation. These facies represent a reef-front association. F4B indicates the presence of bioconstructions and probably a reef-framework (*sensu* Longman, 1981). It is well exposed near M. d'Elio (Fig. 3), while in the Mattinata area (Fig. 2) it has only been recognized in small outcrops near Coppa Guardiola. In this zone, on the other hand, F4C interpreted as a reef-crest (coral rubble zone) is well developed. Facies association 4 corresponds in part to the M. Sacro Limestone (F4B) and in part to the Monte Spigno Formation (F4A and F4C).

Facies association 5 (external margin). It consists of four main lithofacies with a variable areal distribution.

F5A: massive wackestone with *Ellipsactinia* (*E. capriensis* and *E. ellipsoidea*), *Sphaeractinia*, stromatoporoids, *Tubiphytes*. Stromatactis are common in some areas. *F5B:* poorly stratified rudstone with stromatoporoids and some branching and single corals, *Ellipsactinia* is rare. The matrix consists of skeletal grainstone. This facies has been recognized in the transitional zone to Facies association 6. *F5C:* massive grainstone with fragments of stromatoporoids, *Ellipsactinia*, corals, gastropods (*Nerinea* sp.) and crinoid ossicles. Stromatactis is very abundant (Fig. 8). This facies is present in areas adjacent to Facies association 4. *F5D:* small lenses of skeletal grainstone (2-4 m wide and 30-40 cm thick), frequently laminated (low angle concave-convex lamination) and interbedded with F5A and F5C.

Interpretation. This facies association is indicative of an external gently dipping margin (5-10°), below fairweather wave base at a depth between 10 and 50 m (Bosellini & Morsilli, 1994). F5D is probably the result of storm wave action. F5C is related to wave action or small storms in the shallowest zone of this facies association. Facies association 5 corresponds to part of the M. Sacro Limestone.

Facies association 6 (proximal slope). It consists of three main lithofacies with a variable areal distribution.

Fig. 7 - Oolitic grainstone (F2A) with oblique lamination (ripples) (locality M. Spigno, road Cagnano-S. Giovanni Rotondo).

F6A: thick-bedded (1-3 m), frequently amalgamated, skeletal rudstone with a clast diameter of 3-6 cm. Bioclasts are fragments of stromatoporoids, *Ellipsactinia*, *Sphaeractinia* and some corals. This facies is well exposed along the sea-cliff of Torre Mileto (Fig. 3) and near Mattinata (Ripe Rosse). *F6B:* poorly stratified to massive wackestone-packstone with various clast types (diameter from 2-3 mm to 1-2 cm), micritized algae, micritic ooids, stromatoporoids, rare gastropods (*Nerinea sp.*), small lenses (decimeters in size) of grainstone-packstone with micritized ooids and intraclasts. Branching and single corals have been found scattered in this facies. Some *in situ* thamnasteroid corals also occur. *F6C:* in association with F6B there are thick-beds (1-2 m) of grainstone-packstone with abundant crinoid ossicles, echinoid spines and a few single corals (cm-size). F6B and F6C have only been found near "Foce di Capoiale" (see Fig. 3) in a small abandoned quarry. This facies is absent in the Mattinata area.

Interpretation. This facies association and the geometric relationships observable in the field allow to interpret it as a proximal clinostratified slope succession (the dip is between 15° and 20°, therefore less inclined than Facies association 7). Furthermore, the presence of thamnasteroid corals during the Late Jurassic seems to be related to a relatively deep environment (below 30 m water depth) (Wilson, 1975). Resedimentation processes seem to be limited to small debris flows (probably storm driven) on the platform flank. Facies association 6 corresponds to a distal portion of the M. Sacro Limestone.

Facies association 7 (distal slope). This association consists of three main lithofacies.

F7A: thick-bedded (1-2 m) skeletal rudstone with an average clast diameter of 2-3 cm. Bioclasts are fragments of *Ellipsactinia*, *Sphaeractinia*, stromatoporoids and rare corals. *F7B:* intraclastic-bioclastic grainstone, frequently graded; in places laminations are visible in thicker beds. The stratification is frequently obscured by the amalgamation of calcarenite beds. The base is sharp and gently undulated. Small nodules of white chert are also present. *F7C:* thick beds of breccia with a clast size ranging from 6 to 25 cm. The sparse matrix (clast-supported breccia) is grainstone and packstone; clasts are composed of F7A and F7B lithologies. In the distal part of this unit thin micritic beds (F8A) are associated with F7B.

Interpretation. The facies described above can be interpreted as the product of different gravity flow types, from hyperconcentrated flows (F7C) to high-density turbidity currents (F7B) (*sensu* Mutti, 1992). This facies association is interpreted to reflect a distal slope setting. According to the physical relationships directly observable in the field (Fig. 9), the depositional dip was approximately 25-28° passing downslope to 10-15°. Facies association 7 corresponds with the Casa Varfone Formation.

Facies association 8 (base-of-slope to basin). Observations on this facies association come from the distal part of the Casa Varfone Formation, wich includes three different lithofacies.

F8A: thin bedded (5-30 cm) lime mudstone-wackestone with poorly preserved planktonic foraminifers, with whitish chert lenses or nodules; slumps are frequent (Fig. 10). The beds are commonly bioturbated with a sharp or undulating base. *F8B:* thin beds (10-20 cm) of fine grained intraclastic grainstone-packstone, often normally graded with an erosional base. *F8C:* breccia units of variable thickness (2-5 m). They are massive and usually mud-supported, and contain poorly rounded flat clasts (5 to about 30 cm in length) of lime mudstone and chert derived from facies F8A. The matrix consists of chalky lime mudstone and small limestone pebbles (0,5-1 cm). In places, this facies association is partially dolomitized (for example along the S.S. n° 89, near Mattinata), but this diagenetic process did not obliterate textural and structural features. Facies 8A is preva-

Fig. 8 - Wackestone with fragments of *Ellipsactinia* and abundant marine cements (F5C) (M. Vernone, road Carpino-S. Giovanni Rotondo).

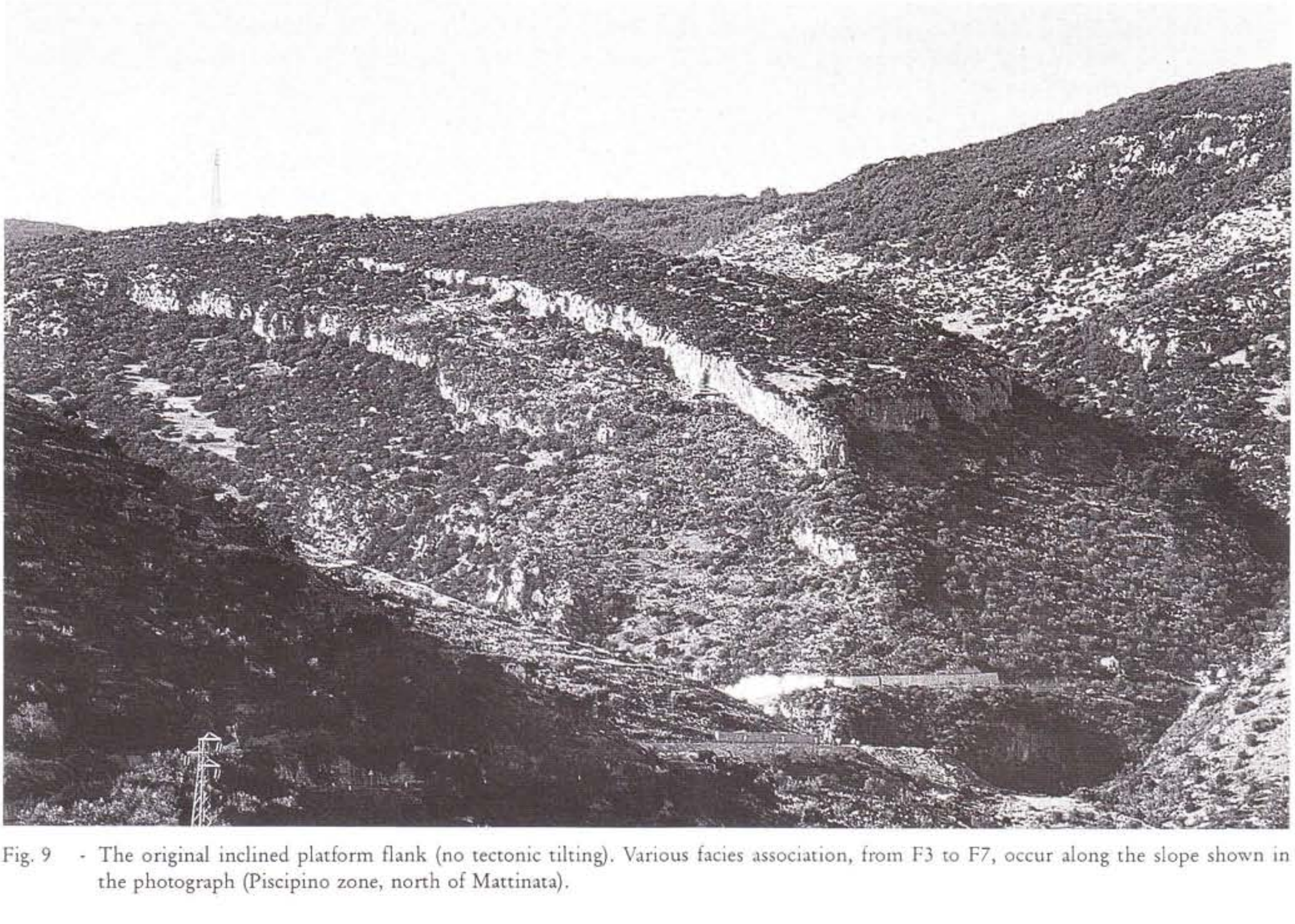

Fig. 9 - The original inclined platform flank (no tectonic tilting). Various facies association, from F3 to F7, occur along the slope shown in the photograph (Piscipino zone, north of Mattinata).

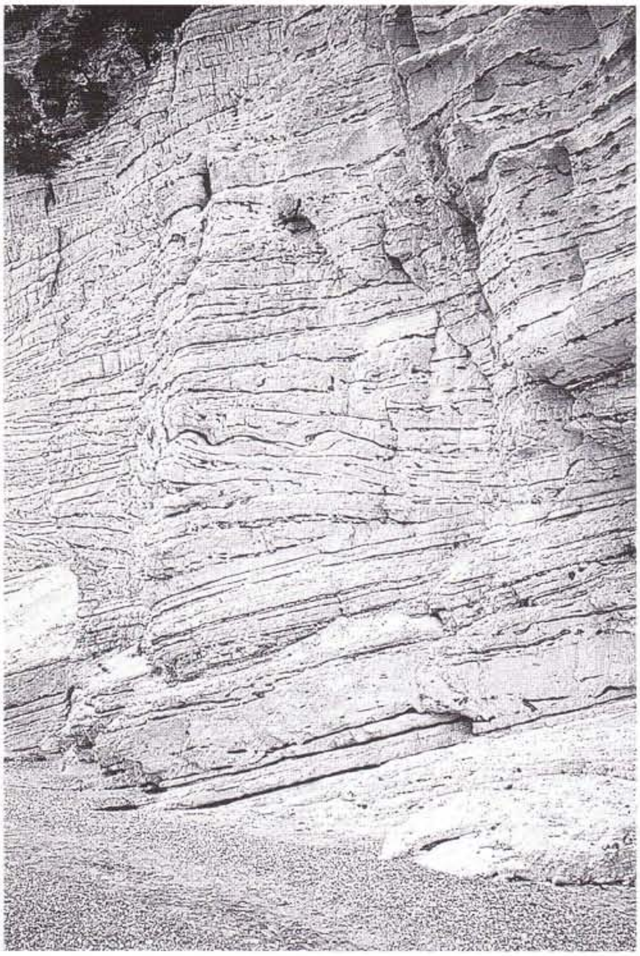

Fig. 10 - White basinal limestones (Maiolica) with chert layers and nodules (F8A), Several slump features are clearly visible (sea-cliff east of Mattinata).

lent in the Maiolica, while F8B and F8C are characteristic of the Casa Varfone Formation.

Interpretation. F8A represents typical pelagic deposition, F8B may be related to low-density turbidity currents and F8C to hyperconcentrated flows (*sensu* Mutti, 1992). The facies association is typical of a transitional zone between the base-of-slope and the basin. Facies association 8 corresponds to the Maiolica and partly to the Casa Varfone Formation.

Discussion: facies distribution and platform margin geometry.

The various facies associations recognized in the Monte Sacro Sequence allow to distinguish several environments and subenvironments which are representative of a mature reef complex (*sensu* Longman, 1981).

As is well known (Schlager, 1991), the facies architecture of a platform is controlled by several factors, including relative sea-level change, carbonate productivity, physiography of the substrate, tectonics, exposure of the margin to ocean circulation and dominant winds (i.e. windward vs. leeward), storms, tides, nutrient supply etc. Therefore, further considerations are presented here on the environmental significance and distribution of the various facies association described previously.

The inner platform facies association (F1) is typical of a peritidal environment. The meter-scale shallowing upward sequences which characterize this facies association are the result of a high-frequence cyclicity. These cycles are similar to those described in the overlying S. Giovanni Rotondo Limestone (Claps et al., 1996) and may be Milankovian in origin (although we have no data to support this hypothesis). The common occurrence of oolite sand sheets in these peritidal cycles also documents frequent storm events.

In isolated Bahamian-type platforms, such as the Apulia carbonate platform, the relative position of the margin with respect to the dominant winds and related storms was very important for the development of the margin architecture and platform growth (Hine & Neumann, 1977; Read, 1982, 1985; Eberli & Ginsburg, 1987). Field evidence indicates that during the Late Jurassic-Early Cretaceous progradation along the southern sector of the Gargano (Mattinata area) was minimal. In contrast, in the northern Gargano (M. d'Elio area) the platform was considerably prograding. Here, in fact, the oolite facies association (F2) overlies the reef front facies (F4) (Fig. 3) and some displaced oolitic-oncolitic clasts were deposited off-bank and occur in the external margin (F5) and proximal slope (F6) facies associations.

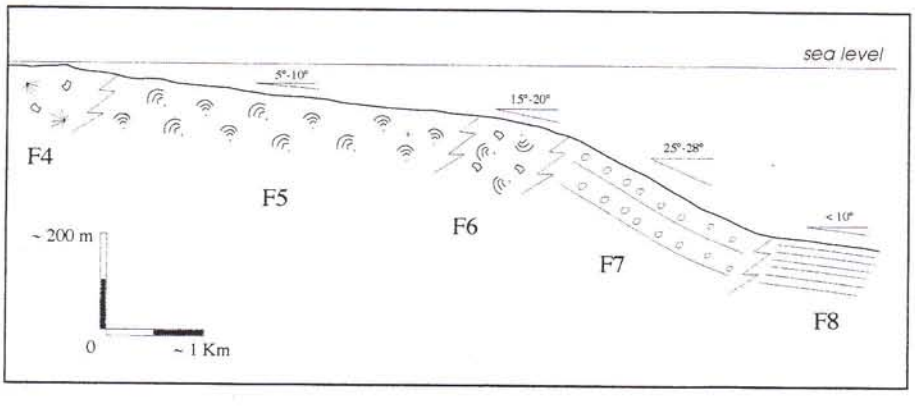

Fig. 11 - Depositional profile of the Gargano platform flank. Declivities and the relative width of the various facies association are based on direct and physically observable field data (compare Fig. 9).

In conclusion, on the basis of our field data, it is possible to suggest a relative windward-leeward position for the southern and northern Gargano platform margins respectively.

As regards the geometry and profile of the platform margin and flank, we had the opportunity to improve the classic facies interpretation with direct field evidence on the slope declivity (Fig. 11). The external margin (F5) shows an inclination of 5°-10°, which increases to 15°-20° downslope (F6). Here there is a relative break in declivity when passing to the slope proper which has an average inclination of 25°-28° (F7). Finally, the transition to the basinal facies (F8) occurs gradually with gentle inclinations (less than 10°). Considering the horizontal distance between the platform top and the basin, and the average inclination of the slope, it is possible to infer a platform relief of at least 500 m. This figure is in accordance with the presence of a drowning unconformity between the platform flank and the overlying basinal sediments (Bosellini & Morsilli, 1997), a stratigraphic relationship typical of high relief platforms (800 m or more; Schlager, 1989).

Conclusions.

Our study has revealed a highly differentiated sedimentary zonation of the Apulia Platform margin for the terminal Jurassic and Early Cretaceous.

A facies belt represented by eight facies associations, reflecting different depositional environments, has been reconstructed along the Gargano tract of the Apulia Platform margin. From inner platform to base-of-slope settings, these facies associations and relative environments include: F1, tidal-flat with transition to shallow lagoon; F2, oolite bars and shoals; F3, reef-flat; F4, reef-front with coral rubble zone; F5, external margin with *Ellipsactinia* and stromatoporoids; F6, proximal slope with bioclastic rudstone; F7, distal slope with breccia and turbidite deposits; F8, base-of-slope to basin transition with pelagic limestones and diagenetic chert. The southern and the eastern tracts of the Gargano margin were probably positioned windward with respect to the dominant winds during the Late Jurassic-Early Cretaceous, while the northern tract (Lesina and Varano lakes) was a leeward margin.

The platform flank and slope show the classic geometry of steep Tethyan platform margins (Bosellini, 1989), rising several hundred meters above the adjacent basin.

The transect across the Gargano peninsula with its optimal exposures, can be regarded as a case model for the stratigraphy of the Jurassic-Early Cretaceous Apulia Platform margins in regions less well exposed than the Gargano or in areas known only from seismic reflection profiles, both offshore and in the subthrust geology of the southern Apennines.

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