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JURASSIC SEDIMENTARY AND TECTONIC PROCESSES AT MONTAGNA GRANDE (TRAPANESE DOMAIN, WESTERN SICILY, ITALY)

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Abstract. The Rosso Ammonitico of the Montagna Grande area is very interesting because of the great diversification in facies and thickness in three very closely situated sections. The Jurassic succession in this area is that typical of the Trapanese Domain. It starts with a thick pile of platform limestones (Inici Formation: Hettangian - Sinemurian) that are overlain by typically condensed and commonly nodular pelagic limestones (Rosso Ammonitico: Middle Jurassic - lowermost Cretaceous). The good exposure of this succession in active quarries allows observation of sedimentological and palaeontological details and to improve the understanding of the Jurassic tectono-sedimentary evolution. The Rocca chi Parra quarry shows a stepped surface, with a relief of some metres, incised in the Inici Formation. It is covered by lenticular or wedge-shaped lithosomes a few metres-thick of highly condensed Rosso Ammonitico. It is interpreted as a slide scar along which a thin but extensive block of lithified platform limestones was detached and slid downslope. The Poggio Roccione quarry shows neptunian sills and collapse structures in the middle part of the Rosso Ammonitico that on the whole is thicker (about 12 m) than at Rocca chi Parra. They indicate sea-floor instability probably due to seismic shocks with brittle to plastic behaviour of sediments depending on their coherence. The Montagna Grande outcrop shows an even thicker succession which includes a wedge of cherty limestones about 10 m thick intercalated between a lower and an upper Rosso Ammonitico calcareous unit.

The features described in these three sections document a highly irregular sea-floor topography which in turn was controlled by several phases of extensional tectonics during Mid and Late Jurassic pelagic sedimentation. Structurally higher sectors closer to fault scarps were affected by a very condensed sedimentation, the opening of subvertical dykes and the triggering of large slides. Structurally lower sectors allowed preservation of thicker successions that were affected by gravitationally-induced soft to hard sediment deformation when tectonics resulted in an oversteepening of the slope.

Riassunto. Il Rosso Ammonitico affiorante a Montagna Grande è molto interessante per l'elevato grado di diversificazione di facies e spessore in tre sezioni molto vicine. La successione Giurassica in quest'area è quella tipica del Dominio Trapanese. Essa risulta costituita da una spessa sequenza di calcari di piattaforma (Formazione Inici: Hettangiano - Sinemuriano) seguita da calcari pelagici condensati e spesso nodulari (Rosso Ammonitico: Giurassico medio - Cretacico inf.).

La buona esposizione di tale successione in cave attive permette di osservare dettagli sedimentologici e paleontologici e di migliorare la comprensione dell'evoluzione tettono-sedimentaria giurassica. Nella cava di Rocca chi Parra una superficie a gradinata, con un rilievo di alcuni metri, è incisa al tetto della Formazione Inici. Tale superficie è coperta da litosomi lenticolari o cuneiformi di Rosso Ammonitico molto condensato dello spessore di pochi metri. Essa viene interpretata come una cicatrice di una frana sottomarina lungo la quale un blocco sottile ma lateralmente esteso di calcari di piattaforma litificati si staccò e scivolò lungo un pendio. Nella cava di Poggio Roccione numerosi filoni sedimentari e strutture da collasso riferibili al Giurassico sup. sono presenti nella parte media del Rosso Ammonitico che è più spesso (circa 12 m) che a Rocca chi Parra. Tali strutture indicano un'instabilità del fondo probabilmente dovuta a shock sismici con un comportamento dei sedimenti da fragile a plastico. L'affioramento di Montagna Grande è caratterizzato da una successione ancora più potente, che comprende un cuneo di calcari selciferi spessi circa 10 metri interposto tra due unità calcaree di Rosso Ammonitico.

Le caratteristiche riscontrate nelle tre sezioni permettono di ricostruire una topografia molto irregolare del fondo marino, a sua volta controllata da una tettonica distensiva che ha agito in diversi momenti nel corso del Giurassico medio-superiore, durante la sedimentazione pelagica. I settori strutturalmente più rilevati e prossimi a scarpate di faglia furono interessati da sedimentazione molto condensata, apertura di filoni sedimentari subverticali e dal distacco di frane sottomarine. I settori strutturalmente più ribassati permisero invece la conservazione di successioni più spesse che furono influenzate da deformazioni dovute a movimenti gravitativi quando la tettonica provocò un'accentuazione dei gradienti di pendio.

Introduction

The Montagna Grande area is one of the sectors in western Sicily where carbonate rocks of Jurassic age referable to the Trapanese Domain crop out (Fig. 1). The Jurassic stratigraphic succession of the Trapanese Domain starts with a thick succession of peritidal platform limestones (lowermost Jurassic Inici Formation) that are unconformably overlain by typically condensed and

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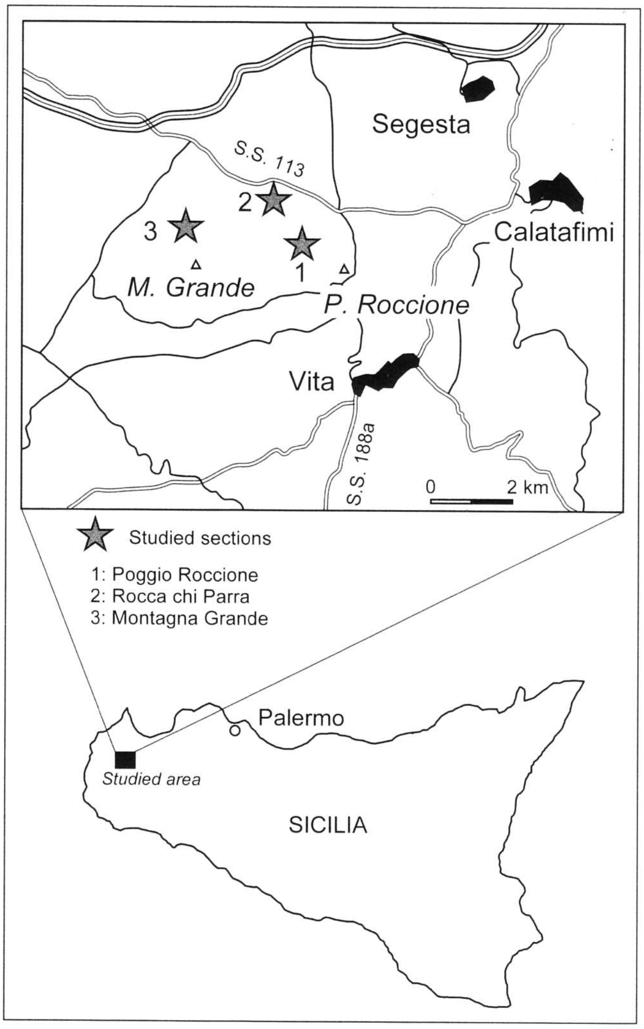

Fig. 1 - Location of the studied area.

commonly nodular pelagic limestones (Middle Jurassic - lowermost Cretaceous Rosso Ammonitico) (Catalano et al. 1996). The bounding discontinuity surface commonly shows a typical pinnacled morphology with thick Fe-Mn crusts in many outcrops in the Trapanese successions (e.g. Di Stefano & Mindszenty 2000). The Rosso Ammonitico limestones, in turn, pass upwards into a thicker succession of pelagic sediments referred to the Lower Cretaceous - Paleogene Lattimusa and Scaglia formations.

Since the classical papers on the Sicilian Jurassic (e.g. Christ 1960; Wendt 1963; Jenkyns 1970; Catalano & D'Argenio 1982; Montanari 1989; Catalano et al. 1996, 2000) the tectonostratigraphic evolution of a wide area in Sicily including the Panormide, Trapanese, Saccense, and Hyblean Domains, like many other units in the Mediterranean Jurassic, is generally considered as a two-stage history involving a phase of sedimentation on a Bahamian-type carbonate platform, followed by drowning and pelagic sedimentation on a submerged plateau. Within the Trapanese Domain different sectors exist which are diversified by diachronous drowning and differences in thickness of successions and pelagic facies associations (e.g. Monte Inici, Erice and Rocca Busambra sectors, Wendt 1963, 1971a, 1971b; Giunta & Liguori 1972; Martire & Pavia 2002). Within this framework, the Montagna Grande area, and in particular the Rocca chi Parra quarry, are interesting because of the high diversification of the Middle - Upper Jurassic deposits ranging from extremely condensed to expanded.

The Jurassic rocks cropping out in the area of Montagna Grande have been studied for more than a century also because of the rich Middle and Upper Jurassic ammonite assemblages (Gemmellaro 1872-82; Christ 1960; Wendt 1963; Jenkyns 1970; Giunta & Liguori 1972; Mascle 1979). Recently some sections of Rosso Ammonitico have been reviewed in the light of the advancements in carbonate sedimentology and ammonite biostratigraphy (Martire et al. 2000; Savary 2000).

The ongoing quarry activity has resulted in new outcrops allowing observation of new details concerning sedimentology, biostratigraphy and taphonomy that contribute to a more refined understanding of the tectono-sedimentary evolution of this sector of the Trapanese Domain.

Description of the sections

Montagna Grande, 750 m high, is one of the highest topographic features in the study area that is located about 7 km south-west of the well known archaeological site of Segesta in western Sicily (Fig. 1). Poggio Roccione quarry, Rocca chi Parra quarry and Montagna Grande natural outcrops have been studied. They lie within a small area of less than 3 km^2 and, in spite of this, show significantly different stratigraphy, thickness, facies and structure. The first two have already been described by Martire et al. (2000) to which the reader is referred to for more details. In the following chapters the name "Rosso Ammonitico" will be used as an informal lithostratigraphic term to indicate all the Middle Jurassic - lowermost Cretaceous pelagic sediments that may show or not a red colour and the typical nodular facies, including also evenly bedded, cherty limestones.

Poggio Roccione quarry

Description. In 2000 a short-lived reactivation of the quarry resulted in the cleaning of the old quarry front that was covered by a thick weathered crust enabling recognition of interesting post-depositional structures in the middle part of the Rosso Ammonitico.

The top of the Inici Formation here is characterised by a pinnacled and Fe-Mn coated surface overlain by the Rosso Ammonitico (Fig. 2). Another peculiar discontinuity occurs about 5 m above the Inici Formation top (beds 5 - 6 boundary). It is sharp and flat except for the presence of centimetre-sized pillars topped by Fe-Mn oxide crusts. This surface separates two units in the Rosso Ammonitico. The lower part is massive on the whole and ranges lithologically from grainstones with thin-shelled bivalves (*Bositra*) and peloids at the base, to nodular wackestones with oncoids, intraclasts and continuous layers of laterally linked stromatolitic domes towards the top. Alignments of truncated ammonite moulds and large firm-ground burrows with Fe-Mn stained

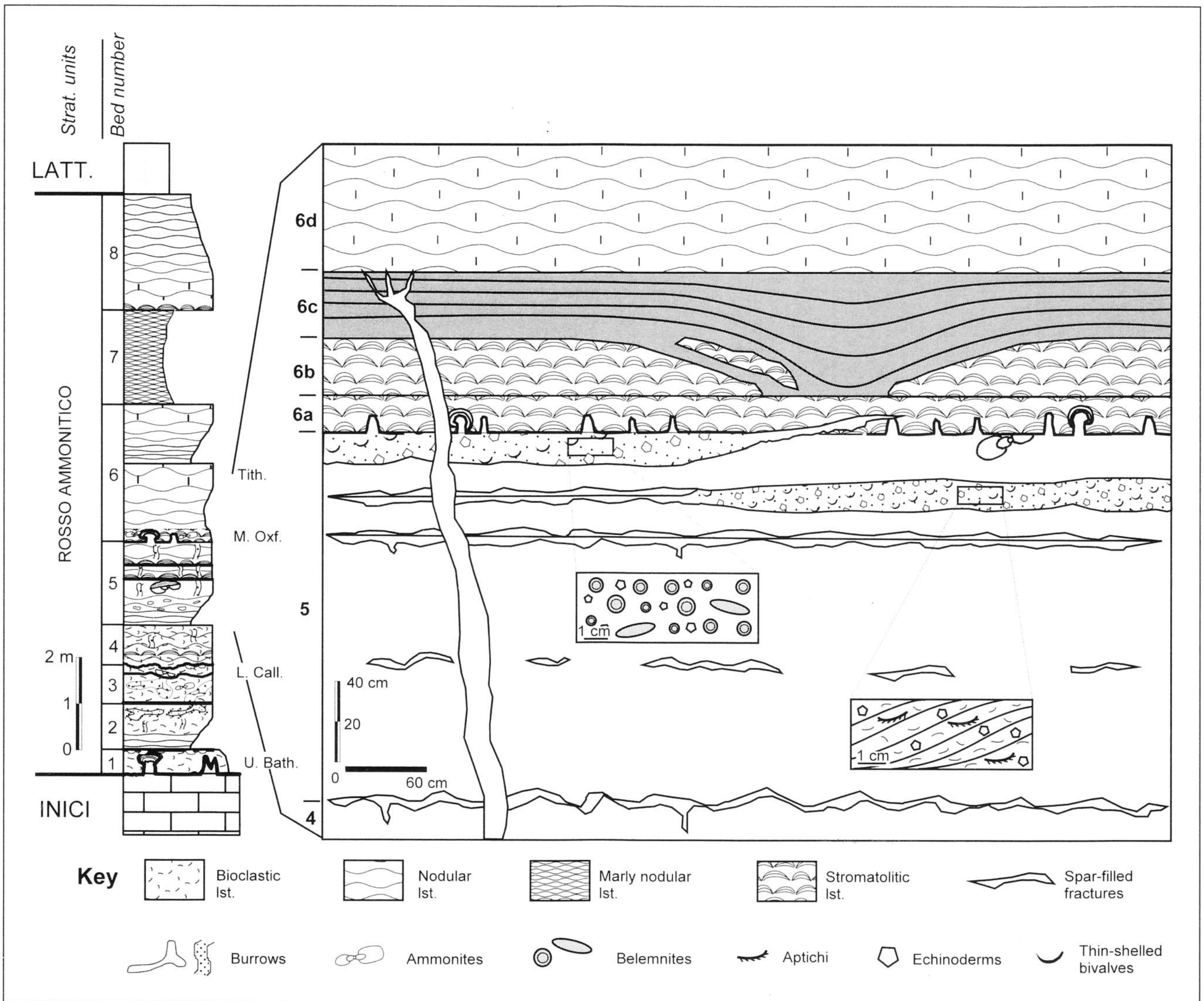

Fig. 2 - Log of the Poggio Roccione section (after Martire et al. 2000) with a close up of beds 4 - 6 evidencing neptunian sills, dykes and collapse structures.

walls, indicate the abundance of erosion discontinuity surfaces.

The presence of some ammonite moulds such as *Homeoplanulites* (*Parachoffatia*) *arisphinctoides*, *H.* (*P.*) gr. *subbackeriae*, *Hecticoceras* (*Prohecticoceras*) *retrocostatum*, *Oxycerites* gr. *aspidoides*, allows to refer the first bed of the Rosso Ammonitico to the lower part of the Upper Bathonian. Other ammonites, among which *Macrocephalites* sp., indicate an Early Callovian age for the upper part of bed 3 (Fig. 2).

The upper part of the Rosso Ammonitico starts with a 30 - 40 cm thick massive bed (beds 6a and 6b) with abundant ammonites also of large size (up to 25 cm in diameter). Texturally it consists of wackestones and packstones with peloids and protoglobigerinids and displays a millimetre-thick stromatolitic lamination. The ammonite assemblage is typically early Middle Oxfordian and can be referred to the *P.* (*Dichotomosphinctes*) *antecedens* Subzone (top of the *P. plicatilis* Zone). Besides very common phylloceratids (e.g. *Holcophylloceras zignodianum*, *Sowerbyceras tortisulcatum*), characteristic forms include *Lissoceratoides erato*, *Tornquistes* cf. *kobyi* (M + m), *Gregoryceras tenuisculptum*, *Passendorferia tenuis*, *P.* (*Dichotomosphinctes*) gr. *antecedens* (C. D'Arpa & G. Melendez, pers. comm.). The finding of a *Pygope* sp. at the top of bed 6 allows to refer it to the Tithonian. The overlying beds are characterised by a well defined nodular structure and different bed packages may be distinguished by the colour, that may range from brick red to pink, clay content, size of nodules, and nodule/matrix ratio. Nodules are generally made up of *Saccocoma* wackestones; they contrast markedly with the matrix, a *Saccocoma* packstone, crossed by clay-rich dissolution seams reflecting the intensive pressure dissolu-

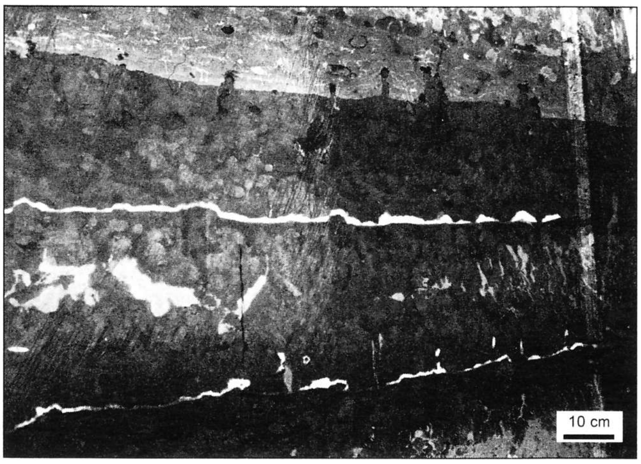

Fig. 3 - Bedding-parallel cracks filled with red micrite and white calcite cement in the upper part of bed 5, topped by the pinnacled discontinuity surface. Poggio Roccione quarry.

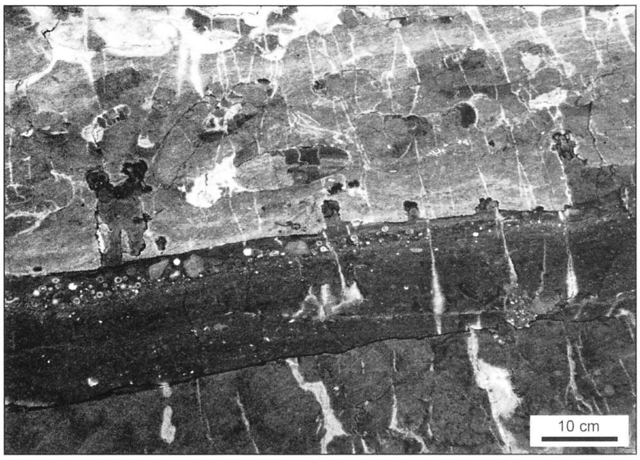

Fig. 4 - Bedding-parallel neptunian sill developed at the bed 5 - 6 boundary where it cuts the pillars at the base. The fissure is filled with a belemnite-rich sediment. Note the abundance of ammonite moulds at the base of bed 6. Poggio Roccione quarry.

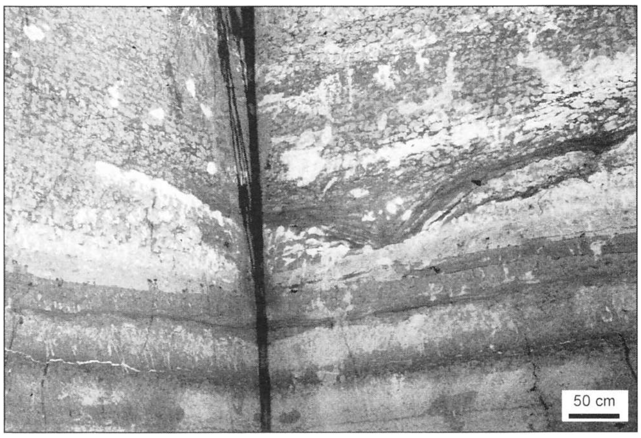

Fig. 5 - Collapse structure in beds 6b and c. Owing to the breakage and sliding of bed 6b, the overlying plastic sediments collapsed into the funnel-like depression. Poggio Roccione quarry.

tion only experienced by the matrix that, differently from the nodules, was not early cemented. Upwards, the texture becomes more and more micritic; the topmost strata pass gradually to the white mudstones of the calpionellid-bearing Lattimusa Formation.

Interesting post-depositional structures are observable within beds 4 to 6 (Fig. 2). The limestones underlying the jagged discontinuity surface (top of bed 5) show a set of bedding-parallel neptunian sills that may be either discontinuous and centimetre-thick or laterally continuous and ranging in thickness from few millimetres to more than 20 centimetres. The filling of the cavities is variable and depends on the size and on the distance from the jagged discontinuity surface. The smallest and deepest fissures (within bed 4, i.e. about 2 m below the discontinuity) are only filled with sparry calcite cement. Up-section, red mudstones fill the lower part of the cavities giving rise to geopetal structures (Fig. 3). In the top 50 cm of bed 5 the cavities laterally enlarge up to more than 20 cm, and are completely filled with coarser sediments such as wackestones or packstones, commonly displaying internal cross-bedding, with echinoderm debris, belemnites and aptychi (Fig. 4). The walls of the sills almost perfectly fit each other and show that, in addition to dilation, some lateral displacement took place during the fissure opening. One of the sills occurs just at the jagged discontinuity between beds 5 and 6, where it cuts through the pillars (Fig. 4), and extends also upwards into the base of bed 6 (bed 6a of Fig. 2).

The overlying beds show a chaotic structure (Fig. 5). The massive stromatolitic layers of bed 6b are locally discontinuous and disrupted into centimetre- to several decimetre-sized slabs which float in a matrix of darker red, marly, nodular limestones of the overlying bed 6c. Where the stromatolitic bed 6b is lacking, a sort of funnel is formed and the overlying nodular limestones of bed 6c show a marked downward bending. About 80 cm above the base of bed 6, a nodular but more calcareous bed (6d) shows no thickness variations and thus represents a seal of the underlying chaotic structure. A vertical dyke 20 cm wide crosscuts beds 4 to 6c and all the horizontal dykes showing signs of a later phase of fracturing.

Calcareous nannofossil analysis of the micritic infillings of the sills allows recognition of the following taxa: *Watznaueria britannica*, *W. manivitae*, *W. barnesae*, *Cyclagelosphaera deflandrei*, *C. margerelii*, *C. wiedmannii*, *Conusphaera mexicana mexicana*, *C. mexicana minor*, *Microstaurus chiastius*, *Polycostella beckmannii* (F. Lozar, pers. comm.). This assemblage is referable to the *Microstaurus chiastus* Zone (Bralower et al. 1989), spanning the Upper Tithonian - Lower Berriasian interval. However, the absence of *Rotelapillus laffittei* and of *Nannocunus steinmannii* suggests the lower part of that zone, i.e. the Upper Tithonian.

Interpretation. The described features can be explained as the result of an instantaneous event of fracturing (seismic shock?) affecting a depositional slope, and postdating the deposition of the nodular marly limestones of bed 6c, but predating sedimentation of bed 6d. Partially to almost completely lithified limestones (beds 3 to 6b) were fractured along irregular bedding-parallel surfaces and affected by a certain degree of lateral displacement, likely induced by gravity (e.g. Castellarin 1982; Winterer et al. 1991). This process did not originate a network of creep-related irregular cavities, as described by Mallarino (2002) in other sectors of the Trapanese Domain (Monte Kumeta), but gave rise to a set of open fissures increasingly larger upward. Those which were closest to, and hence in better communication with, the sea floor were filled completely by coarse sediments. Local oblique laminae represent internal foresets developed within open fissures that trapped sediments actively transported by currents (cf. Sturani 1971; Sarti et al. 2000). Because of a sieve effect of the fissure system, only micrite could trickle into the underlying fissures and the deepest ones were only plugged by calcite cement during later diagenesis. On the contrary, beds 6b and 6c were stiff and still plastic respectively and, bearing no other sediments on top, they behaved in a different way. Slabs of bed 6b slid downslope leaving a concave-up scar, immediately filled by the collapse of the still plastic sediments of bed 6c.

Biostratigraphic data concerning the infilling of the sills suggest a late Tithonian age for fissure opening and thus also for bed 6d which seals the collapse structure. Moreover, as bed 6d is only a few decimetres above bed 6b, which contains Middle Oxfordian ammonites, it may be concluded that Late Oxfordian and Kimmerdigian were mainly non depositional times at Poggio Roccione.

Montagna Grande

This section was measured in natural outcrops located on the northern slope of Montagna Grande. The quality of the exposure is worse than in the quarries and wide tracts covered with soil and vegetation occur especially in the middle part of the Rosso Ammonitico. The top of the Inici Formation is irregular and coated by thick crusts of Fe-Mn oxides like in the Poggio Roccione section. The overlying Rosso Ammonitico crops out along a cliff about 3.5 m high (Fig. 12). It starts with massive grainstones in beds up to 50 cm thick. Grains are mainly represented by peloids and thin shelled bivalves. Upsection, peloids decrease and the texture becomes more micritic giving rise to packstone and, at the top, to wackestone. Undulose pseudobedding surfaces are recognisable within the packstone and grainstone beds. This first bed package is topped by an omission surface with firm-ground burrows filled with wackestones characterised by finer-grained bivalve shell de-

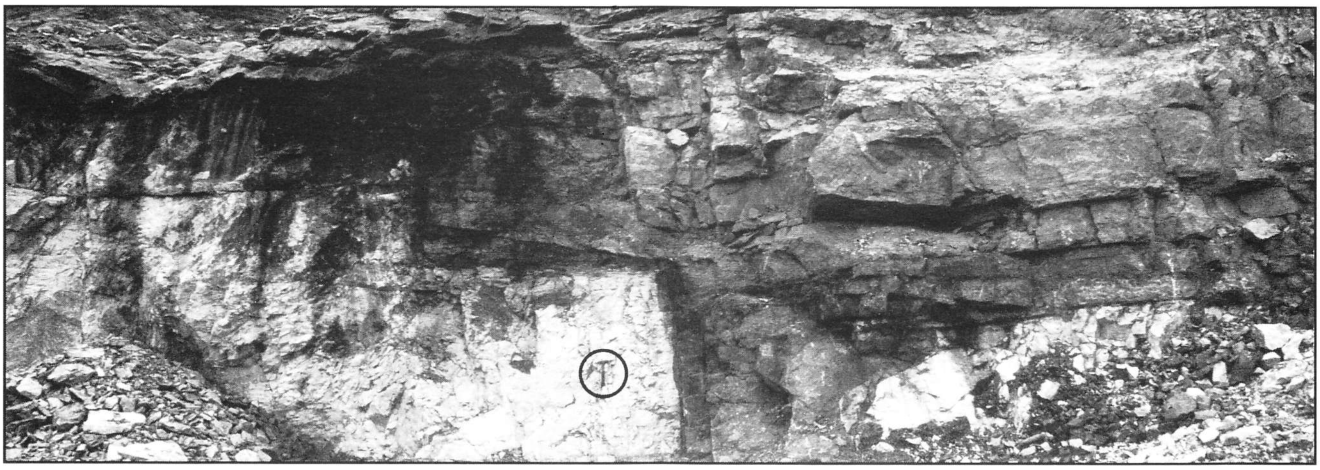

Fig. 6 - West-facing tract of the quarry front exposed by advancing works in 1999. See Fig. 7 and text for explanation. Encircled hammer for scale. Rocca chi Parra quarry.

bris. Above, a covered tract follows which hides about 10 m of section. However, some scattered small outcrops along the grass-covered slope allow documentation of the presence of red, thin-bedded, limestones with chert nodules and ribbons. A second cliff above the covered tract exposes several metres of red nodular limestones.

No detailed biostratigraphic study has been carried out in this section. Nevertheless, a specimen of *Cadomites bremeri* indicates the presence of the Upper Bathonian at the very base of the Rosso Ammonitico. The Lower Callovian is indicated by the finding of some poorly preserved ammonite specimens referable to Reineckeidae at 1.7 m over the base. A lithostratigraphic unit highly similar to the siliceous strata occurs in the same stratigraphic position, sandwiched between two lithosomes of Rosso Ammonitico nodular limestones, in the M. Inici area, located about 15 km to the north-east. There, biostratigraphic studies based on both ammonites and radiolarians allow to constrain the cherty beds to the Middle Oxfordian (*G. transversarium* Zone) - Lower Kimmeridgian interval (Wendt 1963; Pavia et al. 2002; Beccaro 2002). If the same age is inferred at Montagna Grande, the siliceous unit should correspond to the mainly non-depositional period documented between beds 6b and 6d at Poggio Roccione (Fig. 12).

Rocca chi Parra quarry

Description. In this very active and wide quarry, the Inici Formation is spectacularly exposed for a thickness of about 30 m. The most striking feature is the presence of a well developed network of polyphase neptunian dykes, up to 10 m wide, crossing the white limestones of the Inici Formation and easily distinguished through the dark grey colour of the infill. The top of the Inici Formation is flat and unmineralized and Middle Jurassic - Lower Cretaceous pelagic beds of the Rosso Ammonitico display multiple pinchouts (Martire et al. 2000) thickening progressively from less than 1 m in the westernmost part of the quarry, to 3.5 m to the east, i.e. towards Poggio Roccione. This was interpreted as the result of a tilting of the top of the platform and generation of a slope, current erosion of the pinnacled morphology in the shallowest parts, and pelagic sedimentation onlapping this slope and generating Rosso Ammonitico successions increasingly thicker eastward.

A section in the central part of the quarry and another in the westernmost end were measured and described by Martire et al. (2000). Between these two sections, a new exposure shows an interesting and peculiar situation. The sharp Inici-Rosso Ammonitico boundary (Figs. 6, 7) is downthrown of about 5 m on the opposite sides of a subvertical neptunian dyke 1.5 - 2 m wide. The dyke is associated with minor offset but not as much as to explain the apparent displacement. Reconstruction of the original continuity before formation of the dyke, shows that the top surface of the Inici Formation is deeply incised, stepped and merges with a bedding plane over a distance of a few metres (Figs. 6, 7). The small scale morphology of the step is more complicated due to the presence of overhanging ledges of the platform limestones. The stratigraphy of the overlying Rosso Ammonitico shows important changes.

The most complete section occurs above the downthrown block. Here, the top of the Inici Formation is a flat, unmineralized surface, and the Rosso Ammonitico may be subdivided in a lower unit of dark grey limestones, and a upper unit of light grey limestones, overlain by the whitish coloured limestones of the Lattimusa Fm., as described by Martire et al. (2000) from other parts of the quarry. Most beds, especially in the lower part of the Rosso Ammonitico, are separated by discontinuity surfaces marked by black Fe and Mn-coatings or by mineralised stromatolitic beds (*Frutexites*). These surfaces are highly irregular and the beds show a pinch and swell geometry. A lag rich in mineralised lithoclasts and reworked ammonite molds, brachiopods and crinoids may also occur at the base. Lithologically, beds vary from wackestone with abundant, and sometimes also very coarse, echinoderm debris, to packstone with peloids and protoglobigerinids; undulose, mm lamination is often recognizable in stromatolitic domes. Firm-ground burrows, up to 1 cm in diameter, are filled with coarser sediments and have a lighter colour. Larger cavities, with irregular shape, are geopetally filled with laminated sediment and calcite blocky spar and may be interpreted as being due to creep within semilithified sediments (Mallarino 2002).

Most of the beds of the lower, dark grey portion (on the whole about 1 m thick), are fossiliferous and of markedly different ages (Fig. 7):

- bed A contains *Choffatia caroli, C. leptonata, C. (Subgrossouvria) recuperoi* which testify the Lower Callovian and in particular the middle part of the *M. gracilis* Zone. This bed seals the 2-m wide vertical dyke that is not directly datable but that must be pre-Callovian in age;

- in bed B a specimen of *Passendorferia (P.) erycensis* (C. D'Arpa, pers. comm.) indicates the *Gregoryceras transversarium* Zone, within the Middle Oxfordian (Melendez, in Pavia & Cresta 2002);

- in bed C the presence of *Taramelliceras* cf. *obumbrans* associated with *Holcophylloceras zignodianum* and *Euaspidoceras* sp. refers also this bed to the *G. transversarium* Zone;

- bed E belongs to the Lower Tithonian as shown by the presence of *Haploceras* cf. *cassiferum* and *H. staszycii*; the first taxon strongly points to the *S. darwini/V. albertinum* Zone. This bed seals a vertical neptunian dyke, 25 cm wide, related to a re-opening of the larger fissure and filling with a coarse packstone containing abundant crinoid debris and *Pygope janitor* which is common starting from the Lower Tithonian. No ammonites have been found in bed D (about 15 cm thick). However, important gaps corresponding to most of the Kimmeridgian are highly probable, as already suggested for the Poggio Roccione section, in addition to an extreme condensation of the whole Callovian - Tithonian interval.

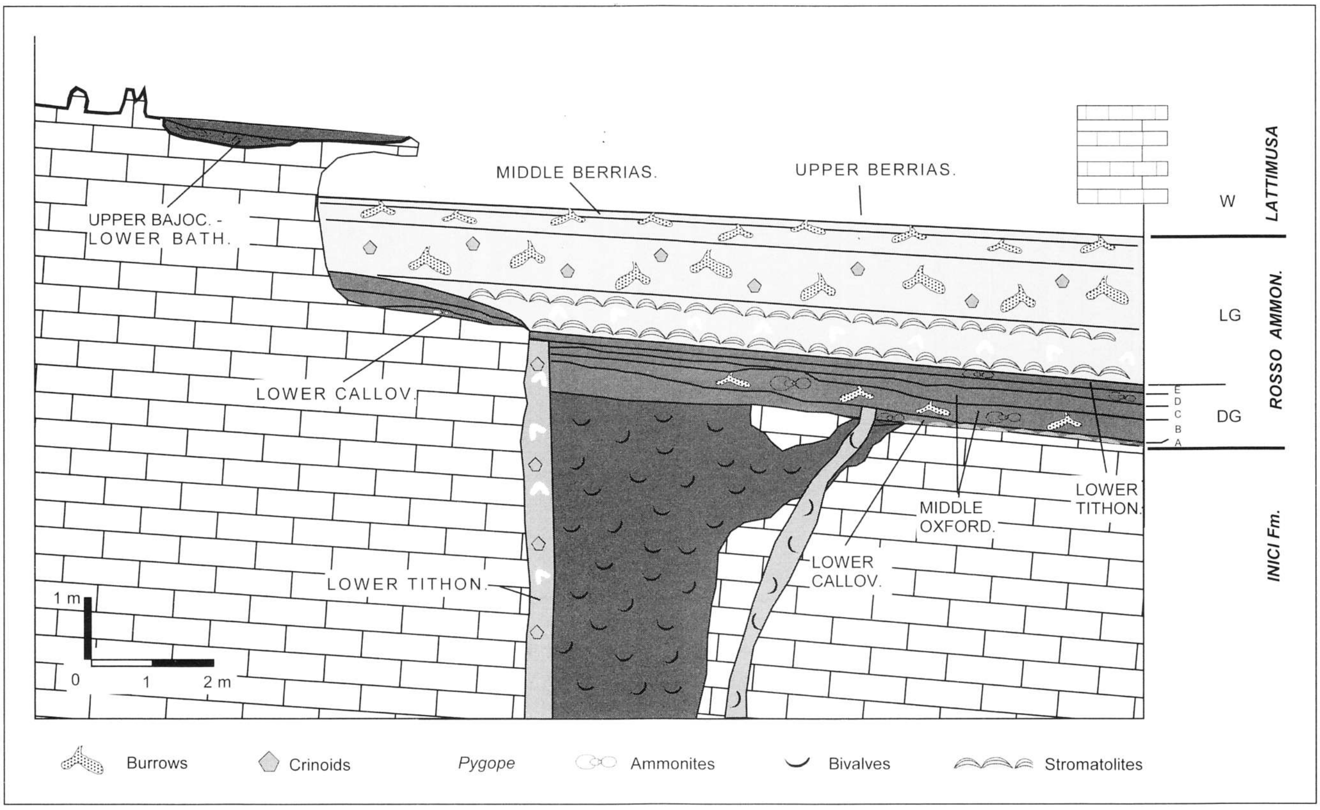

Fig. 7 - Sketch of the complex stratigraphical relationships shown in Fig. 6. DG and LG refer to dark grey and light grey Rosso Ammonitico limestones respectively; W indicates the white limestones of the Lattimusa.

A set of thin beds, very similar in facies and palaeontological content to beds A to E, makes up a sort of apron at the base of the subvertical wall incised within the Inici Fm. (Fig. 7). The main part of the depression, however, is filled with light grey limestones which onlap both the Inici Fm. and the dark grey limestone "apron". This filling sequence, about 2.5 m thick, consists of *Saccocoma*-bearing wacke- to mudstones, locally showing stromatolitic lamination and commonly crossed by a network of cm-large burrows filled with crinoidal packstones. The top bed is a mudstone with intraclasts of radiolarian- and calpionellid-bearing wackestones. The micropalaeontological assemblage (*Calpionella elliptica*, *C. alpina*, *Remaniella cadischiana*) refers this bed to the Middle Berriasian calpionellid Biozone C of Remane (1963; 1998). The bed is bounded both at the base and at the top by glauconite coated discontinuities (Fig. 8). The overlying beds are the white mudstones of the Lattimusa, characterized by *Tintinnopsella carpathica*, *T. longa*, *Remaniella cadischiana*, *Calpionellopsis oblonga*, typical of the Upper Berriasian calpionellid Biozone D2. A hiatus between Rosso Ammonitico and Lattimusa is thus present corresponding to all of the biozone D1.

Another section has been measured on the hangingwall portion of the step incised in the Inici Fm. The top of the Inici Fm. here displays the pinnacled morphology and thick Fe-Mn oxide encrustations (Figs. 7, 9). For a couple of months, in the autumn of 1999, the exploiting works resulted in the exposure of a some metres-wide and few centimetres-thick ammonite-rich lens of glauconitic packstone at the very base of the Rosso Ammonitico. The ammonite assemblage includes common specimens of the *Dimorphinites dimorphus* group, parkinsoniids such as *Parkinsonia subplanulata*, and perisphinctiids

Fig. 8 - Rosso Ammonitico - Lattimusa boundary. All beds are bounded by discontinuities that are more or less intensely coated by glauconite. Firm-ground burrows are particularly well developed at the top of the first bed of the Lattimusa (arrow). Rocca chi Parra quarry. Pencil for scale is 14 cm long.

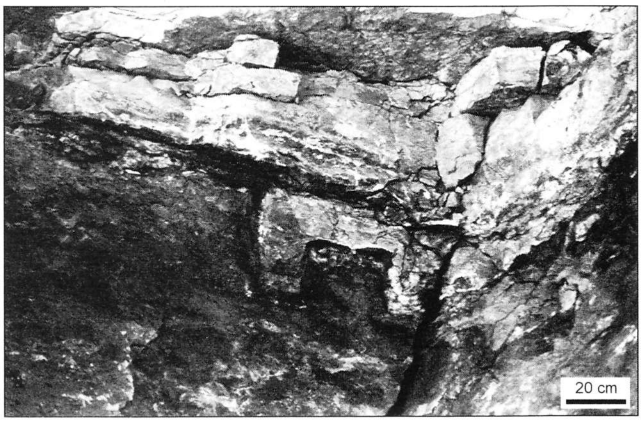

Fig. 9 - Inici Formation - Rosso Ammonitico boundary. Note the pinnacled morphology and the thick Mn-Fe crust that in this quarry can only be locally observed. Rocca chi Parra quarry.

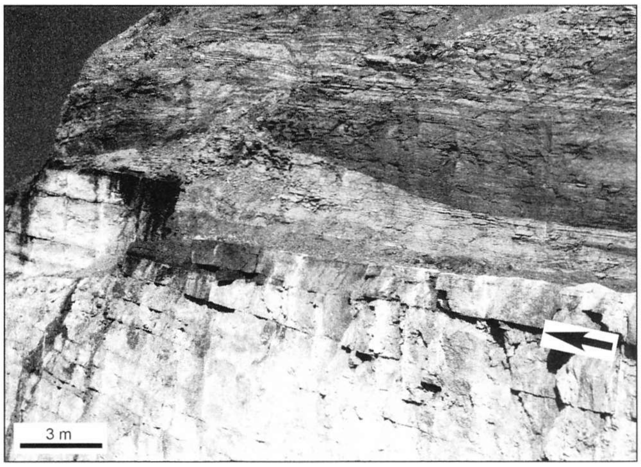

Fig. 10 - The step incised within the Inici Formation is clearly seen due to the contrast in colour and bedding style between the Inici platform limestones and the overlying pelagic Rosso Ammonitico and Lattimusa. Note the slight angular unconformity at the Inici - Rosso Ammonitico boundary (arrowed). Rocca chi Parra quarry.

such as *Lobosphinctes costulatosus* and *Planisphinctes tenuissimus*, all significant of the Late Bajocian *P. parkinsoni* Chron. Furthermore the dimorphic couple *Morphoceras - Ebrayiceras*, scattered parkinsoniids comparable to *P.* (*Gonolkites*) *convergens* and *Lobosphinctes subprocerus* are earliest Bathonian taxa, indicative of the basal *Zigzagiceras zigzag* Chron. The state of preservation of fossils indicates that they are taphonomically reworked in a typically condensed fossil assemblage (Fernandez Lopez 1984, 1991; Pavia & Martire 1997). Evidence of reworking is common and comprises phosphatization of internal moulds, glauconite coating of both the neomorphic shell and the internal mould, lithological discontinuity between mould and matrix, abrasion surfaces of the fossil cutting shell and mould, reverse geopetal structures of the shell infillings.

These discontinuous fossiliferous deposits are locally overlain by dark grey limestones similar to the Callovian bed A described above. More commonly they are directly overlain by white limestone beds that, traced laterally, correspond to beds occurring about 2 m above the base of the Lattimusa, i.e. more than 5 m above the top of the Inici Fm., in the depression-filling succession. The depression, some metres deep, extends laterally for at least some tens of metres up to the westernmost side of the quarry (Figs. 10, 11); its bottom is slightly unconformable on the Inici bedding. The overlying light grey Rosso Ammonitico limestones and the lowest beds of the Lattimusa pinch out towards the southwest and onlap the dark grey, basal Rosso Ammonitico limestones (Fig. 11) (Martire et al. 2000). A symmetrical situation occurs to the east, even though complicated by a possibly Cenozoic fault zone. The block with the pinnacled and Fe and Mn-encrusted inherited rock ground overlain by the Upper Bajocian Rosso Ammonitico deposits therefore represent a few metres-large highstanding portion of the Inici Fm. occurring between two depressions (Fig. 11).

Interpretation. The complex taphonomic features of the Bajocian-Bathonian ammonite-rich deposits indicate that just after drowning the top of the platform was starved of sediment for a long time period during which diagenetic processes such as glauconite and phosphate precipitation took place in very shallow buried sediments periodically winnowed by bottom currents. This resulted in exhumation of ammonite moulds, which were subsequently rolled, abraded and fragmented while exposed on the sea floor, and finally concentrated in a single, highly condensed bed.

The morphology of the top of the Inici Fm. and the geometry of the Rosso Ammonitico beds, show that significant erosion of the Inici Fm. took place before deposition of Callovian pelagic sediments. Erosion may have been caused by current scouring, dissolution or sliding. The first may be excluded because delicate structures such as the pinnacles are perfectly preserved along the surface. Moreover, a stepped morphology can hardly be reconciled with current erosion. Dissolution, under both submarine and subaerial conditions, does not provide a more probable explanation. Karstic features have not been observed at Rocca chi Parra; the sediments directly overlying the erosional surface are Callovian in age and Upper Bajocian - Lower Bathonian pelagic records occur on top of the pinnacled and mineralized Inici top, implying a very unlikely sequence of events i.e. Bajocian drowning of the platform, Bathonian uplift and karstification and a second Callovian drowning. Also a submarine dissolution event of hardened limestones may be excluded if we consider that this event is predated and followed by preservation of aragonite-bearing sediments, such as the ammonite-rich Bathonian and Callovian Rosso Ammonitico limestones.

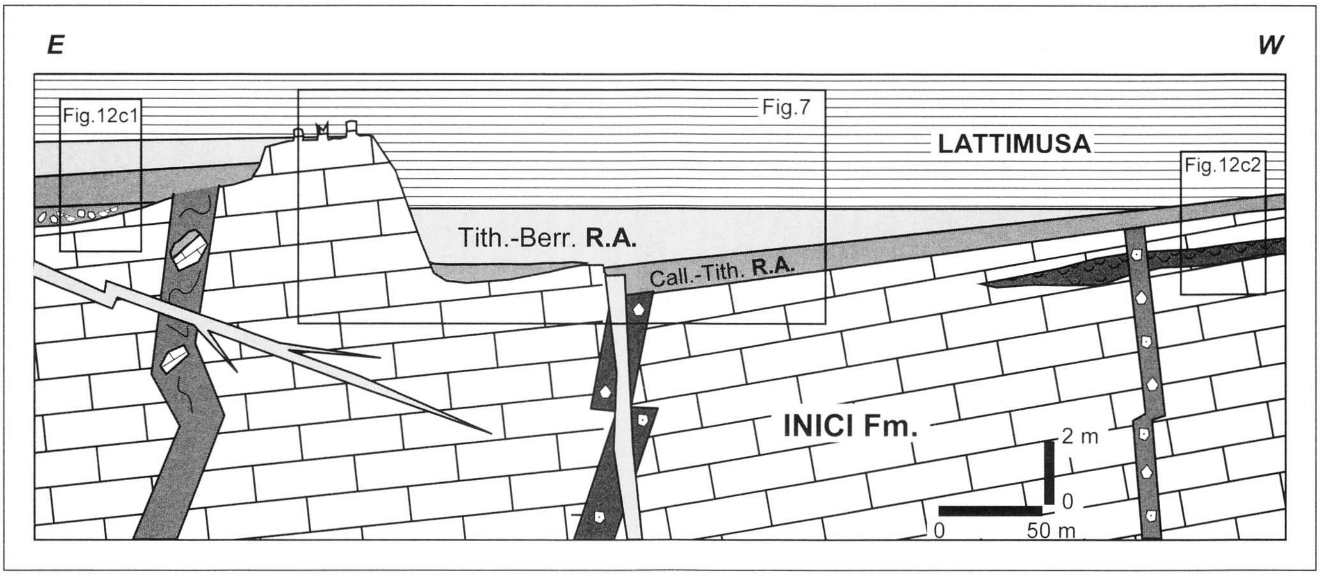

Fig. 11 - Cross-section showing the stratigraphical and geometrical relationships among Inici Formation, Rosso Ammonitico (R.A.) and Lattimusa and neptunian dykes of different generations at Rocca chi Parra quarry. Rectangle in the central part refers to location of Fig. 7. The small rectangles at left and right refer to Rocca chi Parra sections c1 and c2 of Fig. 12.

A submarine slide involving the top layers of the Inici Formation, carrying on top the scattered Bajocian - Bathonian deposits, is considered the most plausible explanation. Detachment surfaces had a stepwise geometry: the flat parts corresponded to preexisting physical discontinuities such as bedding planes; risers cut through lithified rocks possibly following joints related to the fracturating phase that generated the oldest vertical neptunian fissures (Castellarin 1982; Winterer et al. 1991; Winterer & Sarti 1994). Joints likely controlled the location of the detachment surface and the slide trigger was the newly formed gravitational instability after the drowning of the platform and the inception of pelagic sedimentation. A similar situation, although on a smaller scale, has been recently described in another sector of the Trapanese Domain, i.e. Monte Kumeta (Di Stefano et al. 2002; Mallarino 2002). The flat, unmineralized Inici - Rosso Ammonitico boundary, generally observed in the Rocca chi Parra quarry, hence corresponds to a laterally extensive slide scar truncating the Inici Formation and sealed by Jurassic Rosso Ammonitico and Cretaceous Lattimusa sediments (Figs. 10, 11). It is difficult to reconstruct the precise sense of movement of the blocks on the basis of a two-dimensional view. Only a northward sliding is excluded, but all other possibilities are consistent with the geometry of the observed scar. Late Cenozoic tectonics and recent erosion preclude observation of the directly surrounding areas and thus no trace of the slide blocks can be found.

Correlation and discussion

Correlation of three sections measured in the study area reveals the diversification of the stratigraphy of the Rosso Ammonitico (Fig. 12). It is very thin and condensed at Rocca chi Parra, where locally only few decimetres are preserved, thicker at Poggio Roccione, but consisting of chert-free nodular limestones, and even thicker at Montagna Grande where a wedge of siliceous beds occurs. This wedge seems to fill a chronostratigraphical gap documented in the other sections for the Upper Oxfordian - Kimmeridgian, in analogy with the Rosso Ammonitico Veronese of the Trento Plateau (e.g. Clari et al. 1984; Martire et al. 1991; Martire 1996). According to models of sedimentation on Mesozoic Mediterranean extensional continental margins, this is interpreted as the result of pelagic sedimentation over a current-swept sea floor characterised by a highly irregular palaeotopography controlled by tectonic and gravitational processes (e.g. Bernoulli & Jenkyns 1974; Catalano & D'Argenio 1978, 1982; Winterer & Bosellini 1981; Baumgartner 1987; Montanari 1989; Catalano et al. 1996).

The evolution of the Montagna Grande sector may be summarised as follows (Fig. 13). After the drowning of the Inici platform, the top of which was characterised by the pinnacled and Fe-Mn encrusted surface, pelagic sediments rich in ammonites and affected by intense reworking, began to be patchily preserved in the Bajocian. In Bathonian time, an extensional tectonic phase caused an important structural

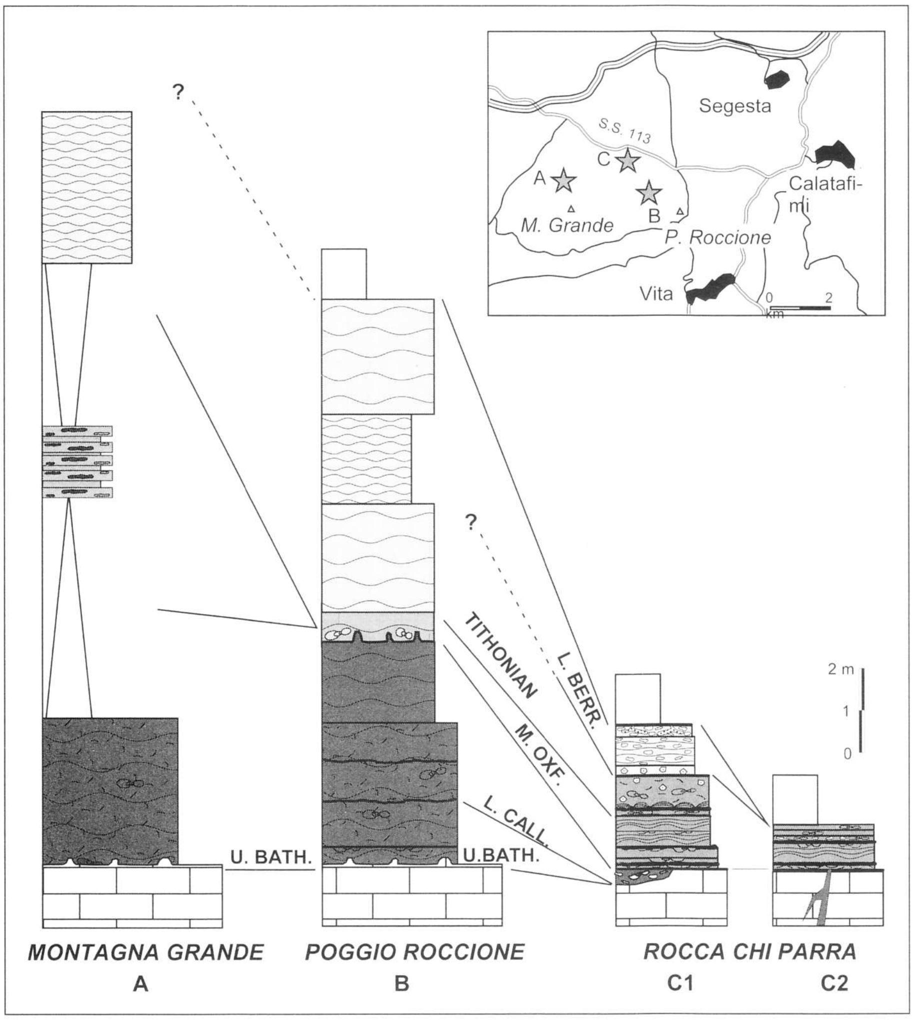

Fig. 12 - Correlation of the Montagna Grande, Poggio Roccione and Rocca chi Parra sections. The two latter sections are modified after Martire et al. (2000).

rearrangement of this part of the Trapanese Domain. Block faulting and tilting generated an irregular sea bottom palaeotopography that controlled the sedimentation pattern. The Poggio Roccione - Montagna Grande transect possibly corresponded to a gentle slope where the thickness of Bathonian - Oxfordian beds increased downslope, i.e. towards Montagna Grande. Rocca chi Parra, instead, became an isolated, highstanding block possibly because of the intersection of normal faults with transverse structures associated with strike slip movements (transfer faults?) recently reported in the same area also by Nigro & Renda (2002) and already suggested for the whole Jurassic Sicilian margin (Catalano & D'Argenio 1982; Catalano et al. 1995, 1996). The strike slip component is documented by the strict association of both normal and reverse movements in correspondence of subvertical neptunian dykes sealed by Callovian pelagic limestones (cf. fig. 6b of Nigro & Renda 2002). The main faults bordering Rocca chi Parra are not directly observable also because they have been probably reactivated by compressional movements in Cenozoic time (Catalano et al. 1995, 1996; Giunta et al. 2002; Nigro & Renda 2002). Sedimentary evidence of Jurassic faulting, however, is common and convincing at Montagna Grande. The fracturing associated with Bathonian tectonics, in fact, resulted in the opening of several large, vertically extensive and differently oriented fissures, and in triggering of large slides which left metres-deep, stepped scars. Callovian - Kimmeridgian Rosso Ammonitico sedimentation thus took place over an irregular rocky bottom, the original pinnacled, drowned top of the platform being only locally preserved. Another tectonic pulse, in the latest Jurassic, could have been responsible for the opening of new fissures and for a slight tilting of the Rocca chi Parra sector; this resulted in the partial, unconformable fill of the scars by Tithonian - Middle Berriasian beds. The same event likely caused a steepening of the gentle Poggio Roccione-Montagna Grande slope and consequent creep of semilithified sediments with formation of sills and collapse structures at Poggio Roccione. The sedimentation of the uppermost part of the Rosso Ammonitico only partially levelled the Bathonian palaeotopography so that the lower part of the Lattimusa was still affected by it, as is documented by pinch out of beds and onlap relationships on the Rosso Ammonitico top.

The described features support the hypothesis, already suggested by previous authors (Catalano & D'Argenio 1982; Montanari 1989), that the Trapanese Domain differs from other coeval similar submerged plateaus (e.g. the Trento Plateau in Southern Alps: Winterer & Bosellini 1981; Martire 1996 or the Saccense Domain in Western Sicily: Di Stefano et al. 2002) where pelagic sediments show rather uniform patterns of facies and thickness distribution that are referable to the pelagic facies association A of Santantonio (1993). On the contrary, the Trapanese Domain was highly dissected by synsedimentary tectonics in a series of fault-blocks connected by steep escarpments or more gentle slopes. This suggests that the Trapanese Domain likely played a role of a marginal area between the Sicanian basin and the wide platform bordering the north African margin and represented by the coalescence of the Panormide, Saccense and Hyblean Domains (Montanari 1989; Catalano et al. 1995, 1996). In this frame, some sectors such as Montagna Grande and Rocca Busambra (Wendt 1963, 1971a; Martire & Pavia 2002) are particularly revealing. Moreover the diversified stratigraphy of Montagna Grande and the tectonically-related sedimentary structures (neptunian dykes, slides, unconformities within pelagic sediments) also clearly show that tectonics did continue to affect sedimentation on submerged plateau also after the major Early Jurassic rifting phase. In this respect, the Montagna Grande sector, in spite of the limited surface area, may be kept as a paradigm of the interplay of tectonics and sedimentation on top of a pelagic plateau.

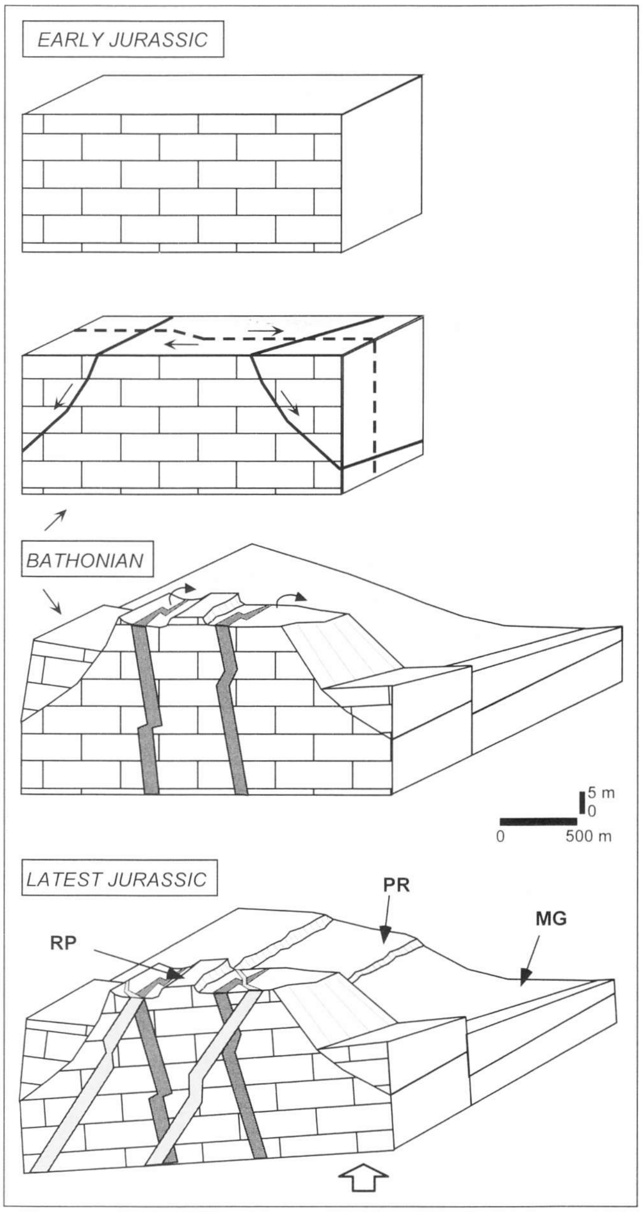

Fig. 13 - Reconstruction of the Jurassic palaeotectonic evolution of the Montagna Grande sector. PR, Poggio Roccione. MG. Montagna Grande. RP, Rocca chi Parra.

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