Riv. It. Paleont. Strat.	v. 98	n. 3	pp. 299-324	tav. 23	Novembre 1992

THE MIDDLE TRIASSIC OF THE BREMBANA VALLEY: PRELIMINARY STUDY OF THE ESINO PLATFORM (Bergamasc Alps)

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Key-words: Anisian, Ladinian, Stratigraphy, Paleogeography, Carbonate platforms, Paleontology, Ammonoids, Southern Alps.

Riassunto. E' stato effettuato uno studio stratigrafico-paleogeografico, integrato con analisi biostratigrafiche sugli Ammonoidi del Calcare di Esino di età Ladinico della Val Parina (Prealpi Bergamasche occidentali). I dati raccolti hanno permesso di evidenziare una articolata stratigrafia interna alla piattaforma anisico sommitale-ladinica della media Val Brembana. In particolare sono state riconosciute 6 litozone che documentano l' evoluzione laterale e verticale del sistema deposizionale di piattaforma carbonatica del Calcare di Esino. Lo sviluppo di questa piattaforma si può sintetizzare in tre principali stadi evolutivi.

1) L' edificio inferiore rappresenta le prime fasi di nucleazione e diffusione (Anisico sup.-Ladinico basale ?) di corpi carbonatici che si radicano in zone già sedi di produttività carbonatica durante l'Anisico Medio ("dolomie peritidali" del Calcare di Angolo).

2) L' edificio intermedio rappresenta la fase principale di aggradazione della piattaforma carbonatica con la costruzione di un buildup delimitato verso nord-est da una depressione intrapiattaforma e verso meridione da facies di piattaforma marginale-pendio prospicienti un bacino (non affiorante) verosimilmente aperto e persistente per gran parte del Ladinico.

3) L' edificio superiore rappresenta la principale fase di progradazione della piattaforma con la diffusione delle facies di piattaforma interna, sovente con sviluppate emersioni sopratidali e formazione di tepees, cappelli diagenetici al tetto di cicli peritidali.

Numerose località fossilifere con Ammonoidi, Gasteropodi, Echinodermi e Lamellibranchi addensati in tasche bioclastiche sono state rinvenute nell' edificio intermedio (in prevalenza nella litozona 4) immediatamente a ridosso del margine meridionale della piattaforma della Val Parina. La raccolta di migliaia di esemplari soprattutto di Ammonoidi e Gasteropodi ha permesso di individuare varie associazioni ad Ammonoidi di età compresa tra il Ladinico Inferiore e la base del Ladinico Superiore. In particolare sono state riconosciute faune appartenenti alle Zone a Curionii ed Archelaus. Sono state rinvenute anche alcune associazioni problematiche di faune ad Ammonoidi, di età probabilmente Ladinico Inferiore, che occupano una posizione stratigrafica all'interno del Calcare di Esino medio-inferiore.

Abstract. The stratigraphy and paleogeography of the ladinian Esino Limestone outcropping in Valle Brembana-Valle Parina, have been integrated with the biostratigraphic analysis of cephalopod fauna. A complex internal structure of the upper anisian-ladinian Esino carbonate platform has been identified. Six different lithozones have been recognized, they record the stratigraphic-paleogeographic evolution of the Esino

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Limestone. This carbonate platform developed through three stages:

1) construction of a lower edifice (Late Anisian-? Early Ladinian) representing the first phase of carbonate platform diffusion on structural highs, which were already the site of carbonate deposition during the Middle Anisian (peritidal dolomites of the Angolo Limestone);

2) buildup of the carbonate complex (main edifice). In this second phase (Early Ladinian-Late Ladinian p.p.) the most important one, the platform growth took place by prevalent aggradation;

3) development of the upper edifice and progradation of the platform in the Late Ladinian. In this third phase, inner platform facies with diagenetic caps at the top of peritidal cycles are common.

The buildup developed in the second phase yields bioclastic packstones with ammonoids, gastropods, echinoderms, and bivalves clustered within lithozone 4 and in the proximity of the southern margin of the platform in Val Parina. Studies in progress of ammonoids and gastropods allowed for the recognition of different fossil assemblages which date from Early Ladinian to Late Ladinian. A few problematic ammonoid assemblage of probably Early Ladinian age, has been found in a stratigraphic level above the base of the Esino Limestone.

Geologic-Stratigraphic Setting.

Introduction.

In Valle Brembana, middle triassic sediments outcrop extensively (Fig.1). The succession mostly consists of carbonate platform deposits: Angolo Limestone, Esino Limestone, Calcare Rosso lithostratigraphic units. However, deeper environments locally established in the Late Anisian and are represented by the limestones and marly limestones of the Prezzo Limestone (Fig. 2). Locally, the lower part of the Esino Limestone makes transition either to the typical Buchenstein Formation or to well bedded limestones with chert nodules and transitional platform-basin facies ascribed to the Buchenstein Formation by Assereto et al. (1977). The lower-middle part of the Esino Limestone is replaced northeastwards by calcarenites and thin bedded, laminated limestones with intercalated tuffs of the Perledo-Varenna Limestone.

The whole triassic succession in Val Brembana belongs to the Parautochthonous of the Southern Alps (Gaetani & Jadoul, 1979). In the middle part of the valley this succession forms a monocline characterized by the decollements of the Dolomia Principale (M. Venturosa, M. Alben) gliding on the upper part of the San Giovanni Bianco Fm. In particular, the decollement of M. Venturosa is related to a N-S transcurrent faults system, which may correspond to the "Transversal Zone" of Val Brembana (Laubscher, 1985). In the studied area, a minor tectonic unit (M. Menna unit) differentiates from the Parautochthonous and is separated from the western, parautochthonous succession (Val Brembana) by a system of NNO-SSE trending faults with dextral transcurrent component (Lenna-Ortighera-Serina line). This latter displaces the E-W trending faults system of Valtorta-Valcanale (Lenna-Serina fault; Forcella & Jadoul, 1990). The M. Menna unit is clearly allochthonous, as indicated by the presence of a thrust plane at its western and northern borders (Fig. 1). The thrust brings the middle and upper part of M. Menna Angolo Limestone upon the carnian units of Val Vedra and Oltre il Colle (Val Vedra tectonic window; Gaetani & Jadoul, 1979). In the westernmost part of Val Brembana, the allochthonous nature of the units is not

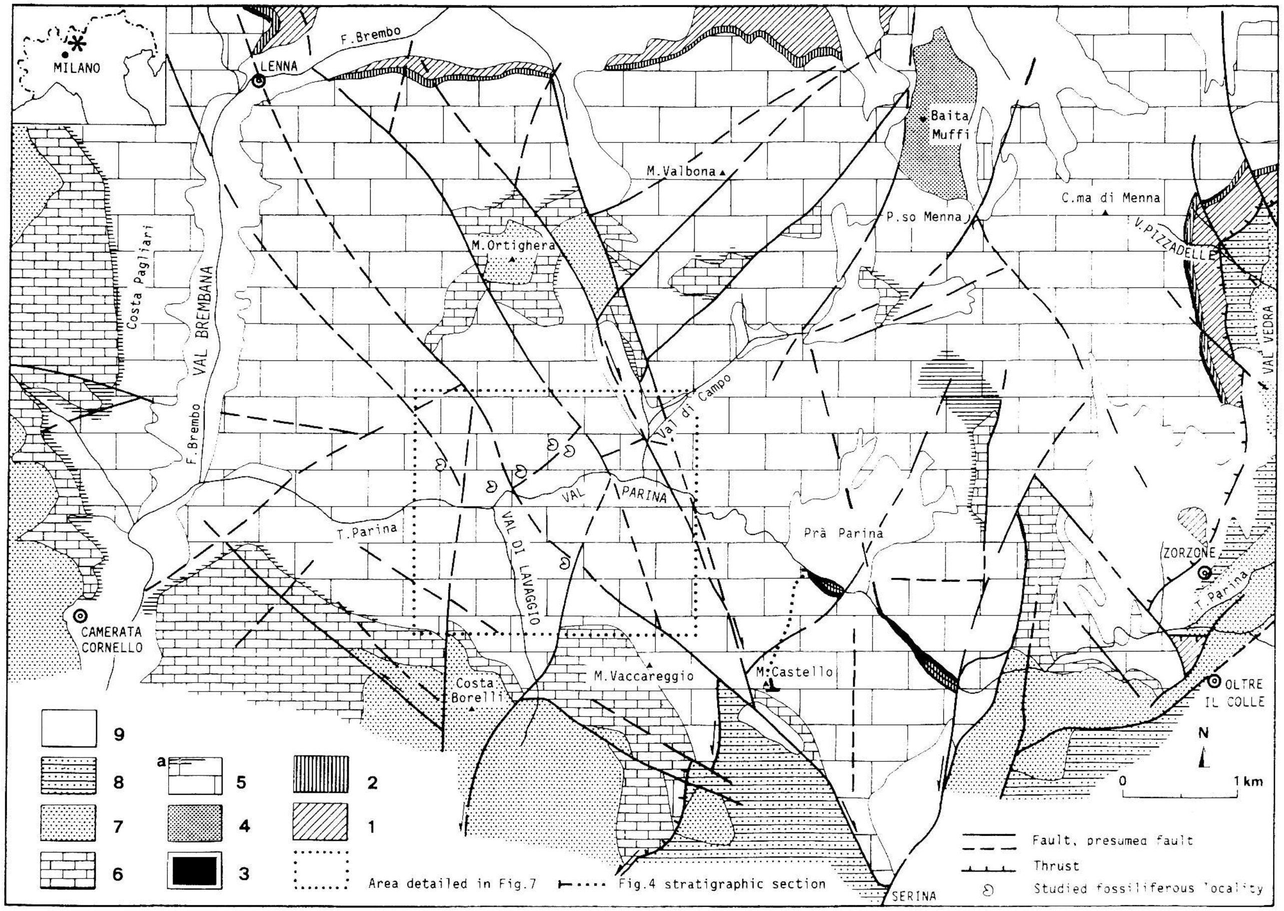

Fig. 1 - Geologic scheme of the Val Parina-M. Menna area. Legend: 1) Angolo Limestone; 2) Prezzo Limestone; 3) Buchenstein Formation; 4) Perledo-Varenna Limestone; 5) Esino Limestone, at the top Calcare Rosso; 6) Breno Formation; 7) Val Sabbia Sandstone, Gorno Formation; 8) S. Giovanni B. Formation; 9) superficial deposits.

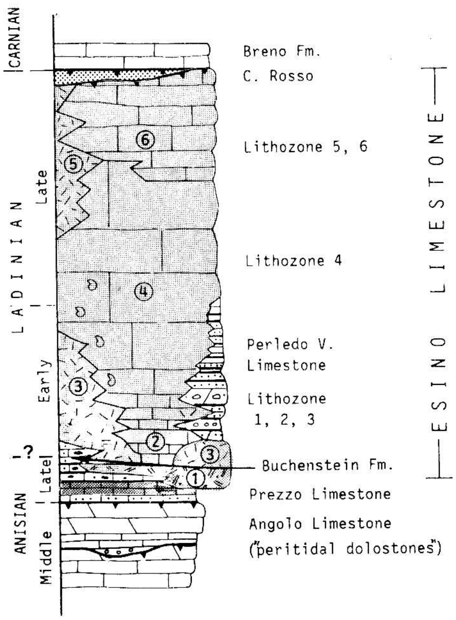

Fig. 2 - Lithostratigraphy of the Middle Triassic succession of the Val Brembana.

evident in the field. Gaetani and Jadoul (1979) and Schonborn (1990) consider as allochthonous the western part of Valle Brembana, while Laubscher (1985) believes it to be rooted to the basement of the Orobic Anticline.

Stratigraphic Units

Angolo Limestone.

Only the upper part of the unit, consisting of carbonate platform limestones and dolomites, outcrops in the studied area. Because it shows different characteristics with respect to the typical Angolo Limestone described in Val Camonica by Assereto & Casati (1965), Jadoul & Rossi (1982) proposed the informal term "peritidal dolomites" for this upper part of the Angolo Limestone. In Val Pizzadelle, the thickness of the "peritidal dolomites " is about 210 m, and can be divided in two cyclic successions. The lower succession (about 60 m outcropping) consists of bio-oo-intraclastic calcarenites and encrinites passing upwards to subtidal-peritidal limestones with small dasyclad Algae, forams, and stromatolites. At the top are present dolomitic limestones with *Dasycladaceae*. Between the lower and upper succession of the "peritidal dolomites", an unconformity marked by small pockets and sedimentary dykes filled with terra rossa has been locally recognized.

The lowermost part of the upper "peritidal dolomites" succession is characterized by a 2.5 m thick transgressive horizon of well bedded, nodular, fetid, locally bioturbated, micritic limestones with intercalated black marls. The overlying "peritidal dolomites" (about 150 m thick) represent a regressive succession consisting of grey to dark grey, bedded to massive dolomites, limestones and dolomitic limestones, organized in 2-8 m thick shallowing upwards cycles. The top of the cycles shows early diagenetic dolomitization of stromatolitic, pisoidal and fenestral lithofacies with intraformational fine grained loferitic breccias. The underlying subtidal interval, with dasycladacean Algae and oncoids, is often strongly bioturbated. Thin layers of clay and micaceous silt frequently intercalate in the succession. In the upper "peritidal dolomites" microfossils are rare or badly preserved because of dolomitization: when present, dasycladacean Algae and benthic foraminifers have been observed.

The topmost Angolo Limestone is characterized by a lens-shaped, 3 to 5 m thick, horizon represented by dark grey micritic nodular limestones with interbedded thin lenses of bioclastic-lithoclastic calcarenites and rudites with crinoids and brachiopods [(*Tetractinella trigonella* (Schlotheim)] with erosional base. The base of this horizon is characterized by a decimeter-scale, silty to marly, micaceous and bioturbated layer with sparse lithoclasts and bioclasts and overlies an unconformity below which peritidal, bioturbated, dolomitic limestones lay. This unit, which records a transgressive phase, is a stratigraphic marker and can be observed in other anisian successions near the Pelsonian-Illyrian boundary in Lombardy ("Banco a Brachiopodi"; Gaetani et al., 1987).

The thickness of the Angolo Limestone in Val Brembana varies from 300 to 350 m.

Prezzo Limestone.

Alternated black, nodular to planar beds of micritic fossiliferous limestones and marly limestones. In the upper part, alternated planar beds of micritic limestones and marls are predominant. The lithofacies are often bioturbated and characterized by the presence of crinoids, pelagic pelecypods, and several layers rich in brachiopods and ammonites (Hofsteenge, 1932; Balini, 1992). Towards the top of the unit, bioclastic-intraclastic packstones, with rare dasycladacean Algae, reworked ooids, small chert nodules are locally intercalate. A thin clayey-tuffaceous layer is often present at the top of the unit. The passage to the overlying Buchenstein Formation is generally sharp, it is more frequently transitional to the Esino Limestone (transitional Buchenstein-Esino lithofacies).

The Prezzo Limestone shows variable thicknesses, maximum values are present in Pizzadelle valley (26 m) and probably in Parina valley (the bottom of the unit here is not outcropping). In the northern areas the thicknesses are from about 7/10 m (north M. Menna slope) to 19 m. Paleontological studies on the rich fauna collected in this unit allow to frame the Prezzo in the Illyrian (Trinodosus Zone) (M. Balini pers. comm.).

Buchenstein Formation.

The typical lithofacies association (*Knollenkalke* Auct.) of this formation is very rare or absent in the studied area. A few meters of nodular mudstones with chert nodules are present in the basal Buchenstein near Piazza Brembana and in Val Parina. The unit consists of well bedded, dark grey, micritic limestones and fine grained calcarenites with interspersed black chert nodules. In the westernmost Buchenstein outcrop of Val Parina (Fig. 1) several light grey tuff layers intercalate in the succession and differ from these already described in this formation (Pasquaré & Rossi, 1969) because of the thickness (one horizon is up 1,5 m thick), the grain size (coarse arenites-siltites) and the presence of cross lamination, graded structures and erosional surfaces. Eastward these lithofacies rapidly decrease in thickness and grain size distribution. In Parina area the middle-upper Buchenstein is dolomitized and rich in dark, laminated, planar limestones with a few lithoclastic calcirudites intercalated at the top.

Maximum thickness of the Buchenstein Fm. is about 19 m in Val Parina. In some other areas it is only a few meters, and the unit rapidly passes either to "transitional Buchenstein-Esino lithofacies" or directly to the Esino Limestone.

"Transitional Buchenstein-Esino lithofacies". This horizon has the same stratigraphic position of the typical Buchenstein Formation and is characterized by a basin-platform transitional facies association. At the base are prevalent the Buchenstein type lithofacies with dark grey nodular, amalgamated micritic limestones and calcarenites with crinoids, echinoids and rare chert nodules. Upward light grey bio-intraclastic platform facies are intercalated. This succession is similar to that described as Buchenstein Formation by Assereto et al. (1977) in the same study area (stratigraphic section north of M. Valbona). In most cases this transitional horizon between the Prezzo Limestone and the Esino Limestone (Fig. 3) presents thicknesses from 10 to 15 m.

On the basis of thickness and stratigraphic position it can be inferred that the two units described represent only the lowermost part of the typical Buchenstein Fm. of Lombardy and, therefore, only the section near the Anisian-Ladinian boundary (sensu Kovacs et al., 1990).

Perledo-Varenna Limestone.

This unit outcrops only in the northern side of M. Menna with lenticular geometry inside the Esino Limestone succession (Fig. 1). It consists of dark, thin bedded laminated, fetid mudstones, locally dolomitized or rich in chert nodules, bioturbated fossiliferous mudstones-wackestones alternated with litho-bioclastic dark to grey calcarenites-rudites. Marly limestones, marls and a few thin tuff layers are present in the lower portion of the unit. At least three m-thick Esino platform breccias or

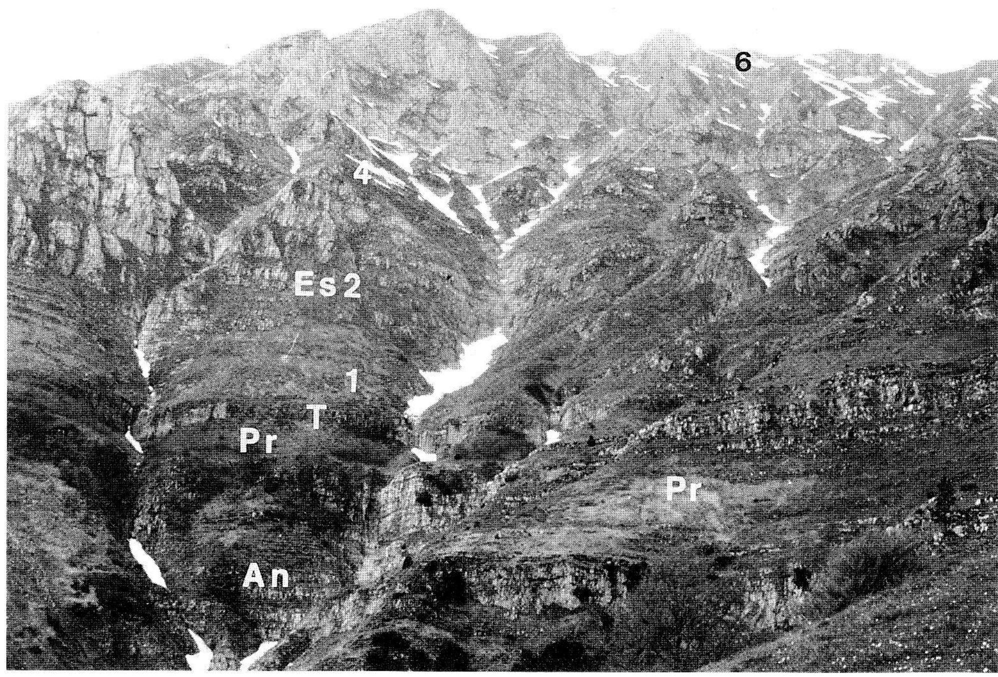

Fig. 3 - View of the stratigraphic succession of the east side of M. Menna-Val Pizzadelle. An) Upper Angolo Limestone; Pr) Prezzo Limestone; T) Transitional Buchenstein-Esino lithofacies; Es) Esino Limestone; numbers are lithozones present.

progradation episodes are intercalated in the succession. Biocalcarenitic facies contain dasyclad Algae, small gastropods and pelecypods; subordinated are the reefal debris. Maximum thickness is about 150 m.

The stratigraphic setting, above the bioclastic and reefal facies of the basal Esino Limestone (with a latemost Anisian-Early Ladinian fauna; Tommasi, 1913; Brack & Rieber,1986) suggests an Early Ladinian age for the lower part of the unit.

The depositional environment of this unit is a intraplatform depression with anoxygenic bottom and carbonate sedimentation coming from the subtidal Esino platform.

Esino Limestone.

Succession thick 750-900 m of grey limestones, and subordinate dolomitized limestones, overlying either the Prezzo Limestone, Buchenstein Formation or the transitional Esino-Buchenstein lithofacies, and underlying the Calcare Rosso. In the studied area the Esino Limestone was first described by Varisco (1881) with the name "Esino-Lenna dolomite". The Esino Limestone outcrops from Camerata Cornello to Lenna as well as in the tributaries Val Parina and Val Secca.

The analysis of a few stratigraphic sections (of which only one is shown in Fig. 4) allowed the recognition of 6 lithozones: lithozones 1 to 3 represent the lower part of the formation, which is mostly massive (lithozones 1 and 3), while lithozones 4 and 6 make up the bedded middle-upper part of the Esino Limestone. Lithozones 3 and 5 consist of massive platform margin facies, locally representing the whole formation (Fig. 2 and 5).

Lithozone 1.

Light to dark grey massive, bioclastic and intraclastic calcarenites (lithofacies association 1a) and/or bioclastic, fossil-rich limestones with brachiopods, gastropods, pelecypods, ammonoids and crinoids (lithofacies association 1b) (Fig. 2, 5).

Typical lithofacies of this lithozone (1a+1b), 10 to 85 m thick, outcrop in the northernmost part of the studied area (Valle di Roncobello). In the southern area, dark grey dolomites and limestones, organized in beds 10 to 60 cm thick, followed by dark limestones and marly dolomites with pockets of fine grained, flat pebble breccias and pelagic pelecypods outcrop at the base of the Esino Limestone (sublithozone 1c-transition to the Buchenstein Formation).

Lithofacies association 1b was described as the Lumachella di Ghegna by Tommasi (1911, 1913). Lithofacies 1b is a large and thick (more then 10 m) lens shape horizon outcropping about 60-100 m above the Esino stratigraphic boundary to a Prezzo Limestone reduced in thickness. This particular lithofacies is at the base of a Esino margin platform succession that is p.p. heteropic and underlying the Perledo Varenna of Baita Muffi (Fig. 1, 2). Findings of ammonites (Tommasi, 1913) of the *A. avisianus* and "C" *reitzi* biozones date lithozone 1 to the Anisian-Ladinian boundary (Assereto et al., 1977). Brack & Rieber (1986) reported the presence in the Ghegna fauna of the new species *Chieseiceras chiesense*, a marker for the "Chiesense horizon" which is located between the Nevadites and Curionii Zones. Therefore, lithozone 1 should include the Anisian-Ladinian boundary, at least in the northern part of the studied area, and considering the Nevadites Zone as Lowermost Ladinian (Kovacs et al., 1990). According to the Brack & Rieber (1986) ladinian chronostratigraphy instead this lithozone is still in the Late Anisian.

Lithozone 2.

Well bedded limestones and dolomitic limestones organized in peritidal cycles with stromatolites and fenestral cavities. It represents the lower Esino Limestone in the Lenna-Piazza Brembana area and on the eastern side of M. Menna (Val Pizzadelle, Fig. 5). Dolomitized inter-supratidal horizons, tepees (Piazza Brembana, Assereto et al., 1977) and radial fibrous cements ("raggioni" of Assereto & Folk, 1980) can be locally observed. At the base and top of this succession, a few discontinuous layers of micaceous shales-tuffs intercalate. This association of structures marks local stratigraphic unconformities due to the periodic subaerial exposures of the platform. Upwards, the unit makes transition to prevalent subtidal, oncoidal lithofacies (lithozone 4).

Thickness of lithozone 2 does not exceed 50-60 m. On the basis of its stratigraphic setting, which is in the lower Esino Limestone but not at its base, lithozone 2 may be considered as the inner platform succession interfingering both with the margin facies of sublithozone 1b, 1c and probably with the base of lithozone 3 (lithofacies association 3a; Fig. 2, 4). The stratigraphic position of lithozone 2 indicates its Early Ladinian age or that its deposition took place at the transition between the Late Anisian and the Ladinian.

Lithozone 3.

Massive bioclastic limestones and patch reefs with *Tubiphytes* and *Porostromata*. The most common lithofacies are represented by massive light grey bindstones and bafflestones, bio-intraclastic calcarenites and nut grey bioclastic micrites with gastropods, dasycladacean Algae (*Teutloporella nodosa, T. herculea*), oncoids and foraminifers (*Ammobaculites* sp., *Diplotremina* sp., *Alpinophragmium perforatum*). Locally bioclastic lenses with pelagic pelecypods and ammonoids are present (M. Castello section; Fig. 4).

Southwards (bottom of middle Val Parina) *Tubiphytes* bindstones became subordinate with respect to intra-bioclastic packstones and wackestones with Problematica, pelecypods, dasycladacean Algae, crinoids, ostracods and rare ammonoids. In particular, the lowermost part of this lithozone consists of massive limestones with pelagic pelecypods, ankerite pockets, and dark grey limestones with crinoids and rare dasycladacean Algae (lithofacies association 3a). Small E-W trending fractures and fine grained breccias with pale red to reddish clasts have been observed at the top of the lower part of lithozone 3. These features may be indicative of an episode of subaerial exposure which affected the lower Esino Limestone of Val Parina (Fig. 4). The associated unconformity may correlate with the inter-supratidal facies of upper lithozone 2.

Pervasive networks of cavities (decimetric to metric scale) filled with isopachous, dark grey to light grey bands of fibrous calcite cements (small and medium evinosponge; Jadoul & Frisia, 1988) characterize this lithozone. In some cases, the fibrous calcite crusts seem to cement both intraclastic, fine grained breccias with gastropods and ammonites, and cavity-fracture- filling coarse breccias (megabreccias) (Fig. 6a). These structures are similar to those observed in the slope facies of the ladinian platform of the Dolomites (Marmolada Limestone; Gaetani et al., 1981). The evinosponges are often associated with tension fractures and small sedimentary dykes, a few centimeters wide, with prevalent E-W trend. These features can be related both to extensional tectonics and to the development of the platform slope-margin.

This lithofacies association has thicknesses of a few tens of meters in the northern M. Menna slope where it overlies, or is partly heteropic with, lithozone 1. In middle Val Parina the maximum thickness is about 250 m. North of M. Menna this lithozone (Fig. 5) is overlain by the Perledo-Varenna Limestone. In Val Parina the facies distribution of lithozone 3 suggests the presence of a basinal succession south-

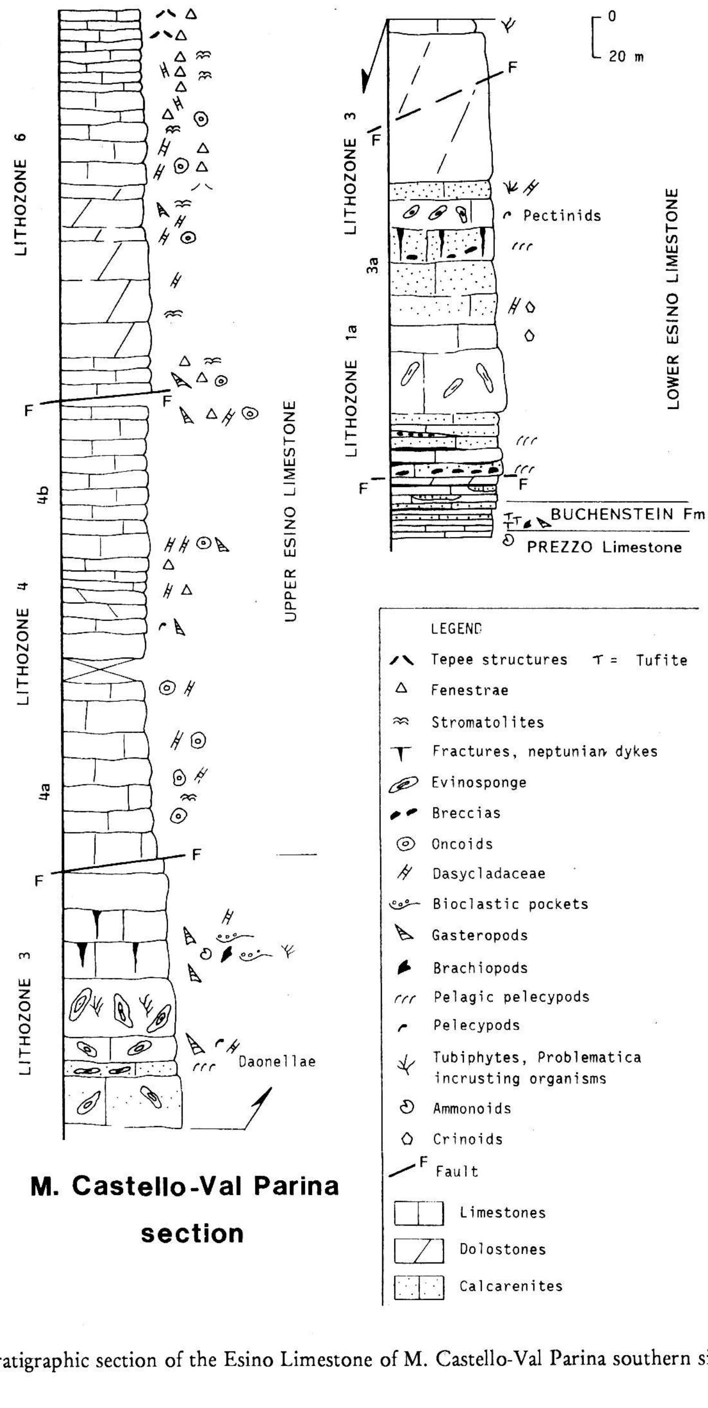

Fig. 4 - Stratigraphic section of the Esino Limestone of M. Castello-Val Parina southern side.

wards (? Buchenstein Formation). The upper part of lithozone 3 may be also coeval with lithozone 4 and with the Perledo-Varenna Limestone of north M. Menna slope (Fig. 5).

The age of these lithofacies association is Early Ladinian because of its stratigraphic position, which is correlatable with/ or underlies the fossiliferous Early Ladinian outcrops of lithozone 4 (Fig. 7).

The association of lithofacies of lithozone 3 represents a buildup margin bound by a intraplatform troughs (Perledo-Varenna Limestone) and/or open basins to the south (Fig. 5).

Lithozone 4.

Thick bedded subtidal limestones characterize the middle, thick part of the Esino Limestone. They overlie lithozones 2 and 3 p.p. Lithozone 4 is common in the northern and eastern parts of the studied area (M. Menna, Lenna, M. Castello) while in Val Parina it interfingers with lithozones 3 and 5 (Fig. 5).

The most common facies associations are: peloidal packstones, wackestones and mudstones with large oncoids, gastropods, pelecypods, foraminifers; bio-intraclastic packstones and subordinate grainstones; algal bindstones with oncoids (lithofacies association 4a). In the middle upper part of the lithozone, packstones-grainstones with dasycladacean Algae (*Diplopora annulata, Teutloporella herculea*), peloids, grapestones, algal coated lumps and foraminifers (*Trochammina* sp., *Ammobaculites* sp., *Erlandinite* sp., *Endothyra* sp., *Diplotremina* sp.) intercalate (lithofacies association 4b). Small dissolution cavities and stromatolitic limestones with fenestrae characterize the top of some beds and evidence a locally evident shallowing upward ciclicity (cycles from 3 to 10 m thick) (Fig. 6b).

The passage to the overlying lithozone 6 is marked by the increased occurrence of bedded peritidal cycles. In Val Parina, bioclastic lenses, 10-100 cm thick, are common both in this lithozone (prevalent lithofacies association 4a) and in the transitional facies to lithozone 3 (Fig. 6d). These lenses mostly consist of bioclastic pockets with a very rich fauna (Tab. 1) dominated by large gastropods (Fig. 6c) (correlatable with Costa Pagliari fauna; Patrini, 1927; Hofsteenge, 1932) or by gastropods in association with ammonoids (the fossiliferous outcrops of groups a, b, c, d, f; Fig. 6d; Tab. 1). The locally high density of fossils, with moderate sorting and the lenticular geometry of the bioclastic pockets are indicative of accumulating by prevalent storm events.

The age of this lithozone, on the basis of the rich ammonoid fauna (Tab. 1, see biostratigraphy of the Esino Limestone), spans from the Early to the Late Ladinian p.p. In Val Parina the boundary between Lower and Upper Ladinian has been recognized in the middle portion of lithozone 4 (Fig. 7) at about 300-400 m from the Esino Limestone bottom and 500-550 m from its top.

Open back reef lagoons, tidal channels and subordinate tidal flats represent the environments of lithozone 4, the average thickness of which ranges from 300 to 450 m.

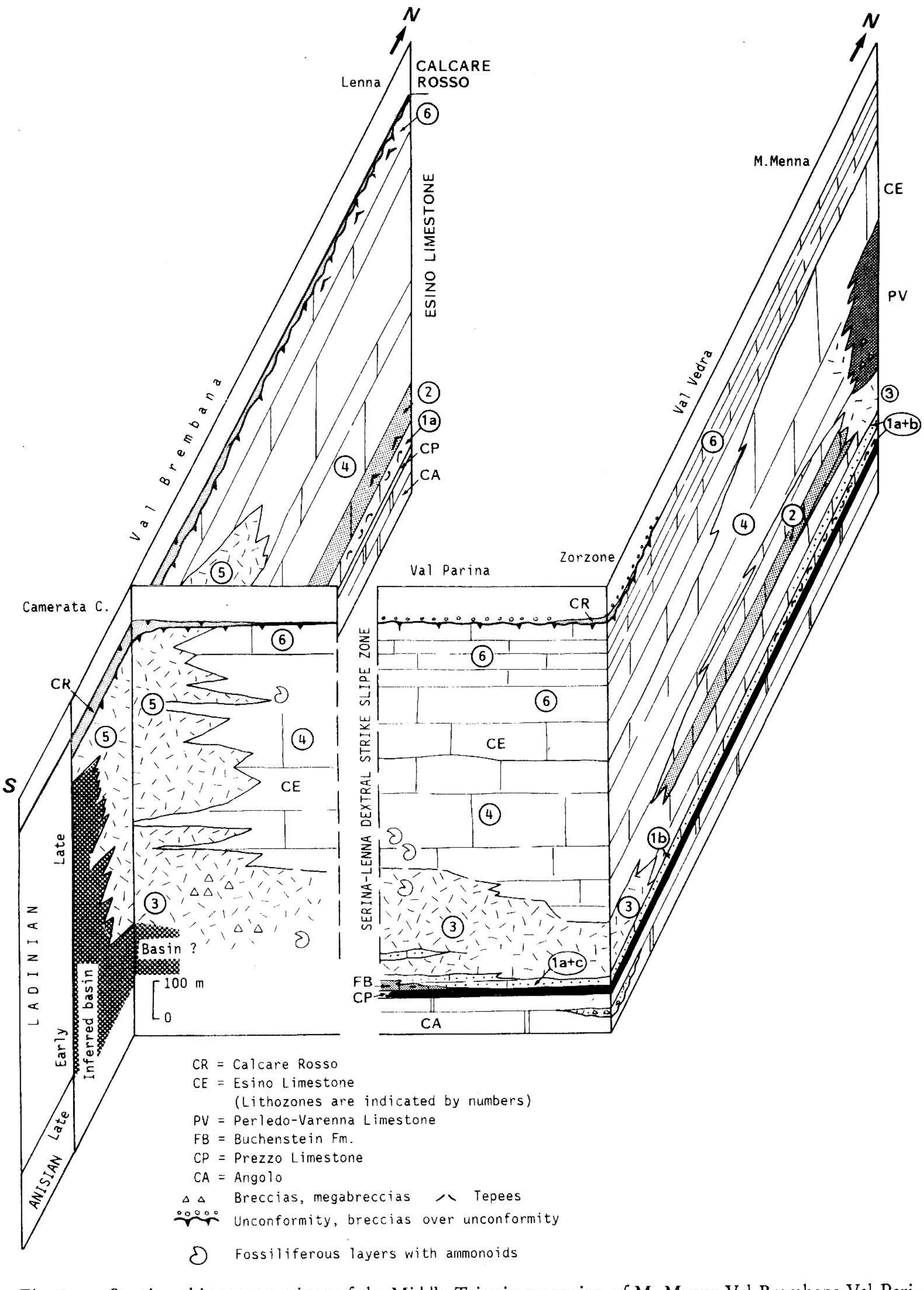

Fig. 5 - Stratigraphic cross sections of the Middle Triassic succession of M. Menna-Val Brembana-Val Parina areas.

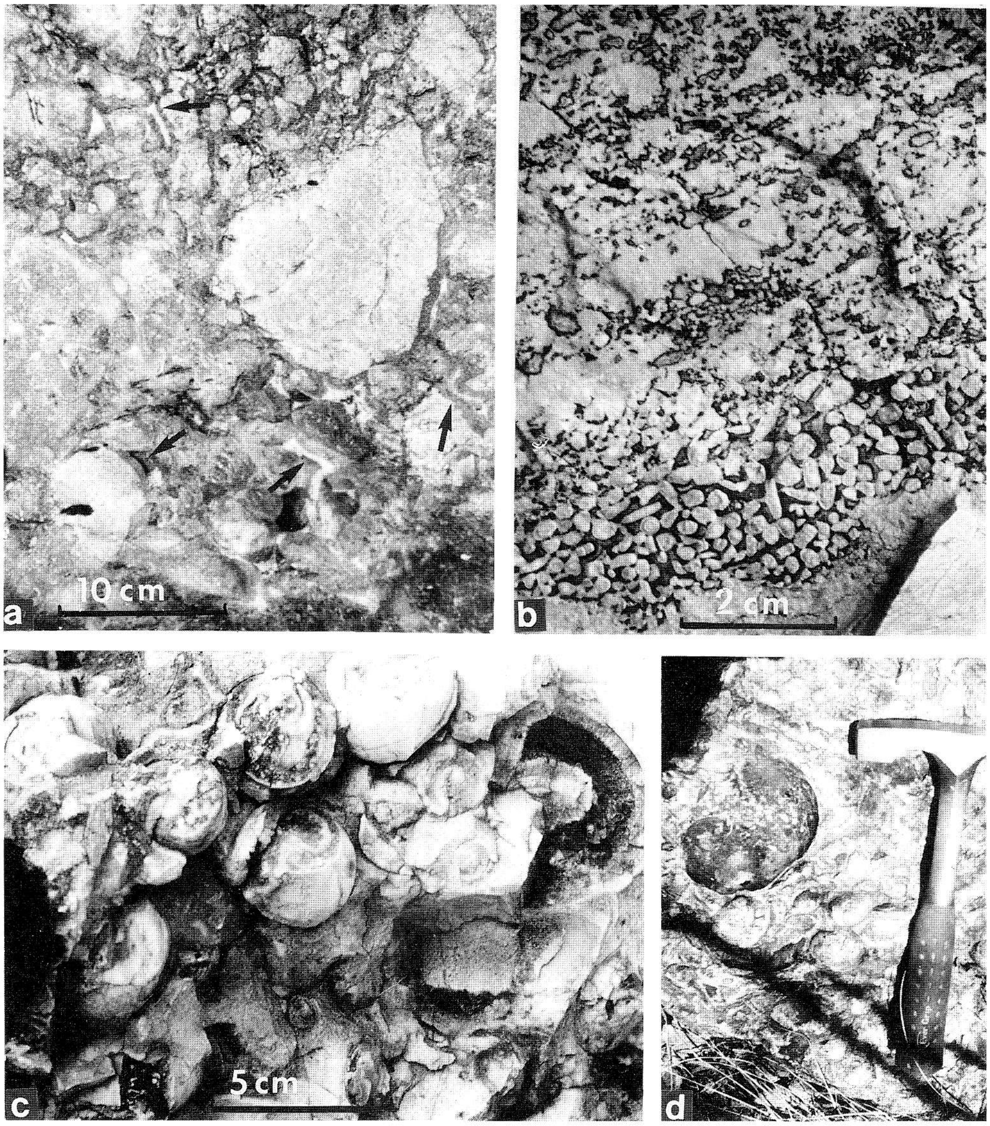

Fig. 6 - Lithofacies of the Esino Limestone. a) Breccias cemented by evinosponge structures (arrows). Marginal-slope lithofacies association of lithozone 3. Val Parina q. 630 m. b) Coarse bioclastic-intraclastic grainstone with oncoids at the base. In the upper portion fenestral wackestones-packstones with a typical first generation of black isopachous calcitic cements. Lithozone 4,Val Pizzadelle. c) Bioclastic pocket with gastropods (*Trachynerita* sp.). Val Parina, outcrop S 746, locality 8 of Fig. 7. d) Bioclastic pocket with ammonoids, pelecypods, gastropods. Val Parina, outcrop S 746.

Lithozone 5.

Massive margin facies with evinosponges, outcropping only in the south-western part of the studied area (at the junction Val Parina-Val Brembana, Fig. 5) where it forms most of the Esino Limestone and is up to 500 m thick. Northwards and eastwards (M. Menna, M. Ortighera, M. Castello), lithozone 5 is replaced by lithozones 4 and 6.

Its characteristic lithofacies are represented by: *Tubiphytes* bindstones, locally metric coral framestones intercalated with fossiliferous algal wackestones, packstones and intra-bioclastic packstones and wackestones-rudstones. Microfacies are bindstones with *Tubiphytes*, blue-green Algae, solenoporaceans and dasycladaceans (*Diplopora annulata, Teutloporella herculea, T. echinata, T. nodosa*), pelecypods, gastropods, ostracods, foraminifers and crinoids. Large and small evinosponge cavities are very common (Jadoul & Frisia, 1988; Frisia et al., 1989). The top of this unit shows karst cavities with internal sediments, isopachous cement crusts, "raggioni" (Assereto & Folk, 1980) and sedimentary dykes, related to the regional subaerial exposure surface marking the top of the Esino Limestone (Assereto et al., 1977). Discontinuous dolomitization phenomena can be observed near the top of lithozone 5.

On the basis of stratigraphic setting, lithozone 5 is considered as Late Ladinian.

Lithozone 6.

Bedded limestones, organized in subtidal and peritidal cycles, mostly outcropping in the central-northern and eastern parts of the studied area. It represents the last 150-350 m of the Esino Limestone (Fig. 3, 4). In some zones, at the core of the Ladinian platform (M. Menna), lithozone 6 cannot be easily distinguished from the underlying lithozone 4. However, lithozone 6 beds are thinner and show frequent intertidal to supratidal (in its uppermost part) sedimentary structures, such as pisoids, dark radial fibrous calcite hemispheroids ("raggioni", Assereto & Folk, 1980) and small tepees.

The typical peritidal cycles, of decimeter to meter scale, are characterized by the presence of planar stromatolite bindstones with fenestrae and, locally, embryo tepees in the intertidal-supratidal part. The predominant subtidal interval of the peritidal cycles is mostly represented by packstones with dasycladacean Algae (*Diplopora annulata, Teutloporella herculea, T. echinata*). Dark grey, lagoonal limestones with small dasycladaceans locally (M. Ortighera) intercalate with these facies (Assereto et al., 1977).

Maximum thicknesses (about 350 m) have been measured in the area of M. Menna and M. Castello (Fig. 3, 4). South-westwards (lower Val Parina, southern slope, and Val Secca) lithozone 6 decreases its thickness or is lacking because it is replaced by lithozones 5 and/or 4 (Fig. 3). The top of lithozone 6 shows pockets-lenses metric thick filled by poligenetic carbonate breccias with clasts derived both from the Esino Limestone and, subordinately, from the Calcare Rosso (Hofsteenge, 1932; Assereto et al., 1977). This lithofacies, correlative with the karst features observed at the top of lithozone 5, are related to the regional subaerial exposure surfaces, and subsequent stratigraphic unconformities, present at the top of the Esino Limestone and in the Calcare Rosso (Assereto et al., 1977; Mutti, 1992).

Lithozone 6 is characterized by an overall shallowing upwards trend connected with the eustatic regression of the Upper Ladinian (Biddle, 1984; Haq et al., 1988). Lithozone 6 is Late Ladinian in age on basis of stratigraphic position and ladinian algal fauna.

Biostratigraphy of the Esino Limestone.

The first recovery of fossils from the Esino Limestone of Val Parina was carried out in autumn 1972 by F. Innocenti and M. Gervasutti, and the specimens (some gastropods and a few cephalopods) are stored in the Museo Civico di Scienze Naturali E. Caffi in Bergamo, along with all the other samples which have been collected afterwards (Paganoni, 1985). In fact, in the following years M. Gervasutti discovered a great number of fossil bearing localities, mostly on the northern slope of Val Parina and within the first 2-3 km from the junction with Val Brembana, at variable elevations (between 500 and 850 m a.s.l.) (Fig. 7). These localities are represented by pockets and lenses of bioclastic rudites (Fig. 6c ,d), the most part of which belongs to the transition between lithozones 3 and 4 and in the lower part of lithozone 4, about 200-350 m from the bottom and 550-500 m from the top of the Esino Limestone (Fig. 1, 2, 3).

All the main groups of macrofossils are represented in the Esino Limestone of Val Parina, namely: corals, brachiopods, echinoderms, bivalves, gastropods, cephalopods, Algae and vertebrates. However, the distribution of these groups is quite variable, as it can be seen from Tab. 1.

Fossils are generally well preserved, even cephalopod shells, though completely replaced by more stable carbonates (calcite). Gastropods may show traces of the original pigmentation, a phenomenon which is more rarely observed in bivalves and nautiloids. Fossil assemblages are variable as a result of environmental evolution and fractionation.

New taxa, both with respect to species and genera, are present in almost all the localities as a consequence both of the occurrence of restricted biotopes, which are rare in the fossil record, and of the incomplete knowledge of the Ladinian fauna.

Main fossil-bearing localities (Fig. 7).

The outcrops of the western part of the northern slope of Val Parina are rich in bivalves and gastropods. However, several cephalopods, brachiopods, echinoderms, and corals are also common. Fossils can be grouped as follows:

Group a: S 754/944/992/993/1032 (S 759 included, which was collected not in place just below S 754). Fossil bearing lenses set at variable elevations, from 550 m (S 754) to 715 m (S 993E) on the northern slope opposite Val di Lavaggio, and eastwards, in the lower part of lithozone 4. A great number of gastropods and bivalves (*Daonella* in S 944E) have been found, along with less abundant corals and brachiopods.

S 746

Taxa	total
Ammon.	6130
Nautil.	397
Belemn.	65
Gastrop.	3660
Bivalves.	367
Brachiop.	-
Corals	3
Echinod.	2
Algae	71
Vertebr.	8
Indeterm.	20

S 938/1060

Taxa	total
Ammon.	1096
Nautil.	15
Belemn.	62
Gastrop.	284
Bivalves	16
Brachiop.	3
Corals	-
Echinod.	1
Algae	15
Vertebr.	-
Indeterm.	2

S 944

Taxa	total
Ammon.	249
Nautil.	23
Belemn.	1
Gastrop.	666
Bivalves	670
Brachiop.	111
Corals	39
Echinod.	20
Algae	12
Vertebr.	-
Indeterm.	4

S 939/1059

Taxa	total
Ammon.	1433
Nautil.	29
Belemn.	23
Gastrop.	560
Bivalves	92
Brachiop.	1
Corals	-
Echinod.	-
Algae	50
Vertebr.	-
Indeterm.	-

S 1010

Taxa	total
Ammon.	173
Nautil.	16
Belemn.	10
Gastrop.	136
Bivalves	80
Brachiop.	14
Corals	9
Echinod.	1
Algae	22
Vertebr.	-
Indeterm.	3

S 754/759

Taxa	total
Ammon.	148
Nautil.	45
Belemn.	10
Gastrop.	522
Bivalves	847
Brachiop.	235
Corals	34
Echinod.	9
Algae	11
Vertebr.	-
Indeterm.	-

S 1011

Taxa	total
Ammon.	270
Nautil.	34
Belemn.	5
Gastrop.	175
Bivalves	147
Brachiop.	29
Corals	26
Echinod.	4
Algae	36
Vertebr.	-
Indeterm.	-

S 992

Taxa	total
Ammon.	76
Nautil.	7
Belemn.	-
Gastrop.	192
Bivalves	187
Brachiop.	24
Corals	11
Echinod.	6
Algae	2
Vertebr.	-
Indeterm.	1

S 993

Taxa	total
Ammon.	53
Nautil.	11
Belemn.	-
Gastrop.	219
Bivalves	92
Brachiop.	34
Corals	37
Echinod.	9
Algae	-
Vertebr.	-
Indeterm.	1

Parina Valley

Taxa	total
Ammon.	11297
Nautil.	632
Belemn.	210
Gastrop.	9141
Bivalves	2979
Brachiop.	587
Corals	221
Echinod.	60
Algae	356
Vertebr.	12
Indeterm.	45

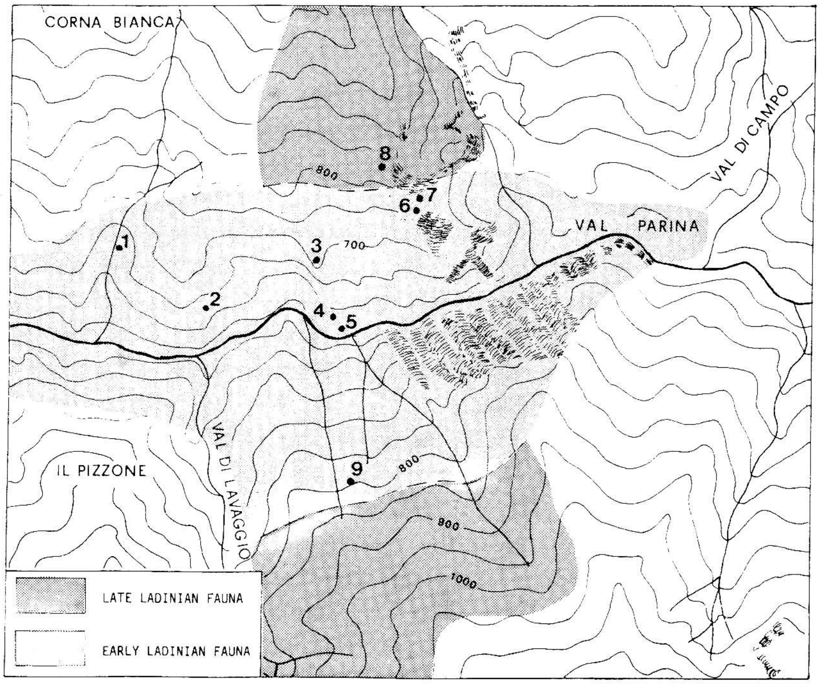

Fig. 7 - Geographic setting of main studied fossiliferous outcrops of Esino Limestone in Val Parina. 1) Outcrops S 1011/1010 in group b; 2) outcrop S 944 in group a; 3) outcrop S 993 in group a; 4) outcrop S 992 in group a; 5) outcrop S 754 in group a; 6) outcrop S 1060 in group e; 7) outcrop S 1059 in group d; 8) outcrop S 746 in group c; 9) outcrop S 1078 in group f.

Crinoids are widespread and locally abundant (S 944F). Cephalopods are not common, though represented by diverse species and genera such as: *Chieseiceras perticaense* Brack & Rieber, *Norites dieneri* Arthaber, *Epigymnites moelleri* (Mojsisovics), *E. paronae* (Longhi) and some species of *Eoprotrachyceras* Tozer.

Eastwards, about 300 m from the junction with Val di Lavaggio, there is the small S 1032 outcrop, which is the last one bearing typical faunas of the western zone and is located near the margin of a cliff facing S 754/759 incise. From here onwards, corals, echinoderms and brachiopods almost disappear.

Group b: S 1011/1117 (S 1010, not in place, included). Lenses set on the northern slope of Val Parina, 200-300 m westwards of Val di Lavaggio, at variable elevations (from 550 to 700 m a.s.l.) in lithozone 4. Cephalopods can be locally abundant (S 1011P, 1011R), among which some species of *Eoprotrachyceras* Tozer have been recognized. Gastropods and bivalves are common, while brachiopods and corals are sub-

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Tab. 1 - Distribution of fauna specimens collected in the main fossiliferous localities of the Esino Limestone in Val Parina.

ordinate (however, the latter are abundant in S 1011G and S 1117A). Echinoderms are rare.

The eastern part of the northern slope yielded very rich faunas, almost exclusively represented by cephalopods and gastropods and distributed as shown in Tab. 1.

Group c: S 746 (S 1040, not in place, included). Very rich outcrop consisting of a group of fossils bearing lenses set at an elevation of 835-840 m. Gastropods and cephalopods are common. Among the latter, *Protrachyceras longobardicum* (Mojsisovics) and *P. steinmanni* (Mojsisovics) have been identified. Bivalves are scarce. Corals, brachiopods and echinoderms are extremely rare.

Group d: S 902/1059/1110 (S 939 included). Small lenses, set at elevations ranging from 820 to 835 m, where small cephalopods are common, among which some specimens belonging to *Argolites* Renz.

Group e: S 954/1060/1179 (including S 938 and 1035). Layers set at elevations ranging from 690 to 775 m and are lateral to the a,b groups (Fig. 7). Ammonites are abundant, with forms which are not present in either group c (S 746) or d (S 902/1059/1110), but may be found in the western levels of groups a and b (S 944, S 1010 etc.). "*Hungarites*" are dominant, though these cannot be referred to any known genera of this group; *Norites dieneri* Arthaber, is common, *Flexoptichytes* rare.

Group f: S 1058/S 1078. These are the most significant layers of the southern side of Val Parina. The first one, opposite S 746 and at an elevation of about 850 m, is rich in gastropods (mostly *Trachynerita*) and also bears cephalopods, among which *Celtites* Mojsisovics, *Argolites* Renz specimens have been found in the small S 1078 outcrop, located westwards a few tens of meters below S 1058.

Paleogeographic evolution of the Esino carbonate platform.

The stratigraphic analysis of the Esino Limestone allowed for the recognition of the following stages in western Bergamasc Alps Late Anisian-Ladinian platform. This study provides a more detailed picture of the middle triassic paleogeography (Brusca et al., 1982):

a) *The lower edifice*. It is the first stage in the development of the Esino carbonate platforms in central Lombardy. Consisting of lithozones 1, 2 and part of 3 (3a) (lower Esino Limestone), it represents the uppermost part of the Late Anisian and, probably, the basal part of the Early Ladinian.

The carbonate depositional system of the Esino lower edifice established on areas which were already sites of peritidal sedimentation (the "peritidal dolomites" of Angolo Limestone) in the Pelsonian, and subsequently subjected to a regional transgressive event in the Illyrian ("Banco a Brachiopodi", Prezzo Limestone). In the latest Anisian, carbonate platform began to grow with the deposition of subtidal carbonates (lithozone 1b) (M.Menna-Lenna area; Fig. 3), and of bioclastic-lithoclastic calcarenites (lithozones 1a-1c). They represent the transitional facies between the carbonate platform and the adjacent basins (transition Esino-Buchenstein and Buchenstein Formation of Val Parina, Piazza Brembana). At the same time, or immediately after this stage, the first reef margins started to form, some of which were built in protected areas, by the action of carbonate producing organisms such as *Tubiphytes* (lithozone 3 of Ghegna-Baita Muffi). As a consequence, the platform differentiated in margins, back reef, and inner platform areas where intertidal-supratidal facies could also occur (lithozone 2). During periods of subaerial exposure, these latter were disrupted by the development of tepee structures (lithozone 2 of Piazza Brembana). Tepees, and the evidences of local emersion at the top of sublithozone 3a (Val Parina), are indicative, if observed on a regional scale, of a regressive trend that can be interpreted as a relative sea level low stand occurred in the earliest Ladinian or at the Anisian-Ladinian boundary.

b) *The aggrading, buildup stage (main edifice).* It is the middle part of the Esino Limestone (lithozone 3 and part of 4), which is characterized by growth of a buildup bound southwards and north-eastwards by open basins and/or intraplatform troughs. This evolution of the platform is due to a transgressive trend, as recorded by the inner platform successions with the prevalent subtidal facies of lithozone 4 growing on the peritidal facies of lithozone 2. At the same time, the thick buildup margins of lithozone 3 developed on the southern rim of the platform. This particular paleogeographic setting may indicate a prevalent aggradation in the carbonate platform with a persistent platform-margin depositional system facing a not outcropping southern basin (Fig. 5). The presence of this latter is mostly inferred from the vertical unchangeable distribution of reefal succession of Val Parina south versant, from the ammonoids and *Daonella* assemblages found, in particular, in its back-reef succession (fossiliferous outcrops in lithozone 4; Tab. 1), but also present in the margin itself (lithozone 3; Fig. 4). The fossiliferous pockets with mixed pelagic and platform bentonic organisms found in back reef facies have been interpreted as prevalent storm deposits.

Different subsidence rates allowed for both the growth of a carbonate buildup and the development of a small intraplatform basin (Perledo-Varenna Limestone of Baita Muffi) towards the northeast (Fig. 1, 3). The Esino platform which bounded this depression was characterized by a minor development of reefal facies and by the lack of fossiliferous pockets rich in pelagic organism.

c) *The prograding phase of the upper edifice.* Late Ladinian in age, it is mostly represented by lithozones 5, 6 and part of lithozone 4 (lithofacies association 4b). The organization, distribution and evolution of this succession are indicative of a regional progradation of the platform on large areas of the Bergamasc Alps, with subsequent widespread occurrence of subtidal and peritidal facies. The intraplatform basins, which had developed in the northern areas (Baita Muffi and northern slope of M. Pegherolo-upper Brembana valley) during the preceding phase, were "conquered" by the prograding upper Esino Limestone. However, southwards (Val Parina-Val Brembana junction) a carbonate platform margin was still present in the Late Ladinian (lithozone 5). This may be proof of the persistence of a south-westward basin (Fig. 5).

The uppermost Esino carbonate platform is characterized by peritidal cycles with diagenetic caps (Bosellini & Hardie,1988): the common supratidal subfacies show tepee structures and erosional phenomena near the top of lithozone 6. These phenomena are particularly intense at the core of the platform, which was the previous site of tidal flat deposition (lithozone 6 of M. Menna-Ortighera Group). Erosional phenomena are recorded by the carbonate breccia pockets, with clasts derived from the Esino Limestone itself, which can be observed eastward and northward at M. Vaccareggio-M. Pedrozio and locally in the M. Menna-M. Ortighera Group (Assereto et al., 1977). Karst phenomena breccias and sedimentary dykes were also widespread, in particular in the platform margin represented by lithozone 5, just below the Calcare Rosso succession. The final subaerial exposure of the platform, and the consequent temporary cessation of carbonate productivity of the late ladinian platform, are evidence of the late ladinian eustatic regression (Biddle, 1984; Jadoul & Frisia, 1988; Gnaccolini & Jadoul, 1990; Mutti, 1992), locally with tectonic overprint.

On the southern margins of the edifice, probably subjected to higher subsidence rates with respect to the northern areas, carbonate productivity recovered with the deposition in onlap of the cyclic peritidal facies Calcare Rosso succession (Assereto et al., 1977; Mutti, 1992). These latter show a number of subaerial exposure surfaces characterized by red paleosoils and tepee structures (Assereto & Kendall, 1977; Assereto et al., 1977; Mutti & Jadoul, 1991; Mutti, 1992).

Conclusions

A) Stratigraphic study with facies analysis of the prevalent Ladinian succession and the biostratigraphy of the middle Esino Limestone of Val Parina put to evidence the complex paleogeographic evolution of the carbonate platforms of Valle Brembana. In fact, the thick Esino Limestone succession consists of a few edifices amalgamated and locally separated by unconformities that may be difficult to distinguish in the field. The evolution in time and space of the Esino Limestone depositional system occurred in three main stages:

1) The first platform nuclei (60-100 m thick) developed in areas which were already sites of carbonate platform deposition in the Middle Anisian. In this same phase, local episodes of subaerial exposure of the platform may be indicative of a tectonic-eustatic event, and subsequent relative sea level fall, occurred between the Late Anisian and the basal part of the Early Ladinian.

2) The main aggradational phase is responsible for the buildup of lithozones 3 and 4 and may be the consequence of variable subsidence rates connected with syndepositional extensional or transtensive tectonics with volcanism. This phenomenon created basins and intraplatform troughs. This stage took place between the Early Ladinian and part of the Late Ladinian.

3) The last phase consists of carbonate upgrading and lateral progradation of the carbonate platform. It is interpreted as connected with a tectono-eustatic regressive trend, which caused several episodes of subaerial exposure in the inner platform facies as well as the widespread occurrence of shallow subtidal and peritidal facies. Only in the southwestern area was present a probably persistent basin. This evolution is similar to that described for the Grigna Settentrionale Esino Limestone (Gaetani et al., 1987). The age, inferred by its stratigraphic position above fauna of the Archelaus Zone, is Late Ladinian, possibly corresponding to the Regoledanus Zone.

B) Studies in progress of the rich fauna of the Esino Limestone of Val Parina will provide more information on the Ladinian carbonate platform fossil associations. A detailed reconstruction of the biostratigraphic succession cannot be carried out, because the preliminary phase of study and the discontinuous distribution of fossil-bearing outcrops. The whole distribution of the studied faunas found in Esino lithozone 4 spans from the Early Ladinian to the Late Ladinian. Problematic it is the interpretation of *group e* fauna (tentatively dated Early Ladinian) because its stratigraphic position inside litozone 4. In particular:

Group a can be ascribed to the Early Ladinian, Curionii Zone (*Chieseiceras perticaense* horizon, Brack & Rieber, 1986), because of the presence of *Chieseiceras perticaense* Brack & Rieber and *Eoprotrachyceras* Tozer.

Group b, with *Eoprotrachyceras* and lacking *Chieseiceras*, may be set at the top of the Curionii Zone (*Eoprotrachyceras recubariense* horizon; Brack & Rieber, 1986). The S 1032 faunas may be more recent.

Group c, with the typical *Protrachyceras* of the Archelaus Zone [*P. longobardicum* (Mojsisovics), *P. steinmanni* (Mojsisovics)], represents the Late Ladinian.

Group d, characterized by the presence of a great number of small cephalopods and with *Argolites* Renz may be referred to the upper part of the Early Ladinian. Similar faunas are present also in *group f* (S 1058/1078), located at a slightly higher elevation and on the southern slope of the valley.

Group e is of difficult interpretation, because the fauna is totally different with respect to the other groups. The most common specimens are some "*Hungarites*" which cannot be referred to any of the known genera of the group. *Norites dieneri* Arthaber, which is generally believed to be an Late Anisian species, is common. This species has been found also in *group a*, ascribed to the Curionii Zone. Some rare *Flexoptychites* are also present; this genus has been citated by Krystyn & Mariolakos (1975) also in Early Ladinian. Because of the great number of new forms and of the limited stratigraphic significance of the identified species, *group e* can be tentatively dated Early Ladinian.

Fossils of the latest Ladinian (Regoledanus Zone) are absent in the Esino Limestone of Val Parina. However, it may be inferred that the top of the upper edifice of the ladinian platform (lithozones 5 e 6 p.p.), and/or the Calcare Rosso succession may represent this time interval.

C) Sequence stratigraphy concepts applied to upper Angolo-Esino Limestone carbonate platforms of Valle Brembana allow for the definition of four local depositional sequences (Jadoul & Gnaccolini, 1992; Gaetani et al., in prep.). The upper Angolo Limestone, in particular the succession of the "peritidal dolomites", may represent a Pelsonian-lowermost Illyrian sequence, as inferred on the basis of its stratigraphic position below the "Banco a Brachiopodi" and the Prezzo Limestone (Farabegoli & De Zanche, 1984; Gaetani et al., 1987). This sequence may correspond to the third tectono-sedimentary cycle of the Late Scythian-Early Ladinian succession recognized in the central-western area of the Southern Alps (De Zanche & Farabegoli, 1988). The second sequence includes the uppermost part of the Angolo Limestone (Brachiopod and Crinoid horizons), the Prezzo Limestone and the basal part of the Esino Limestone (lithozones 1, 2 of the lower edifice). The third sequence is represented only by the middle-upper Esino Limestone. The transgressive part of the sequence may be connected with the aggrading phase of the main edifice buildup, while the progradation of the upper edifice probably occurred during the high stand. The unconformity at the top of the Esino Limestone with karst features (Assereto et al., 1977) represents an important regional sequence boundary. A fourth depositional sequence is recorded by the Calcare Rosso sedimentation (Mutti, 1992; Jadoul & Gnaccolini, 1992).

Acknowledgements.

We gratefully acknowledge for their critical review and for useful suggestions Prof. M. Gaetani, Prof. C. Rossi Ronchetti, Prof. H. Rieber, Dott. M. Balini, Dott. A. Paganoni. We also thank, for contributions in the field work and microfacies analysis, Dott. A. Francesconi and Dott. E. Fois.

This work was supported by MURST 40% grant on Trias researches (Prof. Fantini Sestini) and "Centro di Studio CNR per la Stratigrafia e Petrografia delle Alpi Centrali" of Milan.

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PLATE 23

Ammonoids of Val Parina bioclastic pockets in the lower-middle Esino Limestone (lithozone 4).

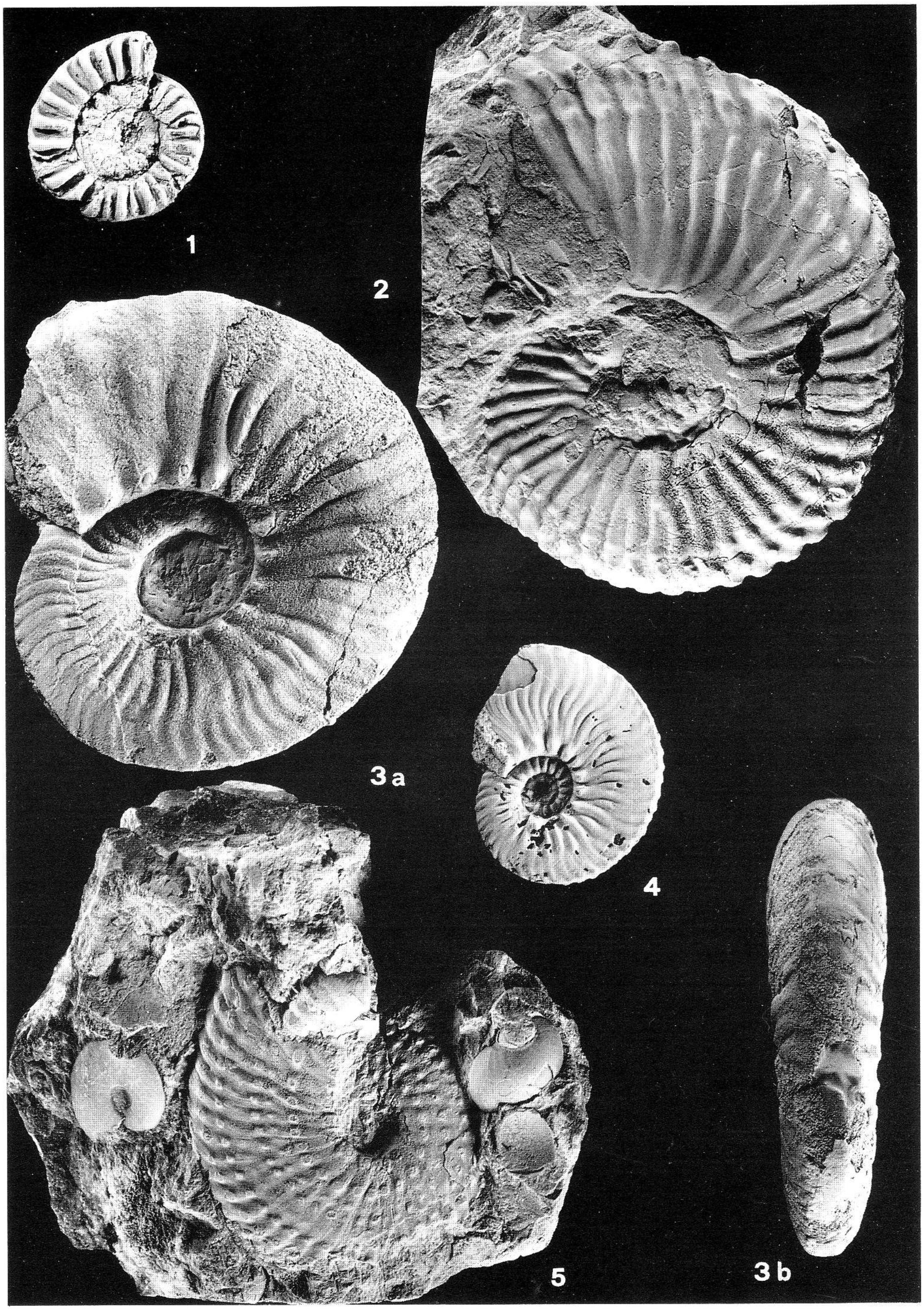
Fig. 1 - *Argolites celtitoides* (Airaghi). Val Parina, Early Ladinian, S 1078a. Side; x 1.

Fig. 2 - *Eoprotrachyceras* sp. n. A. Val Parina, Early Ladinian, Curionii Zone, S 1010a. Side; x 1.

Fig. 3a,b - *Chieseiceras perticaense* Brack & Rieber. Val Parina, Early Ladinian, Curionii Zone, S 754a. Respectively side and venter; x 1.

Fig. 4 - *Chieseiceras perticaense* Brack & Rieber. Val Parina, Early Ladinian, Curionii Zone, S 754d. Side; x 1.

Fig. 5 - *Protrachyceras steinmanni* (Mojsisovics). Val Parina, Early Ladinian, Archelaus Zone, S 746a. Side; x 1.


1
2
3a
4
5
3b