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# FAUNAL ASSEMBLAGE AND PALAEOENVIRONMENT OF SHALLOW WATER BLACK SHALES IN THE TONEZZA AREA (CALCARI GRIGI, EARLY JURASSIC, SOUTHERN ALPS)

**BASSI D., BOOMER I., FUGAGNOLI A., LORIGA C., POSENATO R. and WHATLEY R.C.**

## INTRODUCTION

During the Early Jurassic, a thick shallow water carbonate platform succession, the Calcari Grigi formation (Hettangian-Pliensbachian), was deposited on the Trento Platform (north-eastern Italy). This formation is subdivided into four members, the third of which (the Rotzo Member) is the best known as far as the fossil content is concerned. This member consists of several lithofacies and rich faunal and flora assemblages such as the peculiar plant remains (De Zigno, 1856-1885; Wesley, 1956) and the large bivalves of the *Lithiotis* facies (e.g. Reis, 1903; Berti Cavicchi *et al.*, 1971; Accorsi Benini & Broglio Loriga, 1977; Accorsi Benini, 1979, 1981).

Black shales occur at various localities and at different stratigraphical levels within the Rotzo Member (Avanzini, 1998; Masetti *et al.*, 1998). Some of these deposits are characterized by a well preserved and previously unknown benthic bivalve and ostracod fauna as well as the presence of organic material. Such horizons offer an excellent opportunity to study and assess the poorly known upper Sinemurian-Carixian benthic communities in shallow water restricted environments. We analyzed, in an integrated approach, the faunal assemblage of a black shale horizon outcropping in the Tonezza area (Vicenza, Veneto; Fig. 1) with regard to: (a) the recognition of the taphonomic signatures; (b) the characterization

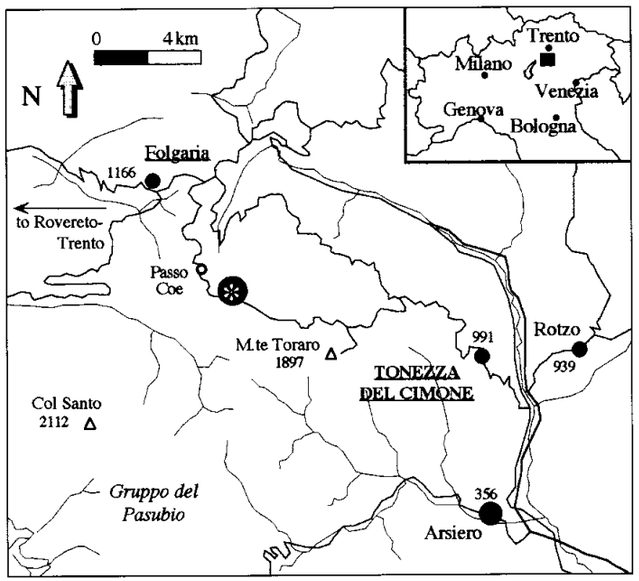


Fig. 1 - Location map of the site (*) investigated in the Tonezza del Cimone area (Vicenza, Veneto, north-eastern Italy).

of the organic matter; (c) the biodiversity and palaeoecology of the benthic assemblage.

The present work represents a preliminary research report of a more comprehensive study on Lower Jurassic bivalve-ostracod assemblages in black shale horizons which occur in the Rotzo Member.

## STRATIGRAPHICAL FRAMEWORK

The Calcari Grigi formation overlies the Upper Triassic Dolomia Principale and is directly overlain by the Toarcian-Aalenian San Vigilio Group or by the upper Bajocian-Tithonian Rosso Ammonitico. The Calcari Grigi are subdivided into four members: Lower and Middle Members, Rotzo Member and Massone Member (e.g. Bosellini & Broglio Loriga, 1971; Krautter, 1985; Beccarelli Bauck, 1988) (Fig. 2). On the western margin of the Trento Platform, the San Vigilio Oolite and the Tenno Formation (Toarcian-Aalenian in age) overlie the Calcari Grigi (e.g. Sturani, 1964; Barbujani *et al.*, 1986).



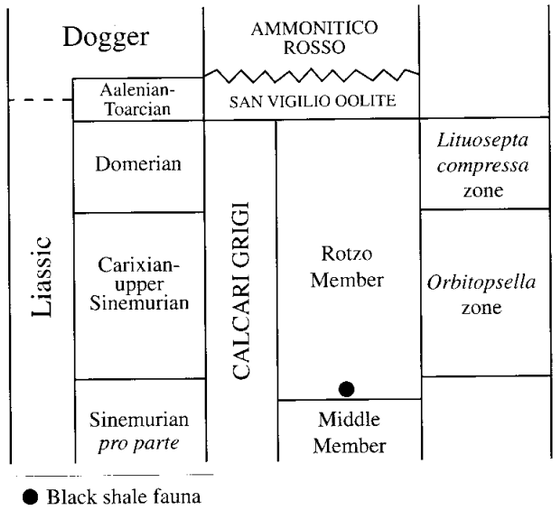


Fig. 2 - Stratigraphical setting of the studied ostracod-bivalve black shales. The black shales are located below the *Lithiotis* facies at the base of the Rotzo Member, and lies below the lower boundary of the *Orbitopsella* zone (Fugagnoli, 1998).

### THE ROTZO MEMBER

This member consists of peloidal, bioclastic, ooidal and intraclastic limestones; marl and clay horizons, which are occasionally rich in plant remains, may also contain coal. Most of the macrofossils are of bivalves, gastropods and brachiopods; echinoids, crinoids, chaetetids and rare corals are also present. The large bivalves (e.g. *Lithiotis*, *Cochlearites*, *Lithioperna*) characterize the widespread «*Lithiotis* facies» (Broglio Loriga & Neri, 1976).

The microfossils of the member belong mainly to peculiar benthic foraminifera (Lituolacea) widespread in the Tethyan domain during the Liassic therefore very useful for biostratigraphy of shallow water succession (e.g. Hottinger, 1967; Septfontaine, 1984, 1985; Bassoullet, 1997). Such taxa allowed the recognition of two biozones in the Rotzo Member: the *Orbitopsella* zone and *Lituosepta compressa* zone (Bosellini & Broglio Loriga, 1971; Castellarin, 1972; Fugagnoli & Loriga Broglio, 1998; Fugagnoli, 1998; Fig. 2). These two biozones span the Upper Sinemurian-Carixian to Domerian ages respectively according to calibrations supported by ammonoids and brachiopods of almost equivalent biozones from Morocco (Septfontaine, 1984, 1985).

The Rotzo Member has been interpreted as a lagoonal environment protected

shales of the Rotzo Member. Such ORB contain only a few benthic species which can be prolifically abundant on some bedding planes. Moreover, the ORB 4 can grade into ORB 5 which marks the transition in sediment fabric type from planar laminated to homogeneous, burrowed fabrics. This is well distinguished in the studied section (Fig. 3), in particular ORB 4 corresponds to the MF 3 and ORB 5 to MF 2 and MF 4, which are remarkably richer in benthic species (i.e. benthic foraminifera, small nerineaceans, brachiopods, and crinoids).

The bivalves may have been driven to the sediment surface in response to a rising redox boundary ($O_2$-$H_2S$ interface), with subsequent mass mortality due to oxygen depletion. They were reworked by relatively weak currents; such short-term winnowing together with a rapid burial concentrated and preserved the shell pavements. The assemblages therefore probably represent an episodically anaerobic benthic environment (see Allison *et al.*, 1995; Wignall, 1996), perhaps in conjunction with fluctuating salinity, in which the absence of bioturbation assured the preservation of the original fabric. The alternation between shell rich and anoxic laminae may represent the influence of seasonal anoxia related to phytal blooms and or detrital organic matter influx within the lagoonal setting.

## ORGANIC GEOCHEMISTRY

Geochemical analysis were carried out in the A.G.I.P./SGEL laboratories of San Donato Milanese (Milan). Proportions of the main 8 mineralogic components were measured from RX spectrometer (difractometer). Rock-Eval pyrolysis was performed on pulverized shale samples.

Calcite together with aragonite represent 93% of the bulk mineralogy; quartz, clay minerals and gypsum are also present.

The total organic carbon (TOC) is 1.48 wt%; oxygen [OI] and hydrogen [HI] indices are 344 mgHC/gCorg and 102 mg$CO_2$/gCorg respectively. The organic matter plots between Types II and III kerogen evolution pathways and shows 60% of amorphous organic matter, which represents the most labile portion of the organic matter (OM). The Production Index (PI) and Tmax values of 0.31 and 424°C, respectively, indicate immature OM. According to Peters' classification (1986), geochemical parameters of the samples describe a good source rock generating potential (Fig. 5 a). The pyrolysis-derived HI and OI values, plotted in a 'modified Van Krevelen diagram' (Peters, 1986; Tyson, 1995) indicate a Type IIb kerogen (Fig. 5 b).

The data provided by the organic geochemistry point to so-called «restricted shales» which are a mixed organic facies (*sensu* Jones, 1987) characterizing weakly oxygenated bottom waters (Demaison & Moore, 1980), with non-oil-prone kerogen related to phytoclast material ('spore' coal).



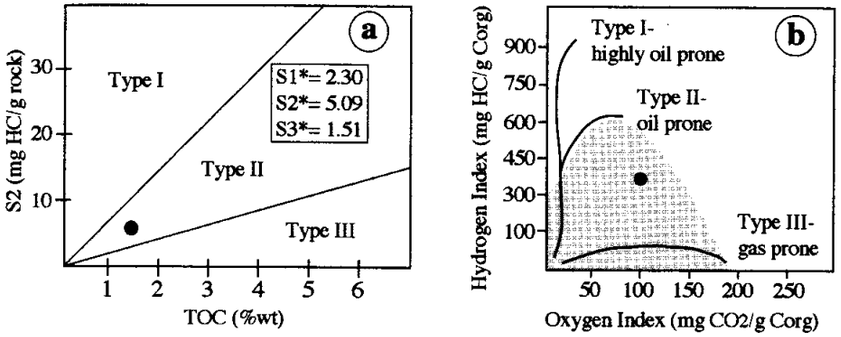


Fig. 5 - Kerogen type of the study black shale horizon defined by (A) cross-plot of TOC and pyrolysis S2 parameter (from Tyson, 1995; * = mg HC/g rock), and by (B) various hydrocarbon- generative types and range of coal composition (stippled) (redrawn from Peters, 1986).

## BIVALVES

The mollusc assemblage of the black shales is entirely constituted by bivalves which are represented by three taxa: *Eomiodon* sp., ?*Myrene* sp. and an Isognomonid of indeterminate genus.

### EOMIODON *SP.*

The bivalve assemblage is dominated by small sized specimens belonging to *Eomiodon* sp. The shell length, measured on the better preserved specimens, ranges from 4.5 to 17.2 mm, with a mean of 11 mm (Pls. 1 and 2). This bivalve, a representative of the family Neomiodontidae, is characterized by an ovoidal and slight carinate shell with an *Astarte*- like sculpture consisting of concentric lamellae (Pl. 2, Fig. 1, 2). These are regularly spaced on the umbonal region where they are often abraded; their distribution and prominence become more irregular towards the margins. The assignment of these specimens to the genus *Eomiodon* Cox is mainly based on the lucinoid hinge structure which has a small cardinal tooth 5b, not always easily detected, and long laterals (Pl. 2, Fig. 3, 4). Teeth AIII and 3a are scarcely developed: the lateral AIII is slightly separated from the cardinal margin and 3a is a small protuberance of AIII. All teeth appear to be cross-striated under high magnification (Pl. 2, Fig. 5).

In the paleontological literature of the Calcari Grigi (e.g. Schauroth, 1865; Boehm, 1884; Tausch, 1890; Clari, 1975) and other Jurassic formations, there are several species (i.e. ?*Astarte kamarica* Tausch, ?*Astarte serradensis* Tausch, ?*Cytherea*

towards the open sea by marginal oolitic bars and shoals (Bosellini & Broglio Loriga, 1971), or as a «ramp-lagoon» protected by a distal littoral complex (Monte Baldo area; Masetti *et al.*, 1998).

## THE BLACK SHALE HORIZONS AND MICROFACIES

The studied stratigraphical section is located near Malga Zonta in the Altopiano di Tonezza del Cimone (Vicenza; Fig. 1). The section spans the upper part of the Middle Member and the base of the Rotzo Member (Fig. 3). The Middle Member is well exposed in a quarry just few metres below the study profile. In the measured profile the upper part of the Middle Member consists of about 3 m of oolitic grainstones covered by ca. 7 m of Quaternary cover. The Rotzo Member consists of about 9 m of mainly wackestones/packstones.

In this section, four black shale horizons occur in a stratigraphical interval not more than 5-7 metres thick, at the base of the Rotzo Member. The shale horizons decrease in thickness through the section from a maximum of 40 cm to a minimum of 5 cm. The first horizon, occurring between two thick wackestone-packstone beds, contains abundant fossil material of bivalves and ostracods which are presented herein. Fossils are also present in the second and third horizon while the fourth is barren.

Four microfacies types, differentiated by particle types (allochems) and fossils were recognized in the measured profile. Microfacies MF 1 belongs to the Middle Member, and microfacies MF 2, MF 3 and MF 4 to the Rotzo Member. The boundary between MF 1 and MF 2-4 is abrupt. MF 2, MF 3 and MF 4 alternate with one another (see profile). The recognized microfacies are, from the bottom to the top of the profile (Fig. 3), the following.

*MF1: oolitic grainstone* – Coarse grained oolitic grainstone (Fig. 4 a), sometimes with peloidal concentrations; ooids approximately 0.5 mm in diameter, principally micritized with a generally micritic core; occasionally concentric layers with a tangential microstructure are distinguished. Bioclasts, represented mainly by bivalve fragments, occur together locally with small benthic foraminifera (*Ophthalmidium* sp., *Earlandia* sp., *Ammobaculites* sp.).

*MF2: bioturbated-peloidal wackestone/packstone* – Peloidal wackestone/packstone locally interbedded with thin calcareous-marly layers (Fig. 4 b). Biotic components, 'floating' in the pelmicritic matrix, represented by small and very thin bivalves, brachiopods, small Nerineacea, small crinoids fragments, rare ostracods, and rare benthic foraminifera (*Amijiella amiji* Henson, ?*Earlandia* sp., valvulinids). Bioclast concentrations are locally visible as laterally discontinuous millimetre scale layers. Bioturbation seems to have played a strong influence in homogenising the sediment.



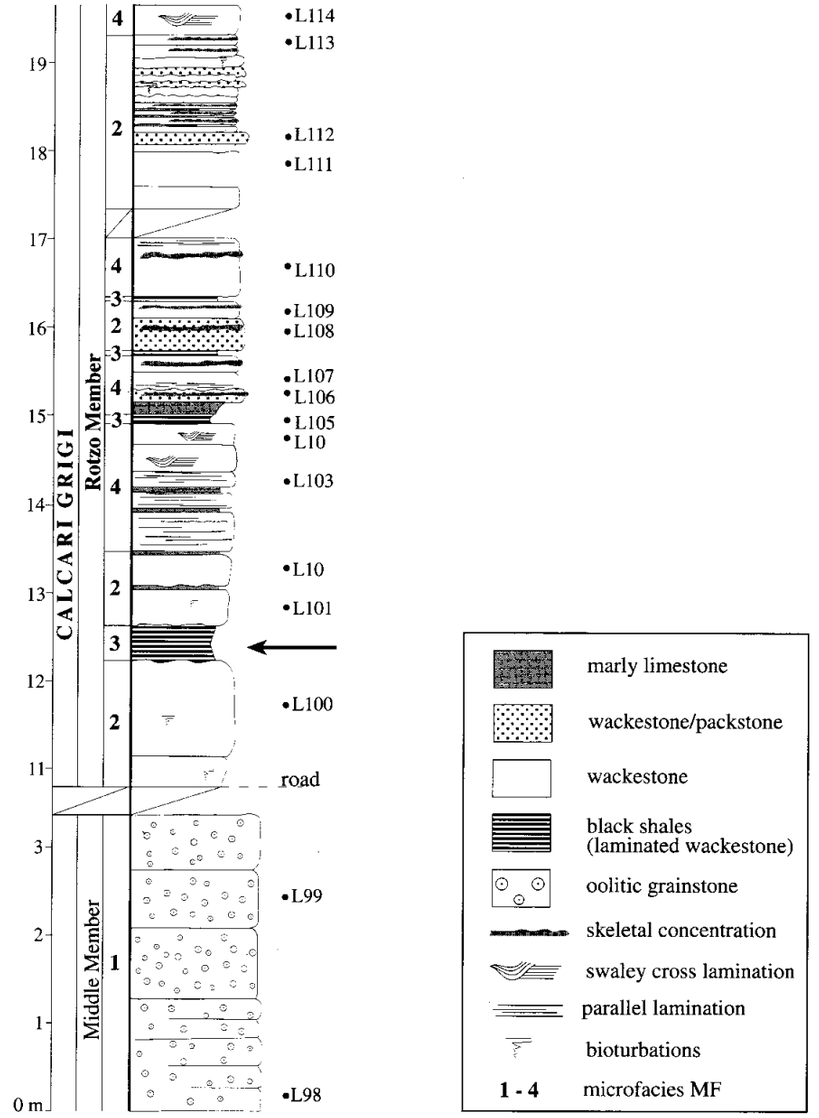


Fig. 3 - Stratigraphical section at Malga Zonta showing the studied horizon (arrowed).

*MF3: ostracod-bivalve black shales* – Micro-laminated wackestone-packstone, mainly dark-grey in colour and strongly fissile, slightly marly (90% $CaCO_3$) and rich in organic matter. Skeletal allochems are primarily small, thin heterodont bivalves and ostracods (Fig. 4 c). Bivalves are closely packed and concentrated in laterally continuous packstone pavements (*sensu* Kidwell *et al.*, 1986) which are about 300 mm thick (approximately one shell thickness). The pavements consist of small sized disarticulated shells and shell fragments. Some of these pavements are dominated by small shells in association with abundant ostracods. The accessory components are plant remains (roots, cuticles, spores) which are often encrusted with pyrite. Groups of packstone pavements alternate with groups of wackestone pavements.

*MF4: bioclastic wackestone/packstone* – Bioclastic skeletal packstones (Fig. 4 d), locally grading into wackestones, sometimes intercalated with thin millimetre-scale marly horizons. Peloidal grainstones may occur within the packstones. The primary components are bioclasts which consist mainly of disarticulated bivalves and brachiopods. Subordinately small gastropod and crinoid fragments are present. Ostracods are abundant at certain intervals, and occur as valves or carapaces. Concentrations of peloids, bioclasts and micritic intraclasts also occur. Bioclasts are often arranged in layers at millimetre and centimetre scale. Sedimentary structures include swaley cross laminations (parallel and low angle laminations). MF 4 differs from MF 2 mainly in having well preserved sedimentary structures.

## TAPHONOMIC ATTRIBUTES

In the black shales, shell accumulations occur in pavements in which most shells are convex-upward; some specimens may occur in convex-up 'butterfly'-preservation (*sensu* Aberhan, 1994; Pl. 1, Fig. 4).

The degree of packing ranges from matrix supported (Pl. 1, Fig. 4) to shell supported (Pl. 1, Fig. 1, 2) with the latter dominating. In many cases the compaction led to deformation and fracturing of shells (Pl. 2, Fig. 2, 3).

No shells show evidence of boring or encrustation. Signs of abrasion are rare and broken shells usually exhibit sharp edges. Large variations in size among individuals, good preservation and occasional convex-down patterns of shell orientation were recorded (Pl. 1, Figs 1, 2). Other features include, in some pavements, a high degree of fragmentation of the delicate bivalve and ostracod shells (Pl. 1, Fig. 3), and the preferentially concordant (parallel to bedding; Fig. 4 c) orientation of valves.

The taphonomical attributes indicate that ostracod-bivalve shell concentrations formed on the soft substrate in quiet conditions since the shell preservation and



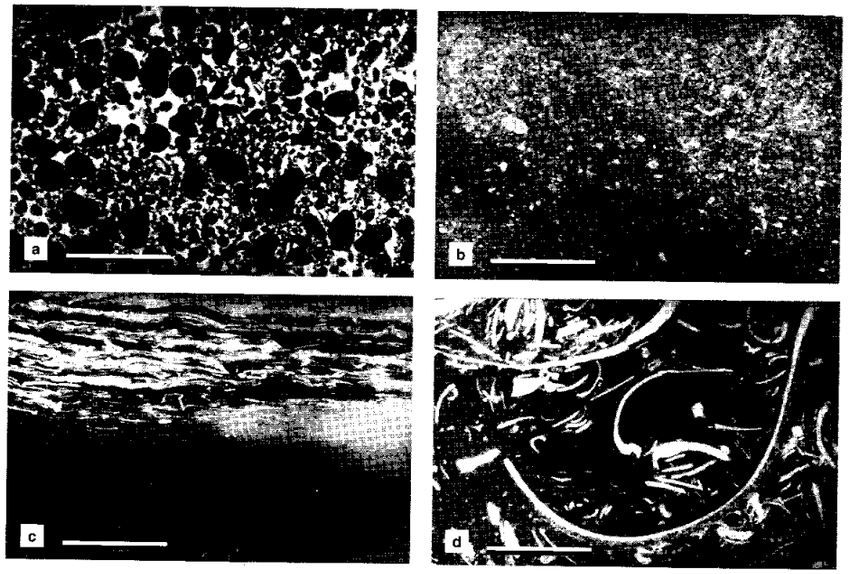


Fig. 4 - Microfacies from the base of the Lower Liassic Rotzo Member in the study profile, Malga Zonta (Tonezza).

a: MF1, oolitic peloidal grainstone; oolites are principally micritized; scale bar = 3 mm.
b: MF2, ostracod wackestone/packstone; scale bar = 3 mm.
c: MF3, micro-laminated black shale wackestone-packstone; closely packed skeletal allochems are primarily small, thin heterodont bivalves; scale bar = 5 mm.
d: MF4, bioclastic skeletal packstones with disarticulated and partly broken thin shells; scale bar = 5 mm.

their orientation indicate a lack of wear and suggest only occasional rapid winnowing. This short-term hydraulic turbulence was episodic and did not involve significant transport. Weakly corroded and thinned aragonitic shells in the black shales may indicate partial solution in low $O_2$ and free $H_2S$ conditions. Despite the shells being very thin, only the outermost surface is weakly corroded. Therefore the low degree of corrasion (*sensu* Brett & Baird, 1986) of the shells suggests short exposure time and/or very low turbulence.

The taphonomic signatures point to a parautochthonous deposit. Relatively high rates of sedimentation in the upper part of the section (see MF 4) apparently prevented formation of thick shell beds, while lower sedimentation rates in the lower part (MF 3) led to concentration of organic remains even prior to occasional rapid winnowing.

According to the classification scheme for oxygen-restricted biofacies (ORB) proposed by Allison *et al.* (1995), ORB 4 is suggested for the bivalve-ostracod black

*serradensis* Tausch, *Eomiodon gardeti* Mongin) similar to those molluscs described herein. Since the *Eomiodon* species are characterized by a broad intraspecific variability (Mongin, 1967), without examination of the type collections it is not possible to clarify the taxonomic position of this taxon, hence the *Eomiodon* specimens are left in open nomenclature.

### *Palaeoecology*

*Eomiodon* is a shallow infaunal suspension-feeding form of soft substrates and is considered a marker of brackish and shallow water environments (Casey, 1955; Hallam, 1976). More in detail, during the Jurassic and Early Cretaceous, it represents a guild of mesohaline (5-18‰) and brachyhaline (18-30‰) (Fürsich, 1994; Aberhan, 1994) or low mesohaline to oligohaline (0.5-5‰) regimes. This latter salinity regime is proposed when *Eomiodon* is represented by small sized shells and is the dominant component of an almost monospecific assemblage (Holzapfel, 1998), as in the present assemblage.

Taphonomic signatures (see above) suggest that the *Eomiodon* sp. association may also be controlled by low dissolved oxygen levels. However, this genus has not previously been considered to be among the Jurassic taxa adapted to oxygen-limited environments.

### ?MYRENE *SP.*

This bivalve is very rare in the assemblage, with only three right valves recorded. The valve has a subtrigonal outline, about 9 mm long, with a strong posterior carina. The sculpture consists solely of growth lines. The hinge is not preserved, therefore the generic determination is uncertain.

### *Palaeoecology*

The genus *Myrene* is generally considered to comprise shallow-water, infaunal, suspension-feeding species which often inhabited brackish environments (i.e. *M. hannoverana*) (Aberhan, 1994; Fürsich, 1994). In the lower Bathonian of the Causses, *M. raristriata* is an opportunistic, strongly eurytopic species with a wide salinity tolerance: it inhabited both mesohaline-oligohaline and hyperhaline environments (Fürsich *et al.*, 1995). Of course, this palaeoecological data cannot be directly applied to the present taxa because of their uncertain generic position.



### *ISOGNOMONID, GEN. IND.*

This taxon is represented by two multivincular, edentolous, right valves, about 12 mm high, with a subrectangular outline (Pl. 1, Fig. 2). The shell wall is thin and has an outer calcitic layer. The generic determination of this Isognomonid is uncertain because our isolated, small sized right valves do not allow us to define if the shell was equi-or inequivalve, which is an important taxonomic characteristic in differentiating Isognominid genera of the Rotzo Member (e.g. *Gervilleioperna*, *Lithioperna* and *Mytiloperna*; Benini & Loriga, 1974; Broglio Loriga & Posenato, 1996). The small size of the valves also hinders the systematic determination, as the Isognomonids systematic determination is generally possible only for the adults and large individuals.

### *Palaeoecology*

The mode of life of our individuals is not ascertainable with certainty, therefore the behaviour of this filter-feeding bivalve may have ranged from epibyssate to semi-infaunal endobyssate, with the commissure plane perpendicular (othothetic) or horizontal (pleurothetic) to the substrate (Seilacher, 1984; Broglio Loriga & Posenato, 1996).

The Isognomonidae are considered by Fürsich (1994) to mark brachyhaline (18-30‰) conditions in which the abundance of Neomiodontid bivalves strongly decreases.

In conclusion, the bivalve faunal characteristics point to soft substrates in a shallow water environment, mostly controlled by very low degree of salinity. The almost monospecific composition of the association and the small size of the individuals suggest a low mesohaline to oligohaline regime. This protected and restricted marginal marine environment was thus subjected to important influx of freshwater. The occurrence of rare allochthonous oligohaline bivalves, such as Isognomonids, indicates that the connection with higher salinity environments was very limited.

## OSTRACODS

The ostracod assemblage recovered from the first black shale horizon at the base of the profile (Fig. 3) is unique.

The assemblage is dominated by a single taxon (dominance of over 95%), which we consider to be closely related to the Jurassic-Cretaceous non-marine genus

*Fabanella* (Boomer *et al.*, in prep.). Two other ostracod species are recognised in the sediments. A new species possibly related to the Jurassic fresh-brackish water *Klieana* marks the earliest known record of this genus, hitherto unknown prior to the Bajocian. The remaining ostracod taxon is assigned to the extant genus *Limnocythere* which is thought to range from the Triassic to the Recent and is generally indicative of oligohaline conditions (Whatley & Moguilevsky, 1998).

The absence of any recognised marine Liassic ostracod taxa indicates that the sediments were deposited in a non-marine setting. An oligohaline environment is evidenced by the generic composition of the ostracod assemblage and the lack of foraminifera in the same samples.

The high abundance and dominance of a single species suggests 'stressed' conditions, possibly a reflection of low (and/or fluctuating) salinity or low dissolved oxygen levels although other environmental factors such as substrate and temperature will have been important.

## CONCLUDING REMARKS

The upper-Sinemurian-Carixian faunal assemblage from the black shales at the base of the Rotzo Member is characterized by a very low richness and high abundance of opportunistic benthic species adapted to brackish environment (from low mesohaline to oligohaline regimes).

The absence of euhaline taxa, such as brachiopods and crinoids, suggests a restricted environment without direct connection to marine water influx. Only small connections with brachyaline habitats, documented by allochthonous light Isognomonid valves, could exist.

High terrestrial organic matter supply and high primary productivity related to seasonal phytal blooms produced dysaerobic bottom conditions.

This restricted environment, probably a relatively large and deep pond in a lagoonal system, was subjected to relatively weak water movement (possible shallow wind driven waves) with relatively low energy winnowing which resulted in minimal transport and sorting.

ACKNOWLEDGEMENTS.

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## RIASSUNTO

*Associazione faunistica e paleoambiente di black shales d'acqua bassa nell'area di Tonezza (Calcari Grigi, Giurassico inferiore, Alpi Meridionali).*

PAROLE CHIAVE: Black shales, Microfacies, Bivalvi, Ostracodi, Tafonomia, Geochimica, Giurassico inferiore, Lias, Veneto, Italia nordorientale.

I Calcari Grigi sono una potente formazione carbonatica di piattaforma depositatesi durante il Giurassico inferiore (Liassico; Hettangiano-Pliensbachiano) su gran parte della Piattaforma di Trento (Italia nord-orientale). Questa formazione è suddivisa in quattro membri: Membro Inferiore, Membro Medio, Membro di Rotzo e Membro di Massone. Il Membro di Rotzo, costituito da vari litotipi carbonatici e da frequenti livelli marnosi talora ricchi di vegetali e bivalvi rappresenta l'unità maggiormente nota dal punto fossilifero. Nell'ambito di questo membro sono stati recentemente segnalati livelli a black shales presenti in varie località ed in differenti livelli stratigrafici. Tali livelli sono caratterizzati da una fauna a bivalvi e ostracodi ben preservata, precedentemente sconosciuta e dalla presenza di materia organica.

Uno studio paleontologico integrato su questi depositi di black shales è stato sviluppato nell'area di Tonezza del Cimone, in provincia di Vicenza (Veneto). L'analisi dei black shales ha riguardato la tafonomia dell'associazione faunistica, la caratterizzazione geochimica della materia organica e la determinazione dei bivalvi e degli ostracodi.

I caratteri tafonomici indicano che le concentrazioni conchigliari si formarono in condizioni di basso idrodinamismo. Le conchiglie erano occasionalmente rielaborate da deboli correnti di fondo e, dopo un trasporto limitato, concentrate in accumuli talora gradati. Il basso grado di corrosione ed abrasione indica un tempo di esposizione sul fondale di breve durata.

L'alto contenuto in materia organica amorfa AOM è associato a frammenti di vegetali continentali. L'analisi della pirolisi evidenza la presenza di cherogene tipo IIb (materiale fitoclastico) indicativo di acque di fondo leggermente ossigenate.

L'associazione a bivalvi è oligotipica ed è costituita da soli tre taxa: *Eomiodon* sp., *?Myrene* sp. e Isognomonidi gen. indet. Fra questi, *Eomiodon* sp., che suggerisce condizioni di bassa salinità (da mesoaline ad oligoaline), è nettamente dominante. La fauna ad ostracodi è rappresentata da taxa non marini indicativi di un ambiente oligoalino. L'abbondanza e la dominanza di una singola specie, sia tra i bivalvi che tra gli ostracodi, suggeriscono condizioni bentoniche stressate imputabili alla scarsa ossigenazione e alla bassa salinità.

Il fondale di questo ambiente ristretto, probabilmente corrispondente ad un ampio e relativamente profondo stagno costiero, era soggetto a deboli correnti di fondo. Episodici eventi di maggiore intensità idrodinamica producevano, dopo un trasporto limitato, degli accumuli conchigliari leggermente gradati.

## ABSTRACT

During the Early Jurassic, a thick shallow water carbonate platform succession, the Calcari Grigi formation (Liassic; Hettangian-Pliensbachian), was deposited on the Trento Platform (north-eastern Italy). This formation is subdivided in four members the third of which (the Rotzo Member) is the best known as far as the fossil content is concerned. Black shale deposits are present in the shallow water

carbonate successions of the Rotzo Member. They occur in various localities and at different stratigraphical levels within the member. These shallow water black shales are characterized by a well preserved and previously unknown bivalve-ostracod fauna as well as the presence of organic material.

An integrated palaeontological analysis was performed on black shale deposits outcropping in the Tonezza del Cimone area (Vicenza, Veneto), concerning the taxonomy, taphonomy and geochemical characterization of the organic matter.

Taphonomic features suggest that shell concentrations of the black shales formed on soft subtrates in quiet conditions. The shells were occasionally and rapidly winnowed and deposited after minimal transport and sorting. The low degree of corrasion corresponds to short exposure time on the bottom. Micrite and clay supply was too low to dilute the shells which accumulated in dense pavements on the bottom.

The Rock-Eval pyrolysis analysis gives a Type IIb kerogen related to phytoclast material and characterizing weakly oxic bottom waters.

The oligotypic bivalve fauna is represented by three taxa: *Eomiodon* sp., ?*Myrene* sp. and Isognomonid gen. indet. Among them, small thin shelled *Eomiodon* sp., which suggests brackish environment, dominate the association. The oligotypic ostracod fauna consists of non-marine taxa which are indicative of an oligohaline environment. The high abundance and dominance of a single species points to 'stressed' benthic conditions. The low diversity bivalve-ostracod assemblage consists of short lived opportunistic benthic taxa.

The absence of euhaline taxa, such as brachiopods and crinoids, suggests a restricted environment without direct connection to marine water influx. Only small connections with brachyaline habitats, documented by allochthonous light Isognomonid valves, could exist.

High terrestrial organic matter supply and high primary productivity related to seasonal phytal blooms produced dysaerobic bottom conditions.

The bottom of this restricted environment, probably a relatively large lagoon system, was subjected to relatively weak currents and episodically influenced by winnowing which resulted in weak transport and sorting producing the benthic fossil assemblages observed.

KEY-WORDS: Black shales, Microfacies, Bivalves, Ostracods, Taphonomy, Geochemistry, Early Jurassic, Liassic, Veneto, north-eastern Italy.

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# PLATES

PLATE 1

Figs. 1-4 – Shell accumulations of *Eomiodon* sp., lower black shale horizon, lower Rotzo Member, Malga Zonta (Tonezza).

1, 2: A dense accumulation (about 4 mm thick), entirely constitute of disarticulated valves without matrix; lower (2) and upper (1) surface views of the same slab; x 1.5. The lower surface is covered by valves which, in average, are larger and unbroken with respect to those located on the upper surface where many shell fragments occur. The nearly concordant position of the valves, convex- down, and skeletal sorting suggests a winnowing mechanism of accumulation of a relatively high hydraulic energy. A right valve of Isognomonid is detectable on the lower left corner of Fig. 2 (arrow).
3: Upper surface of an accumulation in which well preserved valves are associated with worn specimens and shelly fragments; x 3.
4: A sparse valve concentration on the lower bed surface with two «butterfly» specimens on the lower left and upper right corners; x 1.5.

PLATE 1

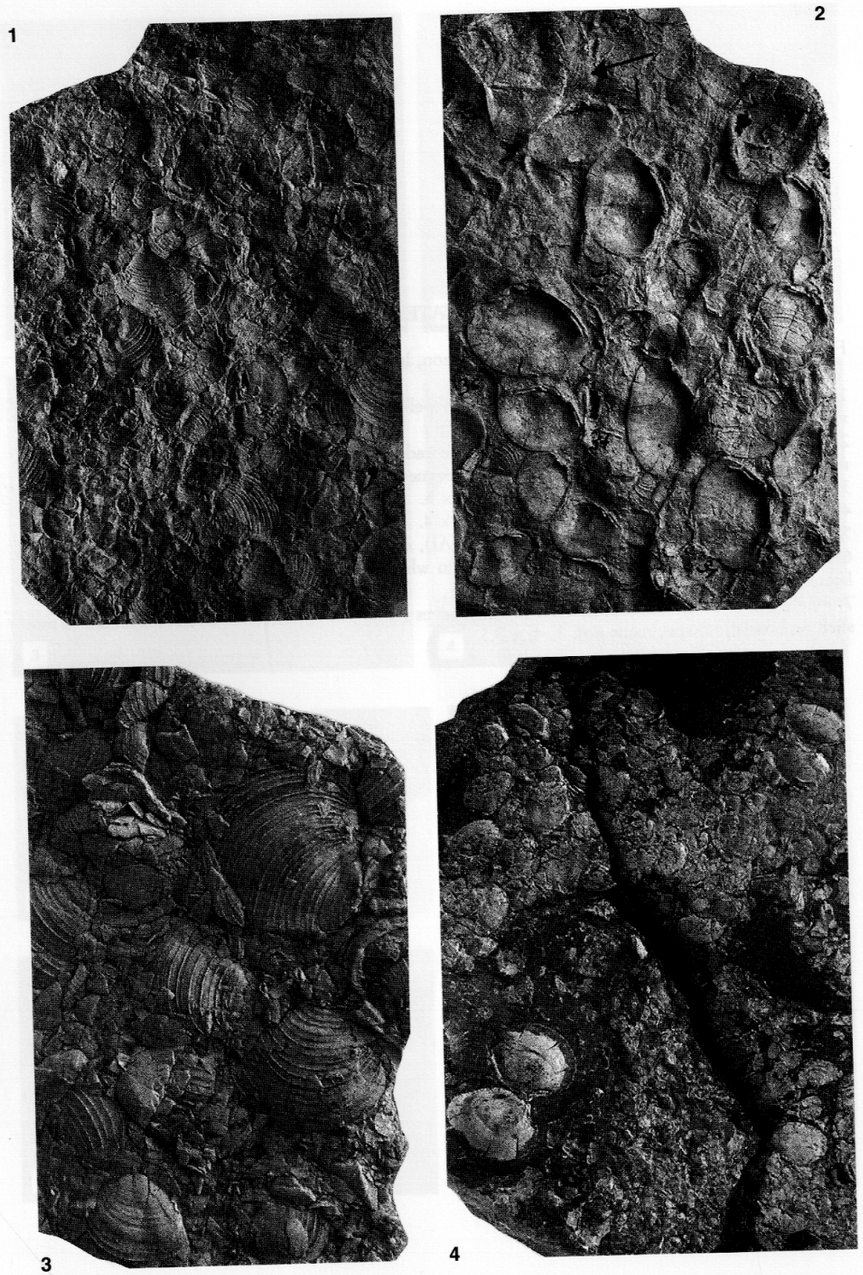

PLATE 2

Figs. 1-7 – *Eomiodon* sp., lower black shale horizon, lower Rotzo Member, Malga Zonta (Tonezza).

1: exterior view of a disarticulated right valve with well preserved concentric lamellae, specimen no. 70; x 4.
2: exterior view of a disarticulated left valve; the radial fracture on the umbo testifies a remarkable reduction of an original strong shell inflation, specimen no. 37; x 4.
3: interior view of a left valve, specimen no. 17; x 5.
4: interior view of a right valve, specimen no. 1; x 4.
5: detail of the crenulated anterior lateral tooth (AI), same specimen of Fig. 4; x 20.
6: detail of the umbonal region of a right valve in which a narrow furrow limits the lunule from the lateral surface, specimen no. 20; x 10.
7: inner view of a right (above) and left (below) valves on the lower surface of a relatively thick (5 mm) shell accumulation, specimens nos. 3, 4; x 3.5.

PLATE 2