Fabrizio Berra & Simonetta Cirilli

Palaeoenvironmental interpretation of the Late Triassic Fraele Formation (Ortles Nappe, Austroalpine Domain, Lombardy)

MILANO, 1997

Rivista Italiana di Paleontologia e Stratigrafia	volume 103	numero 1	pagine 53-70	Aprile 1997

PALAEOENVIRONMENTAL INTERPRETATION OF THE LATE TRIASSIC FRAELE FORMATION (ORTLES NAPPE, AUSTROALPINE DOMAIN, LOMBARDY)

FABRIZIO BERRA* & SIMONETTA CIRILLI°

Key-words: Austroalpine Domain, Late Triassic, stratigraphy, palynofacies.

Riassunto. La Formazione di Fraele (Norico superiore-Retico), costituita da alternanze di materiale terrigeno (argilliti e rare siltiti) e carbonatico (calcari, marne, rare dolomie), affiora nella Falda Ortles (Austroalpino centrale) in alta Valtellina. Questa formazione si differenzia nettamente dalla sottostante Dolomia del Cristallo (Norico), rappresentata da facies di piattaforma interna precocemente dolomitizzate, e dalla soprastante Formazione del Monte Motto (Lias), costituita da calcari e calcari marnosi con selce di ambiente pelagico. Sia il limite inferiore che superiore della Formazione di Fraele sono netti e non sono presenti facies di transizione.

L'analisi delle associazioni a foraminiferi e soprattutto dei palinomorfi ha permesso di datare con precisione la formazione al Norico superiore-Retico, mentre le analisi sedimentologiche, delle microfacies e delle palinofacies hanno permesso di caratterizzare dal punto di vista ambientale la Formazione di Fraele. In particolare è stata individuata la provenienza del materiale terrigeno da un settore cratonico con affioramenti prevalenti di rocce intrusive e/o ortometamorfiche (Europa). Dal punto di vista delle facies, è stata documentata una differenza tra le associazioni caratteristiche della Formazione di Fraele e quelle della Dolomia del Cristallo, evidenziando come il cambiamento ambientale non sia legato solo all'arrivo di materiale argilloso ma piuttosto ad un importante evento in grado di modificare sia la natura del sedimento che le associazioni faunistiche.

Lo sviluppo di nuove nicchie ecologiche è stato controllato da un mutamento paleoclimatico che ha favorito una differenziazione degli organismi: le conseguenze di questo cambiamento sono registrate dalle differenti caratteristiche delle comunità di organismi presenti nelle facies dolomitiche della Dolomia del Cristallo e nelle facies calcareo argillose della Formazione di Fraele. La variazione climatica si sarebbe manifestata con un aumento della piovosità (soprattutto sul settore continentale) in grado di innescare la mobilizzazione ed il trasporto di grandi quantità di materiale argilloso e di acqua dolce verso le zone costiere del golfo della Tetide. L'arrivo nel bacino di grossi quantitativi di acqua dolce ha avuto il duplice effetto di ridurre drasticamente i tassi di salinità e di innescare una stratificazione della colonna d'acqua. Un controllo climatico regionale sull'evoluzione stratigrafica, potrebbe spiegare l'improvviso fenomeno dell'arrivo delle argille e la presenza di potenti successioni calcareo-argillose registrate a livello regionale nei diversi domini paleogeografici del settore europeo della Tetide (Austroalpino, Sudalpino, Appennini, Ungheria, Polonia, Slovacchia etc.).

Abstract. The Fraele Formation crops out in the Ortles Nappe (upper Valtellina, Northern Italy), structurally part of the Central Austroalpine Domain. It consists of fine siliciclastics alternating with carbonates, mostly limestones, rare dolostones and marls. The nature of the siliciclastics indicates a cratonic source area (Europe), where intrusive and/or orthometamorphic rocks were being eroded. The formation differs lithologically from the underlying Norian Dolomia del Cristallo, represented by early-dolomitised inner platform facies, and the overlying Early Jurassic Monte Motto Formation which consists of cherty and marly limestones deposited in a pelagic setting. The upper and lower boundaries of the Fraele Formation are sharp.

Foraminifer and palynomorph assemblages from the Fraele Formation indicate a Late Norian to Rhaetian age.

The sedimentary facies and faunal associations of the Fraele Formation differ from those of the underlying Dolomia del Cristallo because of different paleoenvironmental evolution. The change in environmental parameters was controlled mainly by a climatic change to more humid conditions. This favoured on one hand the mobilisation and transport by rivers of siliciclastic material from the continent to the Tethys gulf, and on the other influenced the sea-water chemistry. Freshwater influxes lowered salinity and inhibited early dolomitisation. Input of low density freshwater resulted in the establishment of a permanent water mass stratification which influenced the benthic life.

This paleoenvironmental reconstruction fits with the sudden clastic input which occurred in several palaeogeographic domains of the western Tethys realm (Austroalpine, Southalpine, Apennine, Hungary, Poland, Slovakia) during the Late Norian.

Introduction.

The Ortles Nappe belongs structurally to the Central Austroalpine (Fig. 1) which represented, during the Early Jurassic, part of the outermost portion of the southern margin of the Penninic ocean. Alpine tectonics strongly affected this part of Adria and resulted in the development of overthrust tectonic units. The Ortles Nappe consists entirely of deformed sedimentary rocks, ranging in age from Norian to Turonian (Caron et al., 1982). Only locally are thin slices of older sediments preserved.

* Dipartimento di Scienze della Terra, Via Mangiagalli 34, 20133, Milano. Present address: Servizio Geologico Regione Lombardia, Via Fabio Filzi 22, 20124 Milano.

° Dipartimento di Scienze della Terra, Piazza dell'Università, 06100, Perugia.

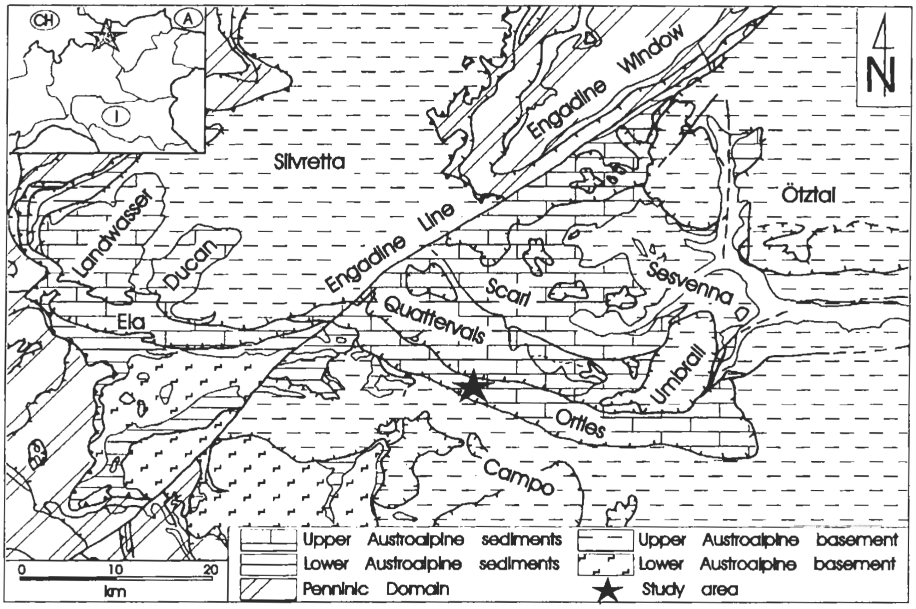


Fig. 1 - Tectonic setting of the Central Austroalpine Domain and surrounding units.

The subject of this study is a sedimentary formation in the Ortles Nappe: the Kössen or Fraele Formation which consists of about 300 m of interbedded limestones and dark shales. The term "Kössen Formation" (or Kössen Beds or Kössen Schichten) is a regional name used for uppermost Triassic successions in the Austroalpine Domain and nearby areas (i.e. Hungary, Slovakia, Poland, etc.), whereas "Fraele Formation" was proposed for the succession of the Ortles Nappe (Pozzi, 1959; Pozzi & Gelati, 1965). In this paper, the latter name is used, because the sections studied are in the type area of the Fraele Formation. For the same reason, local terms proposed for the succession of the Ortles Nappe are used for the underlying and overlying units: the Dolomia del Cristallo (corresponding to Hauptdolomit or Dolomia Principale of the Southern Alps) and the Monte Motto (or Allgäu) Formation respectively (Fig. 2). Post-depositional tectonics strongly affected the sediments of the Ortles Nappe, in turn eliminating or repeating parts of the succession; minor and major faults developed in response to both Early Liassic extension during the opening of the Penninic Ocean (Eberli, 1988; Froitzheim, 1988) and to later Alpine orogenesis.

The Fraele Formation lies on the Dolomia del Cristallo (Fig. 3), which represents part of the early dolomitised inner carbonate platform which formed during most of the Norian, in the inner part of Tethys. This wide carbonate platform was bordered to the east by a marginal facies (the Dachstein Limestone) which passed seaward in the basinal Hallstatt Limestone. The Fraele Formation records an environmental change related to the end of inner platform evolution. The shallow-water sediments of the upper Fraele Formation are overlain by deep-water, thin-bedded cherty limestones (Monte Motto Formation) which are interpreted as syn-rift deposits related to the Early Jurassic opening of the Penninic Ocean (Eberli, 1988).

Late Triassic shaly input has been recorded in other areas of Tethys (Southern Alps: Gnaccolini, 1965a; Masetti et al., 1989; Lakew Tesfaye, 1990; Jadoul et al., 1994; Austroalpine: Furrer, 1981, Golebiowski, 1990; Hungary: Haas, 1993; Poland and Slovakia: Gazdzicki, 1974, Gazdzicki et al., 1979; Northern and Central Apennine: Ciarapica & Passeri, 1980; Ciarapica et al., 1982; Fazzuoli et al., 1988, Cirilli et al., 1993; 1994).

The aims of the present study of a succession belonging to the Ortles Nappe are to integrate the results of sedimentological and palynological analyses, in order to identify the source of siliciclastic material and to explain the abrupt start of fine grained clastic sedimentation along the southern side of the Tethys gulf.

Stratigraphy.

Lithofacies.

The Fraele Formation (Fig. 4, 5) crops out irregularly along an east-west belt, from the Engadine Line to the Stelvio Pass. Toward the east, Alpine deformation completely overprinted original sedimentary structures. The Fraele Formation consists predominantly of limestones and marls with rare dolostones, alternating with fine-grained siliciclastic material consisting mostly of shales and siltstones (Fig. 6, 7).

Four discontinuous and interfingering members were recognised in the Fraele Formation by Furrer (1981).

Above the early dolomitised facies of the Dolomia del Cristallo (Fig. 8a) shaly intervals (Alpihorn

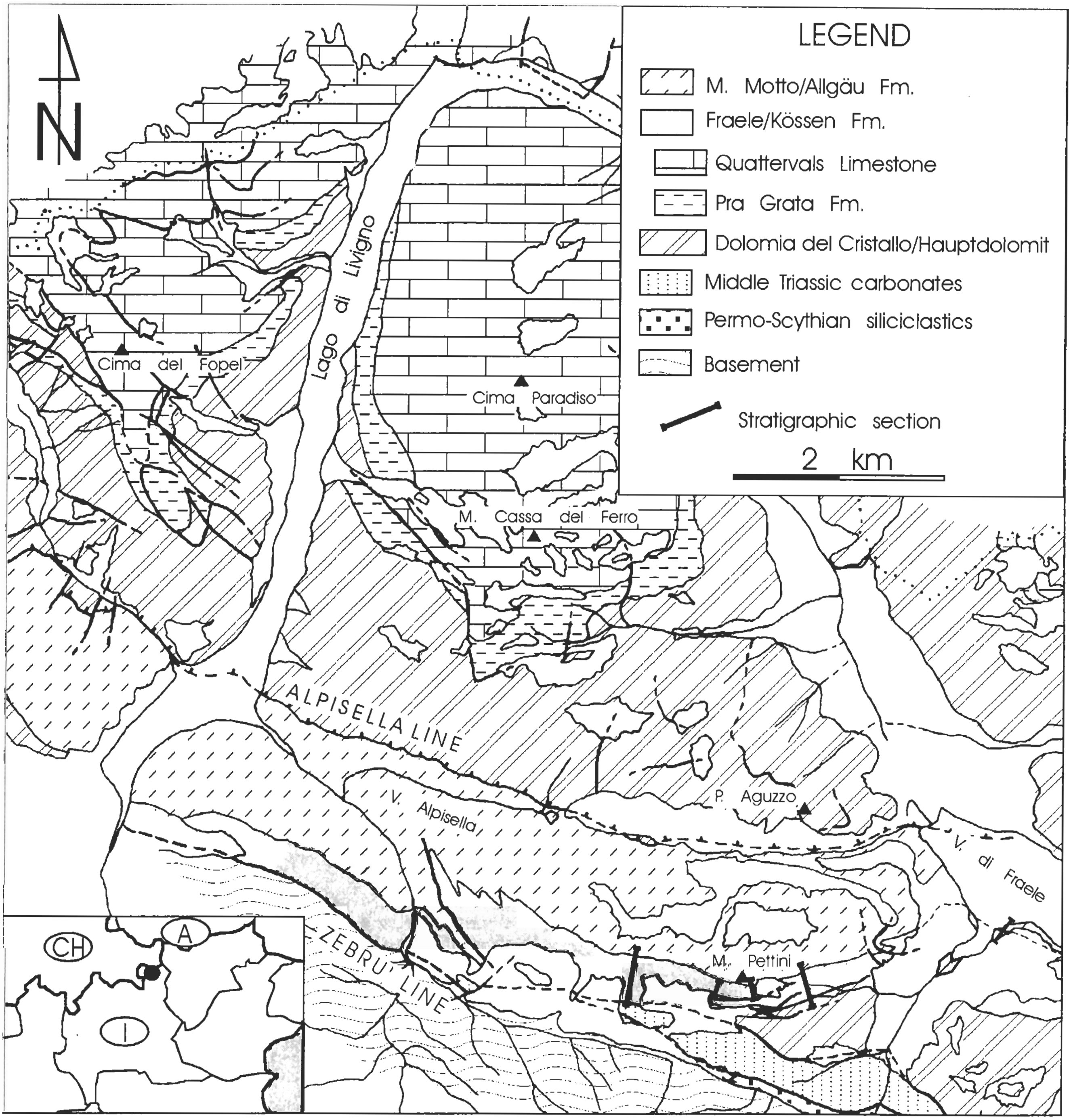


Fig. 2 - Geological map of the study area from 1:10000 field surveying.

Member; Furrer, 1981) clearly mark the base of the Fraele Formation. Siliciclastic input was sudden as no terrigenous sediment occurs in the highest few metres of the underlying Dolomia del Cristallo. The shales in the Alpihorn Member are black and locally reddish and contain limonite and pyrite. The thickness of the shaly intervals ranges from 20-30 cm up to 2 m. Centimetric layers of siltstones to very fine sandstones, locally hybrid (Fig. 8c), are present in the lower Fraele Formation and commonly show low-angle cross laminations disturbed by burrowing (Fig. 7a; 8b). Quartz and less common feldspar are the main constituents; tourmaline, zircon and rare rutile grains, together with opaque minerals, are also present.

Siliciclastics alternate with bioclastic and intraclastic calcarenites and calcirudites are common. Bivalves, gastropods, foraminifers, brachiopods, echinoids and fish scales were recorded. Beds are from few centimetres to 30-40 cm thick, often amalgamated and locally with erosional bases. Graded bioclastic layers are common. Sedimentary structures and facies in the limestones record resedimentation from a nearby carbonate platform,

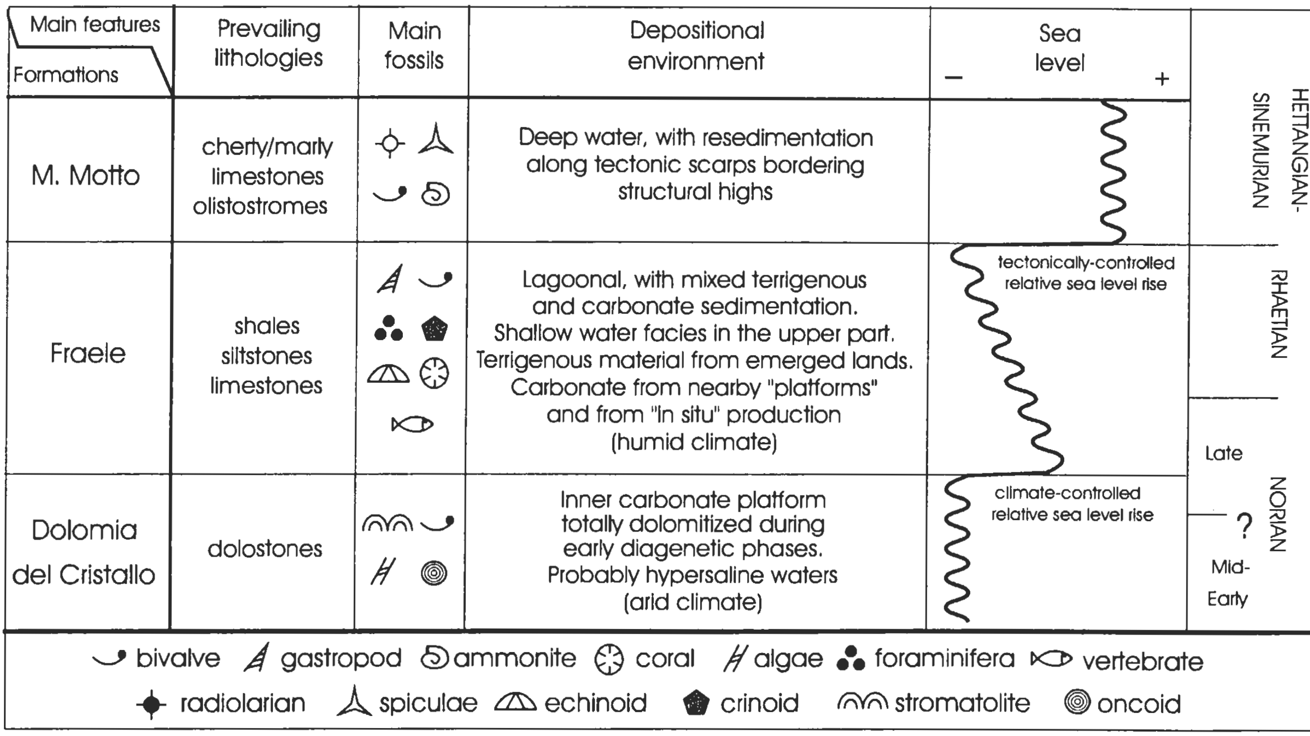


Fig. 3 - Comparison of the main characteristics of the Fraele Formation with those of the Dolomia del Cristallo (below) and Monte Motto Formation (above).

which had a faunal content and facies different from those of the Dolomia del Cristallo (Fig. 8d).

Carbonate content increases upwards through the section, whereas shales become less abundant (Chesaplana Member, Furrer, 1981). Fine-grained limestones, consisting of intraclastic-pellettiferous mudstone-wackestones in decimetric beds become more common. Limestones with monospecific assemblages of brachiopods (*Rhaetina gregaria* Suess; Fig. 9b) or pelecypods (*Rhaetavicula* sp. and other Pterioida) have been found. A minor shaly input is recorded by the overlying Ramoz Member (Furrer, 1981).

In the upper Fraele Formation (Mitgel Member; Furrer, 1981) carbonate production became an *in situ* phenomenon, and conditions changed from subtidal to shallow subtidal-intertidal. Shaly input was limited and carbonate sedimentation prevailed. Oolitic and bioclastic beds (Fig. 10a, b, c), locally showing cross and herringbone bedding (Fig. 7c), and decimetric laminated dolomitic beds become common. This situation can be ascribed to higher carbonate production which diluted the siliciclastics or, more probably, to a reduction of the amount of siliciclastics carried out from the land.

Coral boundstones (Fig. 9a), mainly with *Retiophillia* sp. encrusted by sessile foraminifers (*Tolypammina gregaria* Wendt, *Planiinvoluta* sp.), are abundant in the upper part of the formation and are intercalated with fine intraclastic-pellettiferous wackestone-packstones which yield a few small brachiopods. Megalodontids are present in life position. Light-grey calcarenites in metric beds, sometimes amalgamated, are present in the upper part of the Fraele Formation; some bioclasts are silicified (Fig. 7d).

The massive 6 to 10 m-thick Culmet Limestone (Fig. 4, 7b) which overlies the Fraele Formation (Furrer, 1981) is characterised by fine-grained packstones-wackestones with coprolites (*Paravafreina thoronensis)* and thin-shelled gastropods (Fig. 10d). Dolomitic decimetric nodules are common. Burrows both horizontal and vertical are common throughout the formation, vertical burrows commonly marked by Fe-rich horizons, indicate periods of lower sedimentation and development of hard ground surfaces.

The Culmet Limestone was probably deposited in the inner carbonate platform in an area protected from strong marine currents by oolitic bars and coral patch-reefs. Furrer (1981) separated the Culmet Limestone from the Fraele Formation. In this paper it is regarded as the product of the final stage in the shallowing-upward trend which controlled the depositional evolution of the Fraele Formation. The end of this shallowing is marked by the deposition of the deeper-water sediments of the Monte Motto Formation (Fig. 10e).

A *Chlamys*-bearing horizon (30-40 cm thick) just above the Culmet Limestone (Fig. 4, 7b) marks the beginning of the deepening of the sedimentary basin and predates deposition of the rift-related sediments of the Monte Motto Formation.

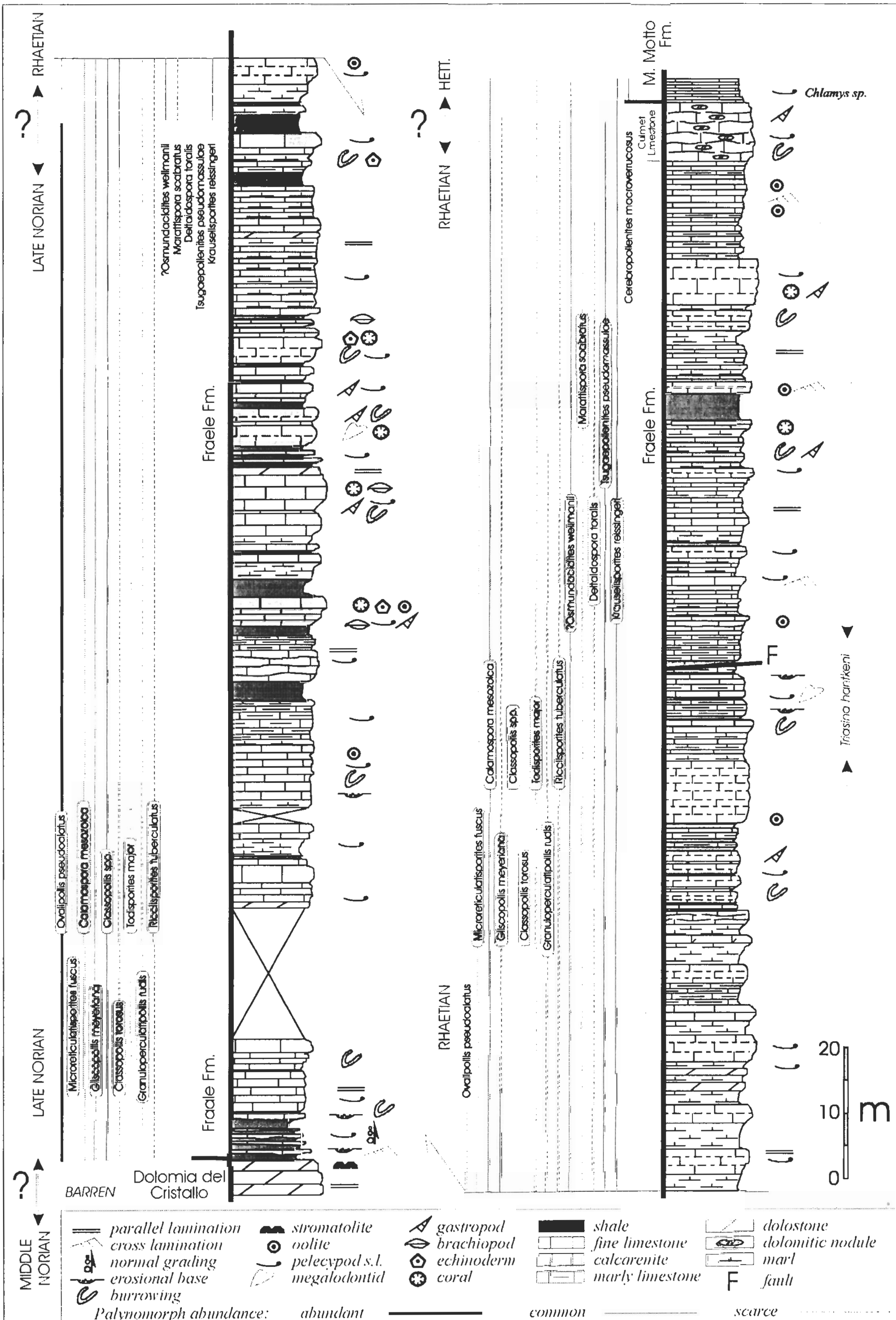


Fig. 4 - Stratigraphic section of the Fraele Formation, with the distribution of palynomorphs.

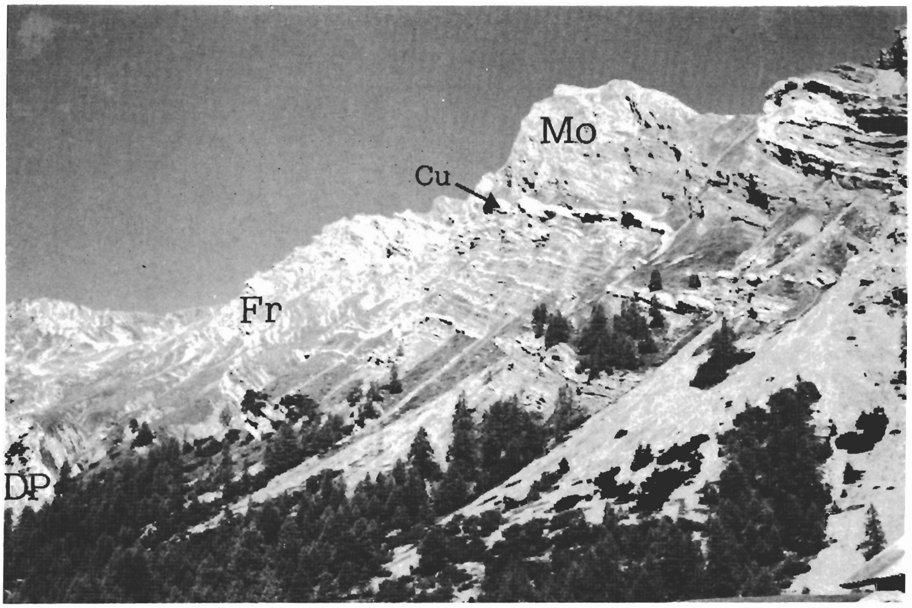


Fig. 5 - View of one of the studied sections of the Fraele Formation. DP: Dolomia del Cristallo; Fr: Fraele Formation (Cu: Culmet Limestone, uppermost Fraele Formation); Mo: Monte Motto Formation. The presence of the recumbent fold (on the right) testifies to the strong Alpine tectonic overprint.

Sediment sources.

Microfacies and palynofacies analysis of carbonates and shales led to considerations about the source areas of clastic sediments and about the rate of supply. The presence of two types of sediments, extrabasinal siliciclastics and mainly intrabasinal carbonates, indicates two different source areas. In the lower Fraele Formation, both siliciclastic and carbonate sediments are redeposited, whereas carbonate material higher in the formation

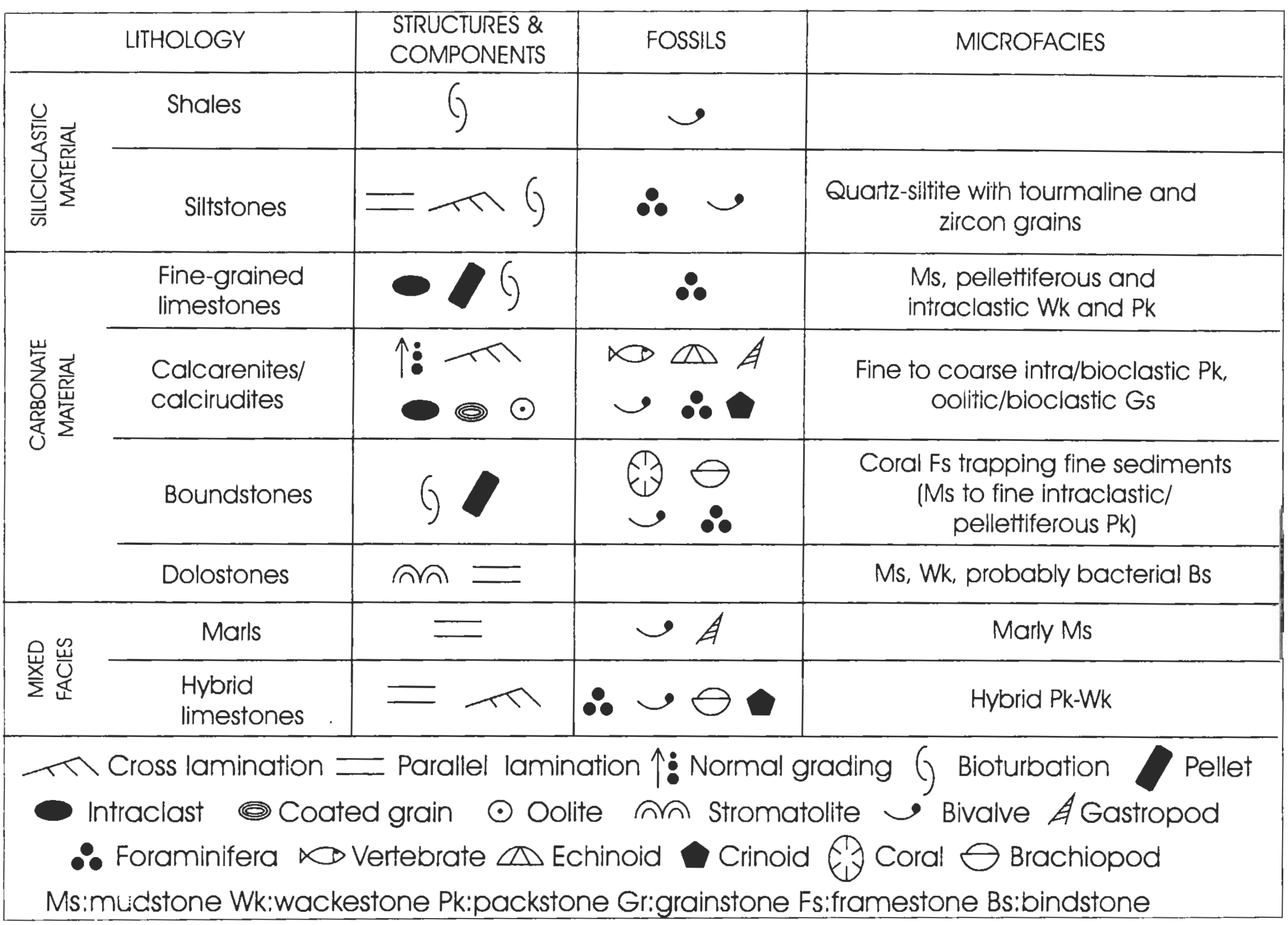


Fig. 6 - Main characteristics of the lithofacies of the Fraele Formation.

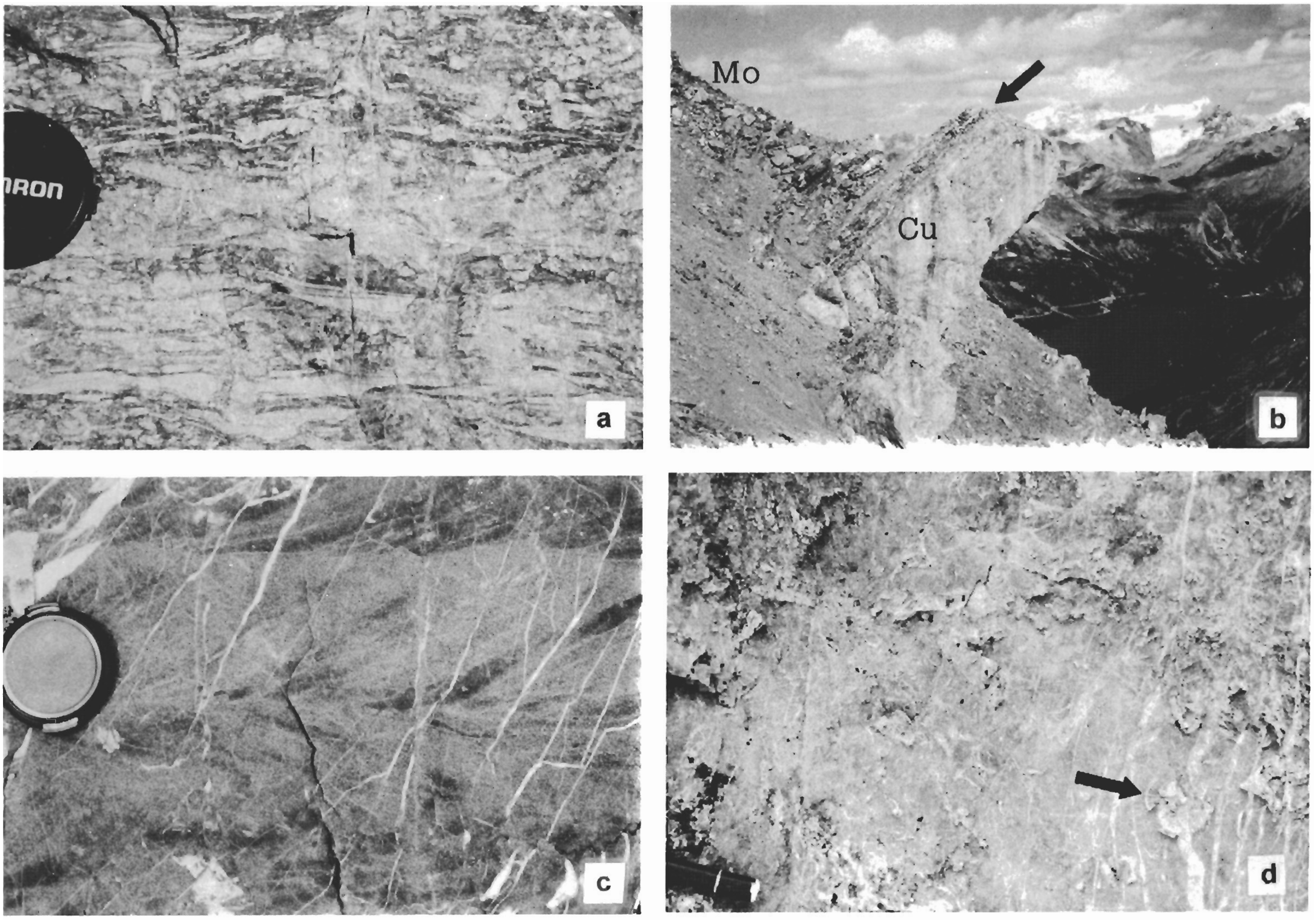


Fig. 7 - Facies and sedimentary structures of the Fraele Formation. a) Laminated and partly burrowed siltstones, lower Fraele Formation (cap is 52 mm large); b) Detail of the boundary Fraele Formation - Monte Motto Formation; the arrow points at the *Chlamys* bearing beds, marking the boundary between the two formations; Cu - massive Culmet Limestone, representing inner platform facies of the topmost Fraele Formation; c) Herringbone stratification of an oolitic deposit (cap is 49 mm in diameter); d) Silicification phenomena affecting bioclasts in the upper Fraele Formation (note the coral fragment).

is mostly the result of in situ production. Siliciclastics indicate a continental source area; grains consist largely of quartz, plagioclase, zircon, tourmaline and rutile (Fig. 8e) suggesting, because lacking of typical metamorphic minerals (i.e. garnet), erosion of a continental crust with outcrops of mainly intrusive or orthoderived rocks.

Palynofacies from the shaly intervals record a significant input of terrestrial organic components, represented mostly by humic fragments (inertinite and vitrinite) and palynomorphs. The presence of a considerable amount of *Botryococcus* sp. (Chlorococcale algae) (Fig. 11h, i) in the lower Fraele Formation confirms a continental source area for this material: most fossil and modern records of this algae are from freshwater lacustrine, fluvial, lagoonal and deltaic facies (Guy-Ohlson, 1992; Tyson, 1995).

Carbonate content shows the presence of nearby carbonate platform areas from which sediment was transported toward basins during the deposition of the lower Fraele Formation. Gradually, during filling of the basins, shallow water facies spread over previously basinal areas. The limestone microfacies and biofacies indicate that these materials did not derive from the Dolomia del Cristallo platform. Brachiopod, coral, echinoid and crinoid bioclasts which are almost absent from the Dolomia del Cristallo, here represent the most typical bioclastic content together with pelecypods and gastropods. This material has a provenance from a platform with ecological characteristics different from those of the Dolomia del Cristallo. The faunal associations appear more comparable with those of the Dachstein Limestone than with those of the Dolomia Principale.

Biostratigraphy.

A biostratigraphical study of the Fraele Formation was carried out using foraminifer and palynomorph assemblages (Fig. 4, 11).

The definition and even the existence of the Rhaetian stage is still matter of discussion (Ager, 1990; Tozer, 1990; Krystyn, 1990): in this paper, Krystyn's (1990) definition of Rhaetian as composed by two ammonoid zo-

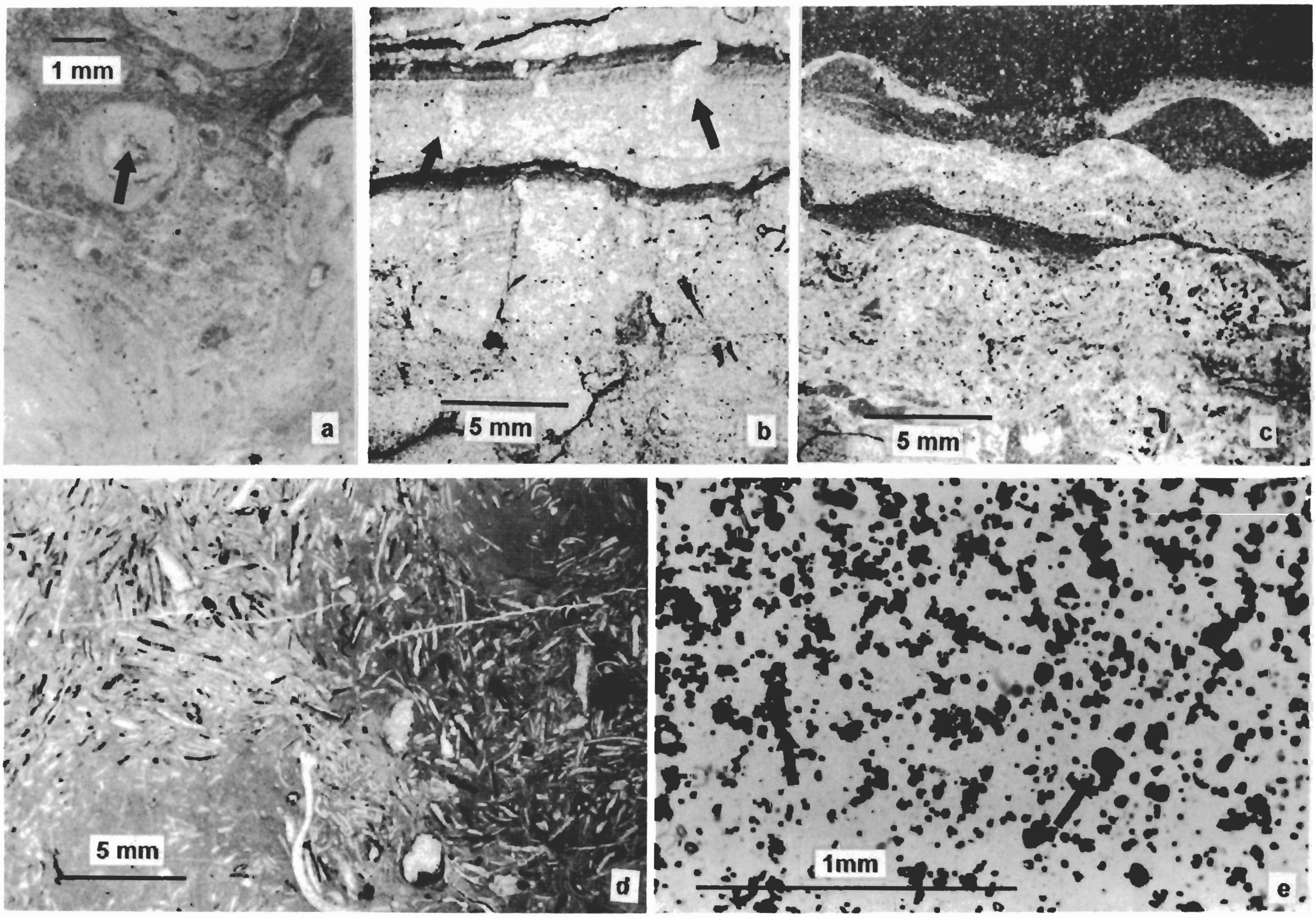


Fig. 8 - Microfacies from the uppermost Dolomia del Cristallo (a) and from the lower Fraele Formation (b-e). a) Oncolitic dolostone. The arrow points at some encrusting foraminifers (*Tolypammina gregaria* Wendt) at the nucleus of an oncolite; b) Laminated siltstone with borings (arrows); c) Hybrid calcarenite; oriented pelecypod shells suggest reworking by bottom currents; d) Bioclastic layer with chaotic orientation of the bioclastic fragments (burrowing?); e) Palynofacies of a silty layer. Note the well-rounded abundant inertinite (black) indicative of a prolonged transport and the presence of transparent minerals (arrows) mainly represented by tourmaline.

nes is adopted. The presence of the bivalves *Rhaetavicula contorta* (Portlock) and *Rhaetina gregaria* (Suess), which are well known throughout the Alpine area, suggest a Late Norian ?-Rhaetian age for the Fraele Formation.

Foraminifer assemblages from the lower Fraele Formation are characterised by monospecific assemblages of *Hoyenella inconstans* (Michalik, Jendrejakova & Borza). Specimens of *Aulotortus friedli* (Kristan-Tollmann), *A.* ex. gr. *communis* (Kristan), *A.* ex. gr. *tenuis*

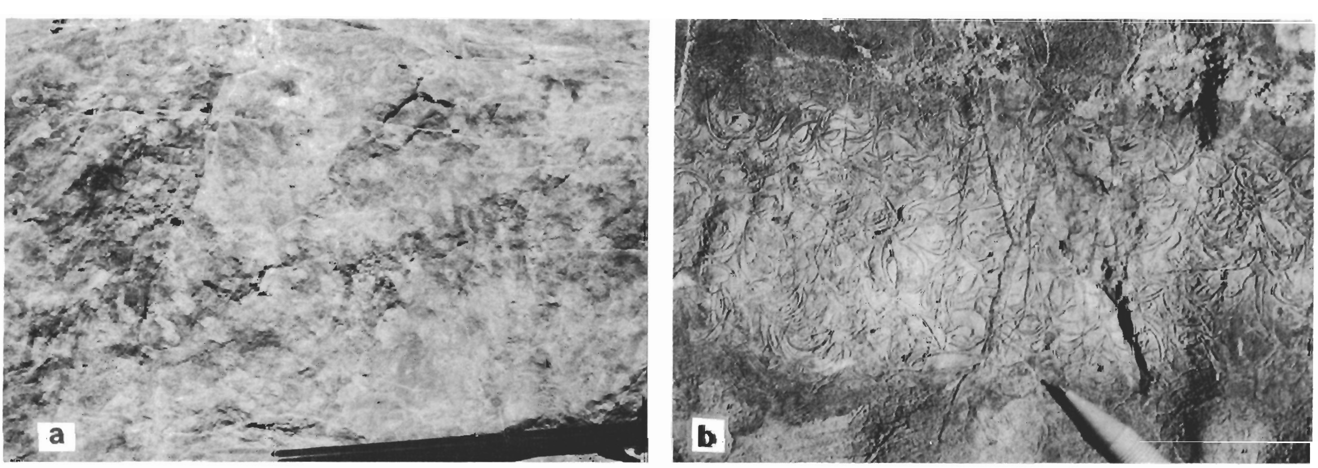


Fig. 9 - a) Coral limestones with a colony of *Retiophillia* sp. in life position in the upper Fraele Formation; b) Limestone bed containing a partly reworked monospecific assemblage of brachiopods (*Rhaetina gregaria* Suess).

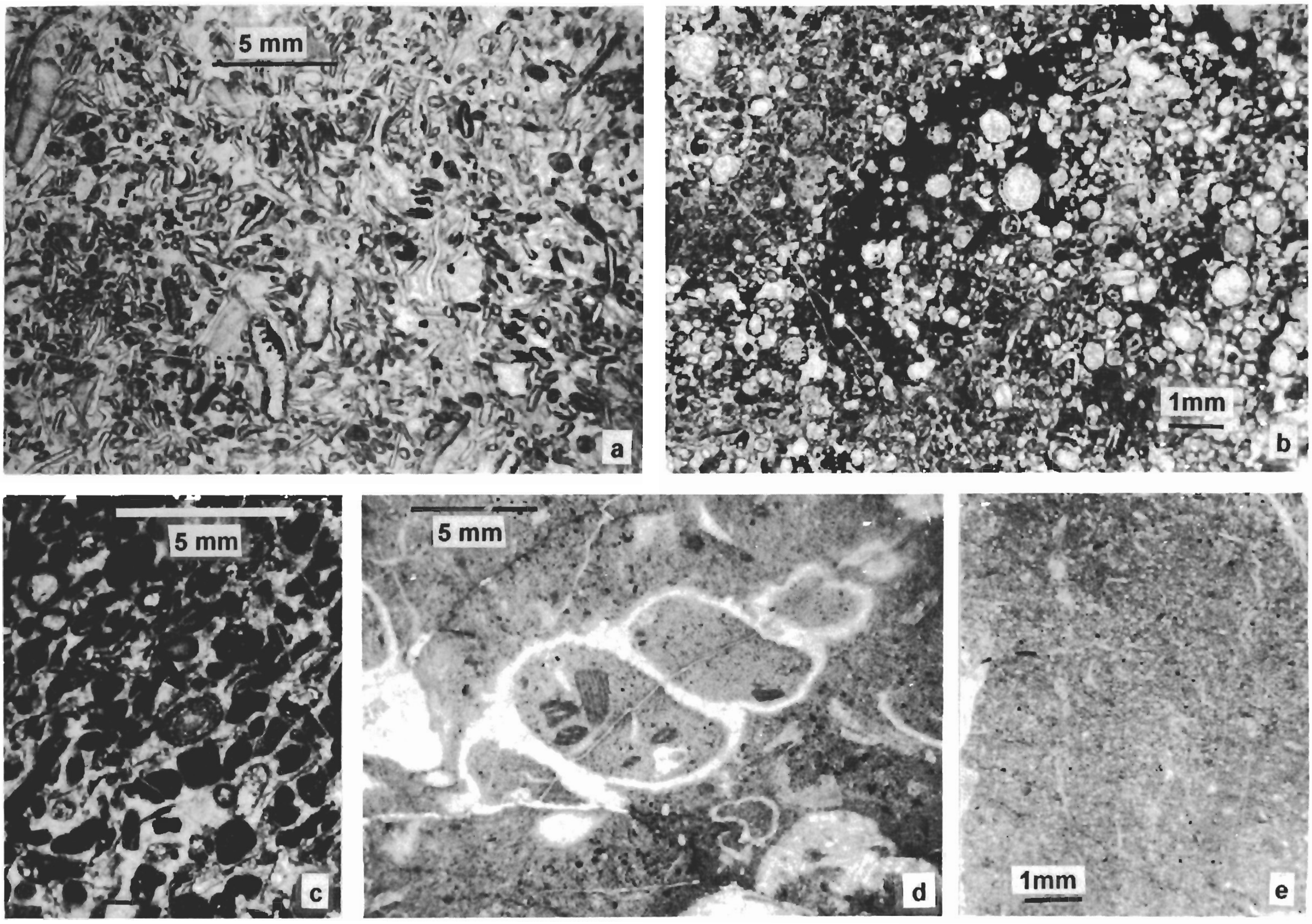


Fig. 10 - Microfacies of the middle and upper Fraele Formation. a) Bioclastic packstone with abundant coated and micritised grains; b) Bio-intraclastic packstone. Bioclasts are mainly represented by foraminifers of different species (mainly Aulotortids); arrows point to *Triasina hantkeni* Majzon; c) Intraclastic grainstone. Among the intraclasts, a deformed specimen of *Triasina hantkeni* Majzon is recognisable; d) Microfacies of the Culmet Limestone (topmost Fraele Formation). The occurrence of thin-shelled gastropods and fecal pellets records a low energy environment; e) Microfacies of the *Chlamys*-bearing bed at the passage Fraele Formation-Monte Motto Formation. Sponge spicules and probably radiolarians are common.

(Kristan), *Lamelliconus* sp., *Ammobaculites/Reophax* sp., Ammodiscidae and Trochamminidae become common in packstones of the middle-upper Fraele Formation where *Hoyenella inconstans* is less common. *Triasina hantkeni* Majzon has been found in oolitic and bioclastic packstones (Fig. 10b, c). *Tolypammina gregaria* Wendt and *Planiinvoluta* sp. are common within coral boundstones. The foraminifer distribution was probably influenced by increased carbonate production and by the change from subtidal to intertidal-subtidal conditions between the base and the top of the formation.

Palynological assemblages add more biostratigraphic data, despite relative high thermal maturity (Berra & Cirilli, in press) and resulting poor preservation of organic material. Only the most resistant palynomorphs can be observed, and assemblages may lack some elements, which are destroyed by thermal catagenesis. Therefore, quantitative study would be meaningless and only qualitative palynological study is possible. Nevertheless, general compositional changes in the assemblages through the Fraele Formation and the appearance of stratigraphically significant elements allow useful stratigraphic resolution. The main stratigraphic variation is shown by *Ovalipollis pseudoalatus* (Thiergart) Schuurman 1976 (Fig. 11a, b) the abundance of which decreases upwards through the section until it disappears. The decrease in abundance is not due to degradational processes, because resistance of this form to high thermal maturity, is documented in the Norian succession of the overlying Quattervals Nappe (Berra & Cirilli, in press). *Classopollis torosus* (Reissinger) Balme 1957 (Fig. 11g), *Gliscopollis meyeriana* (Klaus) Venkatachala 1966 (Fig. 11e), *Calamospora mesozoica* Couper 1958 (Fig. 11d) and *Microreticulatisporites fuscus* (Nilsson) Morbey 1975 (Fig. 11f) are present throughout the section with different percentages. Other significative taxa such as *Krauselisporites reissingeri* (Harris) Morbey, 1975, *Tsugaepollenites ?pseudomassulae*,(Mädler) Morbey, 1975, *Cerebropollenites macroverrucosus* (Thiergart) Pocock 1970, *Deltoidospora toralis* Lund 1977 and

?*Osmundacidites wellmanii* Couper, 1953 appear at different stratigraphic levels within the succession.

The presence of these taxa justify the assignment of this formation to the Norian-Rhaetian (Schuurmann, 1977, 1979; Orbell, 1973; Clement-Westerhof et al., 1974; Morbey & Neves, 1974; Morbey, 1975, 1978; Pedersen & Lund, 1980; Visscher et al., 1980; Fisher & Dunay, 1981; Visscher & Brugman, 1981; Whithaker, 1984; Baudelot & Taugourdeau-Lantz, 1986; Peybernes et al., 1988; Mettraux & Mohr, 1989; Warrington & Ivimey-Cook, 1990; Cirilli et al., 1994; Warrington et al., 1995; Warrington, 1996). Compositional variation in miospore assemblages through Fraele Formation allows recognition of two main palynomorph associations:

1. Lower association, characterised by *Ovalipollis pseudoalatus*, *Microreticulatisporites fuscus*, *Gliscopollis meyeriana*, *Calamospora mesozoica* and very rare specimens of *Classopollis torosus*. Scattered occurrences of *Todisporites major* Couper 1958, *Granuloperculatipollis rudis* Venkatachala & Góczán, 1964 (Fig. 11c) and *Ricciisporites tuberculatus* Lundblad 1954 are recorded. This association could be referred to the upper part of phase 3 of Schuurman (1979), interpretable as Late Norian (Sevatian). The lack of biostratigraphic data from the upper part of the underlying Dolomia del Cristallo prevents determination of the time in the Late Norian at which deposition of the Fraele Formation began, and whether a gap is present between it and the underlying beds.

2. Upper association, more diverse in composition. *Microreticulatisporites fuscus*, *Calamospora mesozoica*, *Classopollis torosus*, *Ricciisporites tuberculatus* are still present; *Granuloperculatipollis rudis* is rare and disappears in the upper part of the range of this association. The boundary with the lower association is marked by the appearance of *Krauselisporites reissingeri*, together with *Tsugaepollenites ? pseudomassulae*, *Deltoidospora toralis*, *Marattispora scabratus* Couper 1958 and ?*Osmundacidites wellmanii*. *Ovalipollis pseudoalatus* is very rare and disappears within the lower part of the range of the association. This association is referred to phase 4 of Schuurman (1977; 1979). The transition between the lower and upper assemblages may therefore correspond to the Norian-Rhaetian boundary (Fig. 4). The upper limit of the occurrence of the upper association is just above the Culmet Limestone, at the level of the appearance of the of *Cerebropollenites macroverrucosus*. This form suggests the beginning of phase 5 of Schuurman (1979) and, even though all taxa characteristic of that phase are not present, may mark approximately the Rhaetian-Hettangian boundary.

The highest occurrence of *Triasina hantkeni* has been observed 6 metres below the Culmet Limestone; between this level and that of the appearance of *Cerebropollenites macroverrucosus* no biostratigraphic data are available.

In the coeval succession of Southern Alps, the Triassic-Jurassic boundary probably falls within the Grenzbivalvenbank (Gnaccolini, 1965b), only few decimetres thick, placed just above the carbonate platform of the Dolomia a Conchodon (Allasinaz, 1992; McRoberts, 1994). If the *Chamys*-bed just above the Culmet Limestone (Fig. 7b) corresponds, as probable, to the Grenzbivalvenbank of Southern Alps it could therefore contain the Triassic-Jurassic boundary.

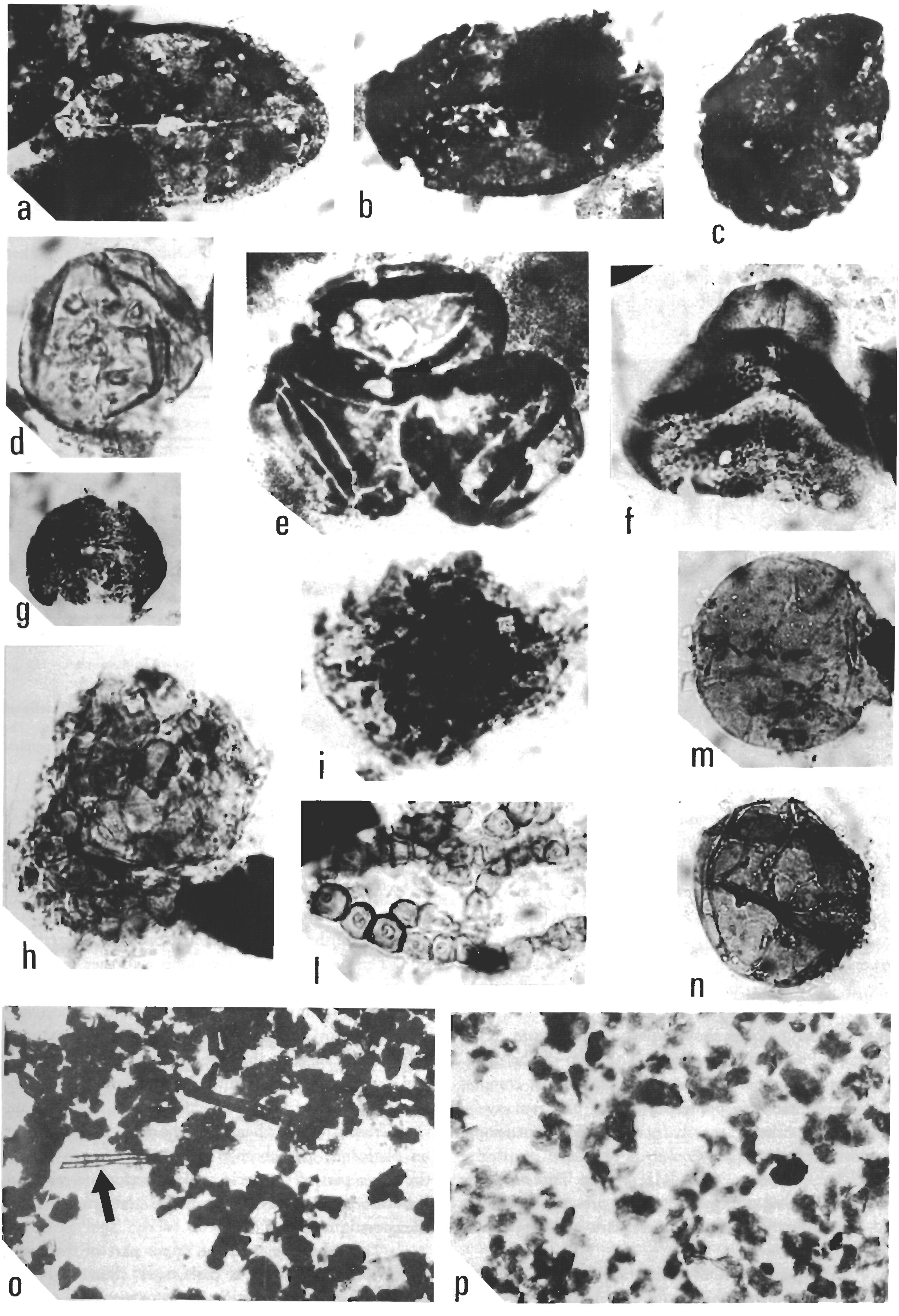
In this interpretation deposition of the Culmet Limestone was probably coeval with that of the Dolomia a Conchodon in the Lombardy Basin, which also represents the recovery of a shallow water carbonate platform free of siliciclastic pollution following the deposition of mixed sedimentation of the Zu Limestone (Jadoul et al., 1994). The Late Norian-Rhaetian sequence in the Lombardy Basin is generally thicker (up to 1500 m) than the Fraele Formation except on some structural highs where comparable thickness may occur (Jadoul et al., 1994).

Facies organisation.

Cyclic facies organisation was observed within the Fraele Formation. It is possible to recognise two different cycles: A-type cycles characterising the lower Fraele Formation and consisting of allocthonous material and B-type cycles with carbonate produced partly *in situ*, and characterising the middle and upper part of the formation.

The base of the Fraele Formation is characterised by the presence of five to seven shale-limestone metric cycles (A-type cycles, Fig. 12). A-type cycles were the subject of a detailed study of microfacies and organic matter, as well as calcimetric analysis. Samples were collected every 15 cm in shales and 30 cm in limestones (Fig. 13). Two main divisions of the cycles can be recognised:

Fig. 11 - Palynomorphs and palynofacies of the lower Fraele Formation. a, b) *Ovalipollis pseudoalatus* (Thiergart) Schuurman 1976, samples FRP4, FRP7; c) *Granuloperculatipollis rudis* Venkatachala & Gòczàn 1964, sample FRP30; d) *Calamospora mesozoica* Couper 1958, FRP30; e) *Gliscopollis meyeriana* Morbey 1975, sample FRP14; f) *Microreticulatisporites fuscus* (Nilsson) Morbey 1975, sample FRP18; g) *Classopollis torosus* (Reissinger) Balme 1957, sample FRP7; arrow points at infrabaculate structures; h, i) *Botryococcus* sp., sample FRP30; l) fungal hyphae, sample FRP28; m, n) *Tasmanites* sp., sample FRP30; o) Palynofacies of FRP11, characterised by abundant inertinite. A wood fragment is indicated by the arrow; p) Palynofacies with pellettiferous amorphous organic matter and other palynomacerals, sample FRP14. (Magnifications: fig. o, p about x300, fig. l about x1500; others about x1000).


a
b
c
d
e
f
g
h
i
l
m
n
o
p

- a lower part consisting of dark shales and siltstones, in which carbonate is lacking or occurs only sparingly, alternating with centimetric calcarenitic mostly bioclastic beds, which gradually prevail in the upper part of the cycle. Burrowing is rare, both in silt-sized material and in carbonates, reflecting a scarcity of life on the sea floor. Palynofacies in the shales are dominated by amorphous organic matter (AOM) and a higher percentage of terrestrial organic components, mainly humic fragments. Palynomacerals are mostly well-rounded vitrinite and equidimensional inertinite (Fig. 11o). Sporomorphs are relatively abundant but usually badly preserved. Biodegradation and pyritization processes are common. The high percentage of AOM reflects enhanced preservation under reducing conditions: its abundance is correlated with low sea bottom oxygen values (dysoxic to anoxic) which prevented the development of macro and microbenthic communities, including burrowers, and thus favoured organic matter preservation.

Fig. 12 - View of the basal cycles of the Fraele Formation. The black line spans a complete cycle.

- An upper part, represented by resedimented amalgamated calcarenites, with scarce siliciclastic content. The palynofacies show a drastic reduction in AOM content which is almost absent at the top of the cycle. Total organic matter content is low and almost completely represented by sporomorphs and palynomacerals, the latter consisting mostly of small equidimensional inertinite fragments.

Botryococcus sp. (Fig. 11h, i) and *Tasmanites* sp. (Prasinophyte algae, Fig. 11m, n) are present throughout the lowermost Fraele Formation cycles, and are concentrated in some levels.

Variations of AOM percentage across A-type cycles provide information about the palaeo-oxygenation fluctuations of depositional environment. During clay sedimentation, the high amount of AOM suggests scarce oxygenation at the sediment-water interface and in the water column (Fig. 14). A large amount of terrestrial organic particles associated with a high percentage of AOM may occur in the vicinity of fluvio-deltaic sources or within turbitites (Tyson, 1993). Observations on modern examples show that the bloom of *Botryococcus* colonies could represent one season's growth in lacustrine and brackish conditions (Guy-Ohlson, 1992) and that these may be carried off-shore by rivers and deposited in marine prodelta and adjacent shelf facies (Tyson, 1995). Therefore, influxes of fresh water can be invoked during deposition of the lower Fraele Formation. The existence of continental runoff induced by a humid climate could explain the high percentage of terrestrial elements and an input of low-density freshwater resulting in the establishment of permanent water-mass stratification. The presence of *Tasmanites* is a further indication of low oxygen values. Correlation between the minimum and maximum $CaCO_3$ content and, respectively, the maximum and minimum of AOM percentage in palynofacies suggests that the depositional environment was starved of sediment during accumulation of the shales. Planktonic carbonate production was negligible during Triassic times when all carbonates were produced on platforms. The absence or scarcity of carbonate in the lower part of the cycle could therefore be related to low carbonate productivity on the platform or to its transport into the basin.

The palynofacies of the upper part of the cycles, which consists entirely of carbonates, show a low percentage of AOM, suggesting better oxygenation and wa-

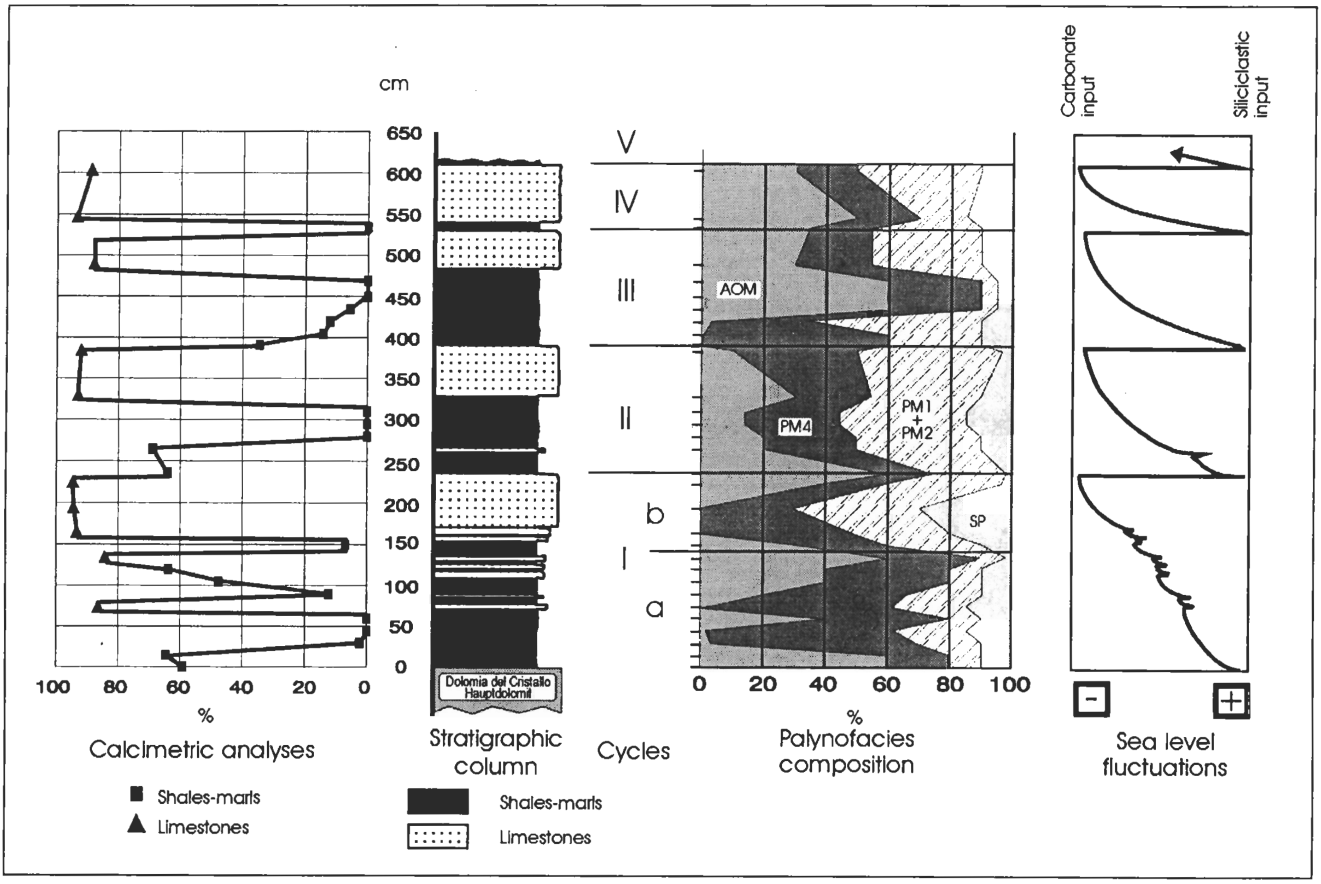


Fig. 13 - Relationships between the parameters used to show cycle organisation and variation in palaeoxygenation: calcimetric analyses, AOM percentage, terrestrial particulate matter and related sea-level fluctuations in the lowermost Fraele Formation. AOM: amorphous organic matter; it is preserved in low-oxygenated environments. PM1+PM2: vitrinite; orange to dark brown partially to moderately oxidised palynomacerals derived from oxidation of higher plant debris and thus of continental origin. PM4: inertinite; black, opaque fragments of terrestrial origin highly oxidised (it is the most stable palynomaceral). SP: Sporomorphs, including pollen and spores; land derived. For details about organic matter classification see Whithaker, 1984, and Steffen & Gorin, 1993.

ter circulation which favoured more diverse faunal associations. Carbonate material was resedimented from nearby carbonate platforms where intertidal conditions were not reached, as shown by facies associations. The sedimentation rate was relatively high, as indicated by the presence of well-preserved particulate kerogen which is indicative of rapid burial, that removed OM from the water-sediment interface, thus avoiding long oxidation.

B-type cycles are characterised by a shallowing-upward trend, previously described by Furrer (1981), which show a lower marly-shaly portion and an upper calcareous part. Fine carbonate material in the lower part of the cycle is interpreted as mostly periplatform ooze. Carbonate production in the upper part of the cycle was mainly an *in situ* process, as indicated by oolitic banks and coral limestones. Dolomitisation phenomena are observed in fine carbonates of the upper part of the cycles. Hard ground surfaces, rich in Fe-oxides and with vertical borings, can be observed locally at the top. B-type cycles may be slightly asymmetrical: above shallow water limestones, before shaly input of the overlying cycle, fine limestones and marly limestones may be present. A genetic model explaining this type of cycles in a coeval succession of Southern Alps (Riva di Solto Shale and Zu Limestone) was proposed by Masetti et al. (1989), whereas an environmental interpretation was presented by Jadoul et al. (1994).

The cyclic succession shows a passage from A-type to B-type cycles; in the uppermost part of the Fraele Formation cyclic organisation is less evident, shales are absent and all the facies show shallow-water features. Across the sections, some portions are randomly organised and cyclicity is not always recognisable. Cyclic sedimentation is determined by two different sedimentary inputs, one extrabasinal and one intrabasinal: the alternation between the two source areas was environmentally controlled. The two kinds of cycles show different lithofacies, deposited at different depth, but the organisation is similar, with a shallowing-upward trend and carbonate increasing in importance toward the top. The shallowing-upward trend and the stacking of the cycles require the continuous development of accommodation space for sediments and document a cyclic variation of the water depth. The main controlling factor on the cy-

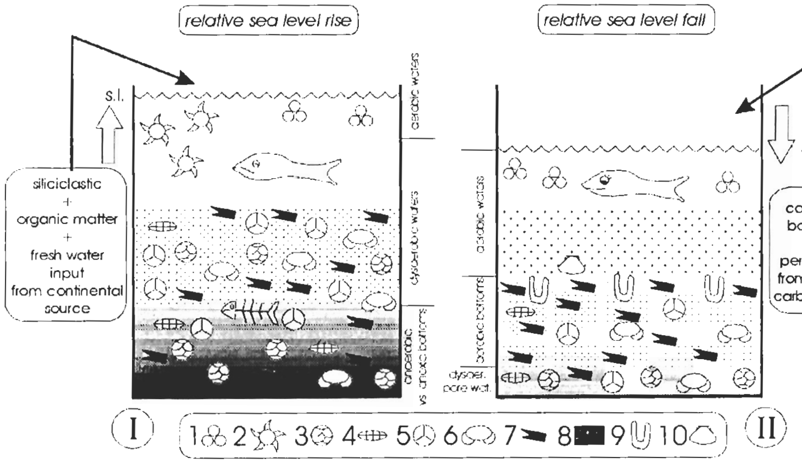


Fig. 14 - Hypothetical reconstruction of palaeoecological conditions at the sea bottom and within the water column during the two phases of relative sea-level fluctuations (terminology after Tyson, 1987). 1) benthic foraminifers; 2) *Botryococcus* sp.; 3) *Tasmanites* sp.; 4) PM3; 5) monosaccates and thick ornamented sporomorphs; 6) bisaccate pollen; 7) PM1+PM2+PM4; 8) amorphous organic matter (AOM); 9) burrows; 10) macrobenthic fauna (mainly bivalves).

clicity was therefore relative sea-level fluctuation, which affected both the variation of the accommodation space on the carbonate production areas and the changes in sediment source and supply. The increased accommodation space created by a relative sea-level rise favoured aggradational evolution and thus prevented exportation of carbonate material basinward, where A-type cycles were deposited. The following gradual relative sea-level fall, reducing the accommodation space, controlled carbonate export basinward and the beginning of progradation. In shallower areas, carbonate was produced *in situ* (B-type cycle), whereas in deeper areas carbonate was totally resedimented (A-type cycle). During episodes of relative sea-level fall, shales were possibly trapped in basins more proximal to the coast line; the existence of topographic highs prevented delivery of shales in the Fraele Formation basin. Succeeding relative sea-level rise led to new shaly input and to the beginning of a new cycle, marked at the base by a hard ground or by transitional marls.

Factors controlling Fraele Formation subtidal cycles are not clearly identifiable. Relative sea-level changes are documented, but mechanisms forcing variations such as eustacy, sediment supply and subsidence are not discernible, due to absence of regular stacking and to strong tectonic overprint. The model proposed by Osleger (1991), considering eustacy (allocyclic control) together with intrinsic processes such as storm waves and wave reworking (autocyclic control) as forcing mechanisms, seems to be confirmed by available data. Existence of allocyclic control could be indirectly supported by the presence of Late Norian-Rhaetian cyclic successions in other Alpine domains (Southern Alps; Masetti et al., 1989; Austroalpine; Furrer, 1981) and surrounding areas (Apennine, Hungary, Poland, Slovakia). This cyclicity is recorded in deposits of different environmental settings and depths, from intertidal flats to deep ramps (Jadoul et al., 1994).

The passage from A-type to B-type cycles in the sections studied documents a gradual progradation of the shallow water facies into the deeper part of the basin until depressions were filled and the shallow water carbonate platform conditions recorded in the upper Fraele Formation were restored. Vertical facies transition reflects the original lateral relationships: A-type cycles were deposited in the deeper part of the original sedimentary basin contemporaneously with B-type cycles in shallower portions of the basin. On structural highs, carbonate platform facies probably persisted from the end of the Dolomia Principale deposition. In the Fraele Formation all the three situations are documented over all the studied area: A-type cycles at the base, B-type cycles in the middle and upper parts and shallow water carbonate platform facies at the top.

Discussion.

Facies and sedimentological features of the Fraele Formation raise questions about the stratigraphic significance of this formation. The presence of a siliciclastic input in Late Norian-Rhaetian times is recorded in many palaeogeographic domains (Southern Alps, Austroalpine, Apennines, Carpathian Mountains etc.) and this event seems to be isochronous (Golebiowski, 1990). The Fraele Formation deposition fits into the regional evolution of the whole Alpine area, but explanation of its depositional model requires consideration of the following points:

- the sharp contact between the Dolomia del Cristallo and the Fraele Formation
- mobilisation of siliciclastic material and location of the source area
- biofacies changes with respect to the underlying Dolomia del Cristallo

The Dolomia del Cristallo inner platform facies are completely dolomitised and shales or siltstones are totally absent. The base of the Fraele Formation is marked by: 1) a sharp facies change represented by an input of siliciclastic material previously not delivered in the

Tethys; 2) changes of ecological niches, of benthic communities and of the origin of carbonate deposits. In the study area inner platform facies deposition did not stop due to siliciclastic pollution, because interfingering of the Dolomia del Cristallo and the Fraele Formation has never been observed. The end of dolomitised inner platform deposition and the abrupt start of clay input could be controlled by a climatic change, preventing production and dolomitisation of carbonates, favouring shales transportation and influencing life conditions. The absence of emersion features and the passage from shallow subtidal-intertidal facies at the top of the Dolomia del Cristallo to the deeper facies of the lower Fraele Formation record a drowning of the inner platform. This was probably related to decreased carbonate production on the inner platform acting together with a eustatic sea-level rise which is recorded by the extension of epicontinental marine beds in the topmost Triassic of NW Europe (Golebiowski, 1990).

During the early Late Triassic, climate on the European continent was arid (Simms & Ruffel, 1990; Visscher et al., 1994); scarce precipitation did not allow the transport of siliciclastic sediments seaward and these were trapped in the basin of the South German Keuper Basin, where evaporitic deposition also occurred. In the Norian-Rhaetian successions evidence of low-salinity epicontinental seas is recorded in Northern Europe together with disappearance of evaporites in the British and German "Rhaetic" (Hallam & El Shaarawy, 1982): the transition to a more humid climate, with increased rainfall and the development of rivers carrying fine siliciclastic material from the inner part of the continent toward Tethys can be suggested. In the lower Fraele Formation at least fresh-water influxes are indicated by the occurrence of *Botryococcus* which is indicative of fresh-water input or of low-salinity conditions. The presence of a more humid climate during the Late Norian was recently suggested by Jadoul et al. (1994) and Cirilli (1995).

In some areas of the wide Dolomia Principale-Hauptdolomit platform, fresh water input modified chemico-physical water conditions, probably preventing early-dolomitisation phenomena and reducing carbonate production. Dolomitisation in the Dolomia Principale was favoured by high temperatures and arid conditions (Frisia, 1990). A change from arid to humid climatic conditions could therefore be invoked to explain the end of pervasive early dolomitisation processes.

Environmental changes can also explain development of different biofacies in the two formations. In the Dolomia del Cristallo the organisms (i.e. corals and sponges) common in the coeval margin facies of the Dachstein Limestone are absent. This absence may suggest the existence of an ecological threshold linked to anomalous water conditions such as high salinity and high temperature on the inner platform.

The occurrence in the Fraele Formation of organisms such as brachiopods, crinoids and corals records the restoration of normal marine conditions. Corals are completely absent in the Dolomia del Cristallo, but are common in the mixed facies of the Fraele Formation, suggesting that anomalous salinity was a stronger barrier for corals than presence of fine siliciclastic pollution.

Siliciclastic material came from a cratonic source area with intrusive or ortho-derived rocks cropping out. According to some palaeogeographic reconstructions (Wurster, 1968) Central Europe represents the nearest cratonic area and shows clear drainage from north to south on the European continent, well recognised until the deformed Alpine chain. From more recent reconstructions (Dercourt et al., 1993) the source area of terrigenous material could be placed in central-eastern Europe, toward the Carpathian area. The Brianconnaise High, placed between the Central Massif and the Austroalpine Domain, prevented supply of sediment from western Europe. Siliciclastic material was carried by rivers which flowed into the Tethyan gulf, delivering clays and silts to areas where inner platform facies were previously deposited. Prevailing shales with rare quartz-rich siltites together with high roundness of the inertinite fragments, is indicative of long transportation and distal position to the source area.

The presence of Upper Triassic fine grained siliciclastic sediments in the Helvetic Domain and of Norian inner platform carbonate with rare siliciclastic intercalations in the Lower Austroalpine domain, documents a proximal-distal trend from central Europe to the Tethys coast. The source area of shales was probably different for other palaeogeographic domains with a similar stratigraphic evolution (Ligurian Apennine, central and northern Apennine). In these latter examples, the siliciclastic material could have been derived from Iberia, placed north-west of the Apennine Domain during the Norian (Dercourt et al., 1993).

Clays coming from European emerged lands, were probably trapped in basins developed between the coast line and the marginal facies of the Dachstein Limestone or in lower lying areas within the inner platform, as occurred for the Kössen Basin (Lein, 1987) or the Lombardy Basin. On more or less isolated and relative structural highs, protected from the siliciclastic and fresh water input, deposition of the Dolomia Principale-Hauptdolomit inner platform carbonate probably continued without recording important changes. Return to shallow subtidal-intertidal conditions at the top of the Triassic succession is related to increased carbonate productivity. The recovery of carbonate platforms in the uppermost Rhaetian was probably favoured by a shifting toward a less humid and warmer climate.

Conclusions.

The Fraele Formation records an important stratigraphic event linked to a sharp environmental change followed at the top by a gradual recovery of carbonate platform sedimentation. The underlying Dolomia del Cristallo represents a portion of the widespread Norian Hauptdolomit-Dolomia Principale inner platform. The overlying Monte Motto Formation consists of Lower Jurassic deep water facies related to the first stage of the opening of the Penninic Ocean (Eberli, 1988). Climate was probably the main factor controlling the start and the development of the sedimentary environment of the Fraele Formation but tectonics seems to have controlled its end. A transition to a humid climate led to the end of the Dolomia del Cristallo deposition and favoured delivery of clays; decrease in clay percentage and an increase in the proportion of carbonate upwards through the succession is probably related to the restoration of warm and less humid conditions.

Marginal facies of the Dachstein Limestone continued their deposition until the end of the Triassic indicating that environmental changes on the inner platform did not affect marginal areas. During the Late Norian-Rhaetian, mixed sediments of the Lombardy Basin, Kössen Basin and Fraele Basin identify a belt between continental-transitional Keuper and Dachstein Limestone margin facies.

In more distal areas (i.e. Balaton Highlands; Haas, 1993; Haas & Budai, 1995) a progradation of the uppermost Dachstein Limestone towards an inner siliciclastic basin is observed. The coral limestones in the upper part of the Fraele Formation and probably also those in the Lombardy and Kössen Basins could represent tongues of Dachstein-equivalent facies, gradually spreading over the shaly lower Fraele Formation and coeval sedimentary units. This colonisation that was previously prevented by the chemical and physical environmental conditions occurring during Hauptdolomit-Dolomia Principale deposition.

In the inner Tethyan gulf, it is possible to recognise sectors where the Hauptdolomit-Dolomia Principale deposition lasted until the end of the Triassic (e.g. Dolomites, Central and Southern Apennine). In these areas, siliciclastic material was not delivered, probably because of the existence of topographic barriers or because the siliciclastic material was trapped in more proximal basins. In more rapidly subsiding areas (i.e. Lombardy Basin, Jadoul et al., 1992), clay sedimentation firstly took place in previous basins and later on highs (Jadoul et al., 1994). On the highs, evidences of emersion are almost absent, whereas phosphatic crusts are present (Jadoul et al., 1994), probably indicating a drowning of the platform during a starvation phase preceding the beginning of clay deposition.

The position of the Fraele Basin with respect to surrounding areas is uncertain. Relations with the Lombardy Basin are not clear due to the presence of the Insubric Line and there is no continuity with the Northern Calcareous Alps (Kössen Basin) to the north-east. At present it is not possible to determine whether the Fraele Basin was isolated from these basins. In thickness the Fraele Formation is more comparable with the Kössen Formation than with the thick Argillite di Riva di Solto-Calcare di Zu-Dolomia a Conchodon succession of the Lombardy Basin. Relative similarity with successions around the Lombardy Basin, may indicate that the Fraele Basin represents part of the northern margin of that basin.

Acknowledgements.

This paper greatly benefited from the careful review and suggestions of Prof. Flavio Jadoul (Milan), Prof. Maurizio Gaetani (Milan) and Dr. Ferenc Góczán (Budapest), who referred the manuscript. A special thanks to Dr. Warrington G. (British Geological Survey, Nottingham, UK) for his carefully review of the manuscript: his scientific suggestions and his review of English greatly improved the quality of this work. We also want to thank to Dr. Roberto Rettori (Perugia) for his assistance in determining the foraminifer assemblages. Thanks also to Mr. Gianpiero Tosti (Perugia) for printing pictures concerning organic matter. Printing expenses were covered by Paleopelagos - CNR (Valeria Zamparelli).

REFERENCES

Ager D.V. (1990) - Rhaetian reconciliation. *Albertiana*, v. 8, pp. 8-9, Utrecht.

Allasinaz A. (1992) - The Late Triassic-Hettangian bivalves turnover in Lombardy (Southern Alps). *Riv. It. Paleont. Strat.*, v. 97, pp. 431-454, Milano.

Baudelot S. & Taugourdeau-Lantz J. (1986) - Découverte d'une microflore dans les Pyrénées catalanes attribuable au Norien-Rhétien. *Rev. Paléob.*, v. 5, pp. 5-9, Genève.

Berra F. & Cirilli S. (in press) - Preservation and thermal alteration of organic matter in the Ortles and Quattervals Nappes (Upper Austroalpine, North-Eastern Lombardy, Italy): preliminary results and implications for regional geology. *Ecl. Geol. Helv.*, Basel.

Caron M., Dössegger R., Steiger R. & Trümpy R. (1982) - Das Alter der jüngsten Sedimente der Ortler-Decke (Oberostalpin) in der Val Trupchun (Schweizerischen Nationalpark, Graubünden). *Ecl. Geol. Helv.*, v. 75, pp. 159-169, Basel.

Ciarapica G. & Passeri L. (1980) - La litostratigrafia della serie triassica del Promontorio occidentale del Golfo di La Spezia. *Mem. Soc. Geol. It.*, v. 21, pp. 51-61, Roma.

Ciarapica G., Cirilli S. & Passeri L. (1982) - La serie triassica del Monte Cetona e il suo confronto con quella di La Spezia. *Mem. Soc. Geol. It.*, v. 24, pp. 155-167, Roma.

Cirilli S. (1995) - Upper Triassic black shales in the western Tethys and their palaeoclimatological meaning. In. Black Shales models, 3rd EPA Workshp, Oscmann W. (Ed.), Europal, v. 8, p. 63, Lyon.

Cirilli S., Bucefalo Palliani R. & Pontini M.R. (1993) - Palynostratigraphy and palynofacies of the Late Triassic R. contorta facies in the Northern Apennines: I) the La Spezia Formation. *Rev. Paléob.*, v. 12, pp. 179-192, Genève.

Cirilli S., Bucefalo Palliani R. & Pontini M. R. (1994) - Palynostratigraphy and palynofacies of the Late Triassic R. contorta facies in the Northern Apennines: II) the Monte Cetona Formation. *Rev. Paléob.*, v. 13, pp. 319-339, Genève.

Clement-Westerhof J. A., Van der Eem J. G. L. A., Van Erve A. W., Klasen J. J., Schuurman W. M. L. & Visscher H. (1974) - Aspects of Permian, Triassic and Early Jurassic palynology of western Europe. - A research project. *Geol. Mijnbouw*, v.53, pp.329-341, Utrecht.

Dercourt J., Ricou L.E. & Vrielynck B. (eds.) (1993) - Atlas Tethys Paleoenvironmental Maps. Gauthier-Villars, 307 pp., 14 maps, 1 pl., Paris.

Eberli G.P. (1988) - The evolution of the southern continental margin of the Jurassic Tethys Ocean as recorded in the Allgäu Formation of the Austroalpine Nappes of Graubünden (Switzerland). *Ecl. Geol. Helv.*, v. 81, pp. 175-214, Basel.

Fazzuoli M., Fois E. & Turi A. (1988) - Stratigrafia e sedimentologia dei "calcari e marne a *Rhaetavicula contorta*" Auctt. (Norico-Retico) della Toscana nord-occidentale. Nuova suddivisione formazionale. *Riv. It. Paleont. Strat.*, v. 94, pp. 561-618, Milano.

Fisher M. J. & Dunay R. E. (1981) - Palynology and the Triassic/Jurassic boundary. *Rev. Palaeobot. Palynol.* v. 34, pp. 129-135, Amsterdam.

Frisia S. (1990) - Caratteristiche sedimentologiche ed evoluzione diagenetica della Dolomia Principale (Norico) del Lago d'Idro e delle Dolomiti di Brenta. Tesi di Dottorato, 156 pp., Milano.

Froitzheim N. (1988) - Synsedimentary and synorogenic normal faults within a thrust sheet of the Eastern Alps (Ortler Zone), Graubünden, Switzerland. *Ecl. Geol. Helv.*, v. 81, pp. 593-610, Basel.

Furrer H. (1981) - Stratigraphie und facies der Trias-Jura-Grenzschichten in den Oberostalpinen decken Graubündens. Ph.D. Thesis, Geol. Inst. Univ. Zürich, 111 pp., Zürich.

Gazdzicki A. (1974) - Rhaetian microfacies, stratigraphy and facial development in the Tatra Mts. *Acta Geol. Polonica*, v. 24, pp. 17-118, Warszawa.

Gazdzicki A., Kozur H. & Mock R. (1979) - The Norian-Rhaetian boundary in the light of micropaleontological data. *Geologija*, v. 22, pp. 71-112, Ljubljana.

Gnaccolini M. (1965a) - Calcare di Zu e Argilliti di Riva di Solto: due formazioni del Retico lombardo. *Riv. It. Paleont. Strat.*, v. 71, pp. 1099-1121, Milano.

Gnaccolini M. (1965b) - Il Trias in Lombardia (studi geologici e paleontologici) XII. Il Retico nelle regioni comprese tra il Lago di Lugano ed il ramo orientale del Lago di Como. *Riv. It. Paleont. Strat.*, v. 71, pp. 415-448, Milano.

Golebiowski R. (1990) - The alpine Kössen Formation, a key for European topmost Triassic correlations. *Albertiana*, v. 8, pp. 25-35, Utrecht.

Guy-Ohlson D. (1992) - *Botryococcus* as an aid in the interpretation of palaeoenvironment and depositional processes. *Rev. Palaeobot. Palynol.*, v. 71, pp. 1-15. Amsterdam.

Haas J. (1993) - A "Kösseni-medence" kialakulasa és fejlodése a Dunantuli-középhegységben (Formation and evolution of the "Kössen Basin" in the Transdanubian Range). *Földtanu Közlöny*, v. 123, pp. 9-54, Budapest.

Haas J. & Budai T. (1995) - Upper Permian-Triassic facies zones in the Transdanubian Range. *Riv. It. Paleont. Strat.*, v. 101, pp. 249-266, Milano.

Hallam A. & El Shaarawy Z. (1982) - Salinity reduction of the end-Triassic sea from the Alpine region into north-western Europe. *Lethaia*, v. 2, pp. 169-178, Oslo.

Jadoul F., Berra F. & Frisia S (1992) - Stratigraphic and paleogeographic evolution of a carbonate platform in an extensional tectonic regime: the example of the Dolomia Principale in Lombardy (Italy). *Riv. It. Paleont. Strat.*, v. 97, pp. 29-44, Milano.

Jadoul F., Masetti D., Cirilli S., Berra F., Claps M. & Frisia S. (1994) - Norian-Rhaetian stratigraphy and paleogeographic evolution of the Lombardy Basin (Bergamasc Alps). Field Trip Guide Book, pp. 5-38. 15th IAS Regional Meeting, Ischia.

Krystyn L. (1990) - A Rhaetian stage - Chronostratigraphy, subdivisions and their intercontinental correlation. *Albertiana*, v. 8, pp. 15-24, Utrecht.

Lakew Tesfaye (1990) - Microfacies and cyclic sedimentation of the Upper Triassic (Rhaetian) Calcare di Zu (Southern Alps). *Facies*, v. 22, pp. 187-232, Erlangen.

Lein R. (1987) - Evolution of the Northern Calcareous Alps during Triassic time. In Flügel W. & Faupl P. (Eds.) - Geodynamics of the Eastern Alps. Deuticke, pp. 85-102, Wien.

Masetti D., Stefani M. & Burchell M. (1989) - Asymmetric cycles in the Rhaetic facies of the Southern Alps: platform-basin interaction governed by eustatic and climatic oscillations. *Riv. It. Paleont. Strat.*, v. 94, pp. 401-424, Milano.

McRoberts C.A. (1994) - The Triassic-Jurassic ecostratigraphic transition in the Lombardian Alps, Italy. *Palaeogeog., Palaeoclim., Palaeoecol.*, v. 110, pp. 145-166, Amsterdam.

Mettraux M. & Mohr B. (1989) - Stratigraphy of the Triassic/Jurassic boundary in the Préalpes Médianes nappe: Facies and palynology. *Ecl. Geol. Helv.*, v. 82, pp. 743-763, Basel.

Morbey, S. J. & R. Neves (1974) - A scheme of palynologically defined concurrent-range zones and subzones for the Triassic Rhaetian Stage (sensu lato). *Rev. Palaeobot. Palyn.*, v. 17, pp. 161-173, Amsterdam.

Morbey S. J. (1975) - The palinostratigraphy of the Rhaetian Stage, Upper Triassic in the Kendelbachgraben, Austria. *Palaeontographica*, B, v. 152, pp. 1-75, Stuttgart.

Morbey S. J. (1978) - Late Triassic and Early Jurassic subsurface palynostratigraphy in northwestern Europe. *Palinologia*, Num. extraord. 1, pp. 355-365, Leon.

Orbell G. (1973) - Palynology of the British Rhaeto-Liassic. *Bull. Geol. Surv. G.B.*, v. 44, pp. 1-44, London.

Osleger D. (1991) - Subtidal carbonate cycles: Implications for allocyclic vs. autocyclic controls. *Geology*, v. 19, pp. 917-920, Boulder.

Pedersen K. R. & J. J. Lund (1980) - Palynology of the plant-bearing Rhaetian to Hettangian Kap Stewart formation, Scorseby Sund, East Greenland. *Rev. Palaeobot. Palyn.*, v. 31, pp. 1-69, Amsterdam.

Peybernes B., Martini R., Taugordeau-Lantz J., & Zaninetti L. (1988) - Caracterisation micropaléontologique du Rhetien dans les Pyrenees Francaises entre Garonne et Mediterranee. *Rev. Paléob.*, v. 7, pp. 137-161, Genève.

Pozzi R. (1959) - Studio stratigrafico del Mesozoico dell'Alta Valtellina (Livigno-Passo dello Stelvio). *Riv. It. Paleont. Strat.*, v. 65, pp. 2-54, Milano.

Pozzi R. & Gelati R. (1965) - La formazione di Fraele. Studi Ill. Carta Geol. d'Italia Form. Geol., fasc. 1, 10 pp., Roma.

Schuurman, W. M. L. (1977) - Aspects of Late Triassic palynology. 2. Palynology of the "Gres et schiste à *Avicula contorta*" and "Argiles de Levallois" (Rhaetian) of the northeastern France and southern Luxemburg. *Rev. Palaeobot. Palyn.*, v. 23, pp. 159-253, Amsterdam.

Schuurman, W. M. L. (1979) - Aspects of Late Triassic palynology.3. Palynology of latest Triassic and earliest Jurassic deposits of the Northern Limestone Alps in Austria and southern Germany, with special reference to a palynological characterization of the Rhaetian Stage in Europe. *Rev. Paleobot. Palynol.*, v. 27, pp. 53-75, Amsterdam.

Simms M.J. & Ruffel A.H. (1990) - Climatic and biotic change in the late Triassic. *Journ. Geol. Soc. London.*, v. 47, pp. 321-327, London.

Steffen D. & Gorin G. (1993) - Palynofacies of the Upper Tithonian-Berriasian deep-sea carbonates in the Vocontian trough (SE France). *Bull. Centres Rech. Expl. - Prod. Elf Aquitaine*, v. 17, pp. 235-248, Pau.

Tozer E.T. (1990) - How many Rhaetians? *Albertiana*, v. 8, pp. 10-14, Utrecht.

Tyson R.V. (1987) - The genesis and palynofacies characteristics of marine petroleum source rocks.In Brooks J. & Fleet A.J. (Eds.) - Marine Petroleum Source Rocks, *Geological Society Special Publication* No. 26, pp. 47-67, London, U.K.

Tyson R.V. (1993) - Palynofacies analysis. In Jenkins D.G. (Ed.) - Applied Micropaleontology, pp. 153-191, Kluwer Academic Publishers, Amsterdam.

Tyson R.V. (1995) - Sedimentary organic matter. Organic facies and palynofacies, Chapman & Hall, pp. 1-615, London U.K.

Visscher H. & Brugman A. W. (1981) - Ranges of selected palynomorphs in the Alpine Triassic of Europe. *Rev. Palaeobot. Palyn.*, v. 23, pp. 1-117, Amsterdam.

Visscher H., Schuurman W. M. L. & Van Erve A. W. (1980) - Aspects of a palynological characterization of Late Triassic and Early Jurassic "Standard" units of chronostratigraphical classification in Europe. *Proc. IV Int. Palynol. Conf.* (1976-1977), v. 2, pp. 281-287, Lucknow.

Visscher H., Van Houte M., Brugman W.A. & Poort R.J. (1994) - Rejection of a Carnian (Late Triassi) "Pluvial Event" in Europe. *Rev. Palaeobot. Palyn.*, v. 83, pp. 217-226, Amsterdam.

Warrington G. (1996) - Mesozoic-Tertiary spores and Pollen. 20A - Triassic spores and pollen. In Jansonius J. & Mc Gregor D.C. (Ed.) - Palynology: principles and applications, American Association of Stratigraphic Palynologists Foundation, v. 2, pp. 755-766, Dallas.

Warrington G. & Ivimey-Cook H. C. (1990) - Biostratigraphy of the Late Triassic and Early Jurassic: a review of type sections in southern Britain. *Cahiers Univ. Catho. Lyon*, sér. Sc., v. 3, pp. 207-213, Lyon.

Warrington G., Ivimey-Cook H. C., Edwards R.A & Whittaker A. (1995) - The Late Triassic-Early Jurassic succession at Selworthy, West Somerset, England. *Proceedings of the Ussher Society*, v. 8, pp. 426-432, London.

Whittaker M.F. (1984) - The usage of palynostratigraphy and palynofacies in definition of Troll Field geology. In Offshore Northern Seas - reduction of uncertainities by innovative reservoir geomodelling. Norskpetrol. forening, article G6, Oslo.

Wurster P. (1968) - Paläogeographie der deutschen Trias und die paläogeographische Orientierung der Lettenkohle in Südwestdeutschland. *Ecl. Geol. Helv.*, v. 61, pp. 157-166, Basel.

Received March 19, 1996; accepted October 25, 1996