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PALYNOSTRATIGRAPHY OF THE MUFARA FORMATION (MIDDLE-UPPER TRIASSIC, SICILY)

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Riassunto. Nelle successioni del Triassico Superiore della Sicilia nord-occidentale sono state riconosciute quattro associazioni palinologiche. L'analisi palinologica della Formazione Mufara ha contribuito, insieme ai dati relativi a rari conodonti, alla costruzione di uno schema biostratigrafico che va dal Ladinico superiore al Carnico superiore. Questo intervallo di tempo viene qui interpretato in termini di "*Camerosporites secatus* phase". Nell'ambito di questa fase si è cercato di riconoscere una progressiva diversificazione dei taxa addizionali, sulla base dell'evoluzione composizionale delle associazioni riconosciute.

L'associazione A è caratterizzata dalla presenza di elementi quali *Foveosporites visscheri, Gordonispora fossulata, Sellaspora rugoverrucata, Weylandites magmus* e *Enzonalasporites vigens*, caratteristici del passaggio Ladinico-Carnico e dalla comparsa dei primi elementi carnici, *Patinasporites densus* e *Vallasporites ignacii*, insieme con un gruppo "long-ranging" di predominanti bisaccati. Questa associazione è inoltre segnata dall'assenza di *Camerosporites secatus*.

Nell'associazione B, *C. secatus* è presente in modo discontinuo ed è associato ad alcune forme già presenti nell'associazione precedente (*P. densus, V. ignacii, E. vigens, Praecirculina granifer, Partitisporites novimundanus*). *Aratrisporites tenuispinosus, Kyrtomisporis ervii, Striatoabieites aytugii* compaiono per la prima volta e, insieme con *Foveosporites visscheri, Gordonispora fossulata* e *Sellaspora rugoverrucata*, permettono di riferire l'associazione al Cordevolico-Julico inferiore.

L'associazione C è caratterizzata dalla presenza di *C. secatus, P. densus, E. vigens, V. ignacii, P. granifer, Duplicisporites granulatus* e da forme che scompaiono nello Julico e nel Tuvalico inferiore (rispettivamente *Partitisporites novimundanus* e *Lagenella martinii*). Questa composizione può considerarsi di transizione tra quella dell'associazione precedente (B, Carnico inferiore) e la successiva (D, Tuvalico).

Sulla base della persistenza di forme presenti nelle associazioni precedenti, quali *C. secatus, P. densus, E. vigens, V. ignacii* e sulla base delle prime comparse di *Partitisporites quadruplicis* e *Samaropollenites speciosus*, l'associazione D viene riferita al Tuvalico (Carnico superiore).

Abstract. The study of 10 sections of the Mufara Formation in northern Sicily yielded four palynomorph associations ranging in age from late Ladinian/early Carnian to late Carnian, and identified a trend in the compositional evolution of the assemblages within the *Camerosporites secatus* phase. The primary goal of this study was to create a composite section of the Mufara Formation, giving a tentative stratigraphic order to the 10 investigated successions on the basis of palynomorphs range intervals.

The oldest assemblage (A) is dominated by long-ranging bisaccates but is characterised by the presence of transitional Ladinian-Carnian taxa such as *Foveosporites visscheri, Gordonispora fossulata, Sellaspora rugoverrucata, Weylandites magmus* and *Enzonalasporites vigens*, and by the incoming of the first Carnian elements, *Patinasporites densus* and *Vallasporites ignacii*. Assemblage A is distinguished from the younger ones (B-D) by the absence of *Camerosporites secatus.*

Assemblage B includes taxa which are present also in assemblage A (*P. densus, V. ignacii, E. vigens, Praecirculina granifer* and *Partitisporites novimundanus*). *Camerosporites secatus, Aratrisporites tenuispinosus, Kyrtomisporis ervii* and *Striatoabieites aytugii* occur for the first time and, with the last occurrences of *F. visscheri, G. fossulata* and *S. rugoverrucata,* indicate that this assemblage is of Cordevolian-early Julian age.

Assemblage (C) comprises an association of *Camerosporites secatus, Patinasporites densus, Enzonalasporites vigens, Vallasporites ignacii, Praecirculina granifer,* and *Duplicisporites granulatus*, and taxa with LADs (Last Appearance Datum) in the Julian and the early Tuvalian (*P. novimundanus* and *Lagenella martinii* respectively). This assemblage may be interpreted as transitional between assemblage B and D.

Assemblage D comprises a typical Carnian association of *Camerosporites secatus, Patinasporites densus, Enzonalasporites vigens* and *Vallasporites ignacii,* and includes the first occurrences of *Partitisporites quadruplicis* and *Samaropollenites speciosus*, which indicate a Tuvalian substage (late Carnian) age.

Introduction

Following the work of Martini et al. (1991a, b), an attempt was made to improve the biostratigraphic characterisation of the Mufara Formation (Schmidt di Friedberg et al. 1960). The palynological study of several successions which lack significant faunal elements, except for sparse conodonts, was carried out. Stratigraphic relationships between the different successions are not eas-

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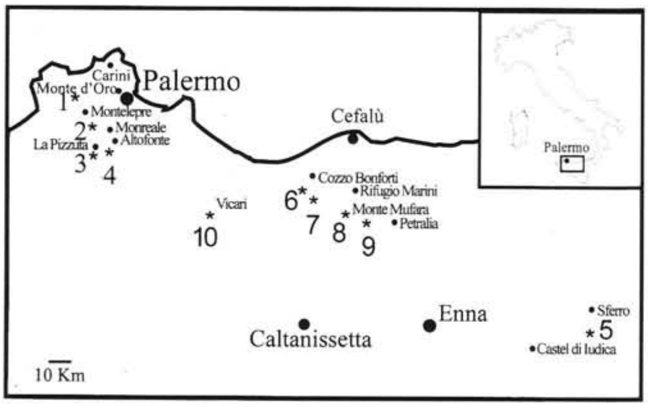


Fig. 1 - Geographic location of the ten sections investigated: 1) Pizzo Montanello, 2) Torrente Cuba, 3) La Pizzuta, 4) Cozzo Paparina, 5) Gambanera, 6) Cerda-Nicosia, 7) Cozzo Tabarani, 8) Monte Mufara, 9) Valle Faguara, 10) Vicari.

ily resolvable in the field because of the complexity of the tectonic setting and structural framework. The palynomorph stratigraphic potential was used to provide a useful biostratigraphic framework, an essential basis for further investigations.

The study showed also a trend in the compositional evolution of the palynological assemblages and a progressive diversification within the *Camerosporites secatus* phase (Visscher & Krystyn 1978).

Historical background

The study area extends from the Madonie Mountains in central northern Sicily, west of the Palermo region, to the north of the Sicani Mountains in northwest Sicily (Fig. 1). These mountains comprise a segment of the Apennine-Maghrebid chain, which is the dominant structural element in northern Sicily and is formed by mainly east/west-trending nappes in a fold and thrust belt. The nappes incorporate carbonate, silico-carbonate and siliciclastic sediments, and result from the deformation of pre-existing paleogeographic domains, platforms and pelagic basins formed during the Mesozoic regional extension phase (Catalano & D'Argenio 1978; 1982; Catalano et al. 1978).

In the Early Miocene, the collision of the Sardinian Block with the African margin initiated the forward migration of the thrust belt-foredeep system and the deformation of the paleogeographic domains from internal to external zones (Catalano et al. 1978; Catalano & D'Argenio 1978; 1982; Broquet et al. 1984).

Originally the Mufara Formation was described as comprising varicoloured, blue, green, purple, reddish, grey or black clays or marls with thin intercalations of dolomitic limestone. The formation was named after the locality in the eastern Madonie Mountains where it was first measured and studied (Schmidt di Friedberg et al. 1960). However, its lower boundary was not observed at this site.

Caflysch (1966) identified some *Halobia* sp., *Daonella* sp. and rare *Trachyceras* sp. in the Mufara Formation, and considered this assemblage to be Late Triassic.

In addition to *Halobia* sp., Mascle (1967) observed some foraminifera (*Rectoglandulina* cf. *simpsoensis* Tappan, *Dentalina* cf. *cassiana* Gümbel, "*Cornuspira*" liasina Terq., *Lenticulina* cf. *cassiana* Gümbel) and ostracods (*Simeonella* sp.), indicative of a Late Triassic age.

Subsequently, Senowbari-Daryan & Abate (1986) observed Carnian reefal elements, Ladinian (Anisian?) dasycladacean grainstones, and Norian *Cayeuxia* bindstone and pisoid facies in lenses of reworked material intercalated in the marly levels of the Mufara Formation.

Martini et al. (1991a, b) investigated outcrops of the Mufara Formation at localities in the Palermo and Madonie mountains and reported miospore assemblages containing *Camerosporites secatus, Duplicisporites granulatus, Praecirculina granifer, Patinasporites densus* and *Samaropollenites speciosus* from marly intervals. The miospores indicated a late Carnian age, which was confirmed by conodonts extracted from calcarenites (Martini et al. 1991a, b).

More recently, Di Stefano et al. (1998) described deposits corresponding to the Mufara Formation from the Monte Altesinella (central Sicily). Those deposits comprise deepwater marls and limestones, containing radiolarians, halobids and conodonts, and interbedded gravity-flow calcarenites and calcirudites. Di Stefano et al. (1998) attributed the association with *Gladigondolella tethydis* and *Paragondolella polygnathiformis* to a mid-Carnian (Julian) age.

Location of the sections

The sections are located along a northwest-southeast belt from the Palermo Mountains to the Madonie Mountains, encompassing the provinces of Palermo, Enna and Caltanissetta (Fig. 2, 3). The exact position of the productive sections is described below, from west to east:

Pizzo Montanello section (Palermo Mountains, Panormide Domain; latitude: 38°06'30"N, longitude: 13°09'51"E) (Figs. 1, 2). The section crops out on a road which connects Carini to Montelepre along the eastern flank of Pizzo Montanello (964 m). The 50 m thick succession is characterised mainly by marls intercalated with limestones, calcarenites and rare calcirudites.

Torrente Cuba section (Palermo Mountains, Panormide Domain; latitude: 38°05'32"N, longitude: 13°13'82"E) (Figs. 1, 2). It is located in the Vallone Vaddi Cuba (between Montelepre and Monreale) and consists essentially of intercalations of marls, marly limestones and calcarenites (15-20 m).

La Pizzuta section (Palermo Mountains, Imerese

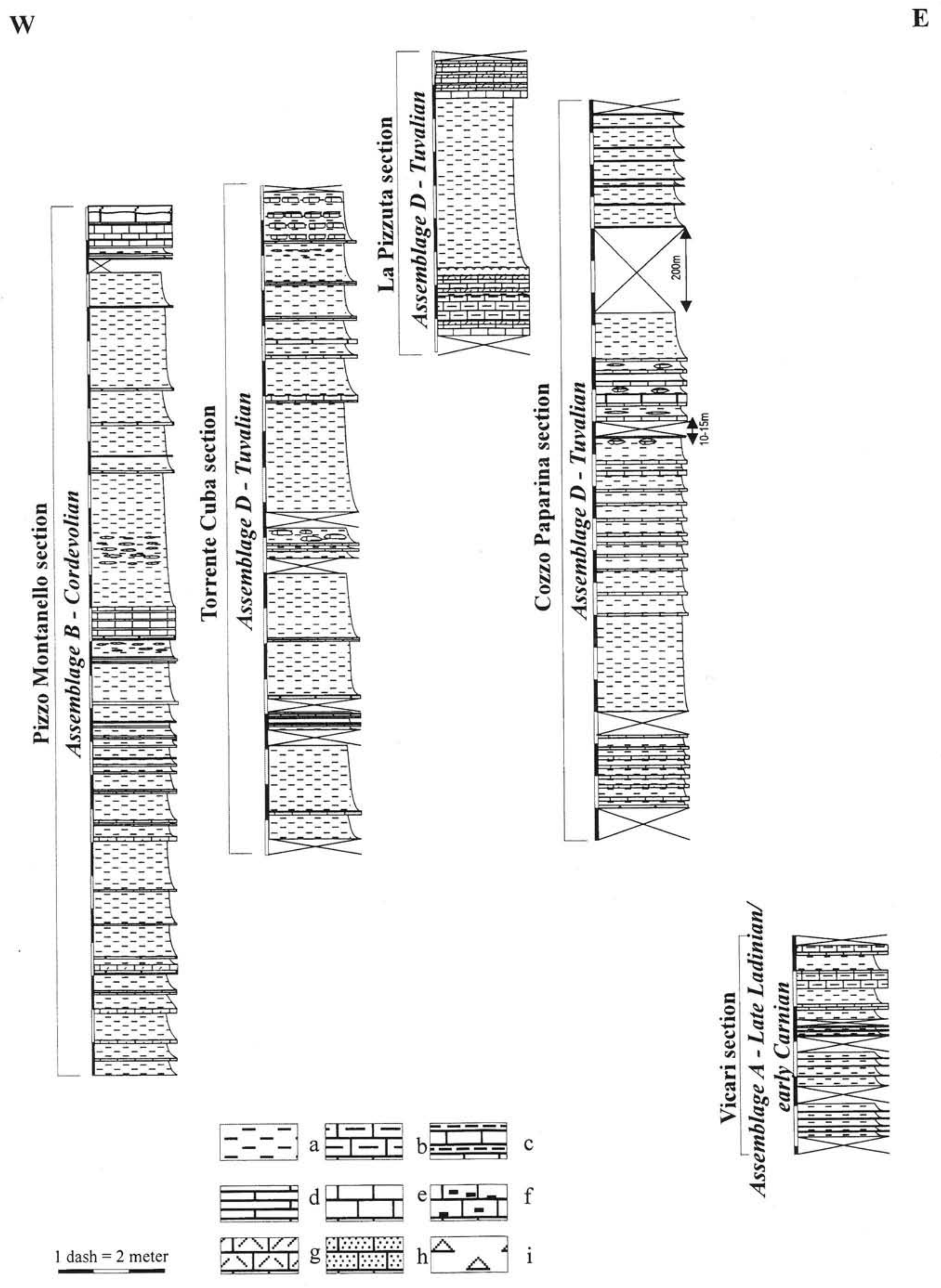


Fig. 2 - Lithological sections of the successions in the Palermo Mountains. Litologies: a) marl, b) marly limestone, c) limestone with marly interbeds, d) finely bedded limestone, e) limestone, f) cherty limestone, g) bioclastic limestone, h) silty limestone to calcareous siltstone, i) breccia.

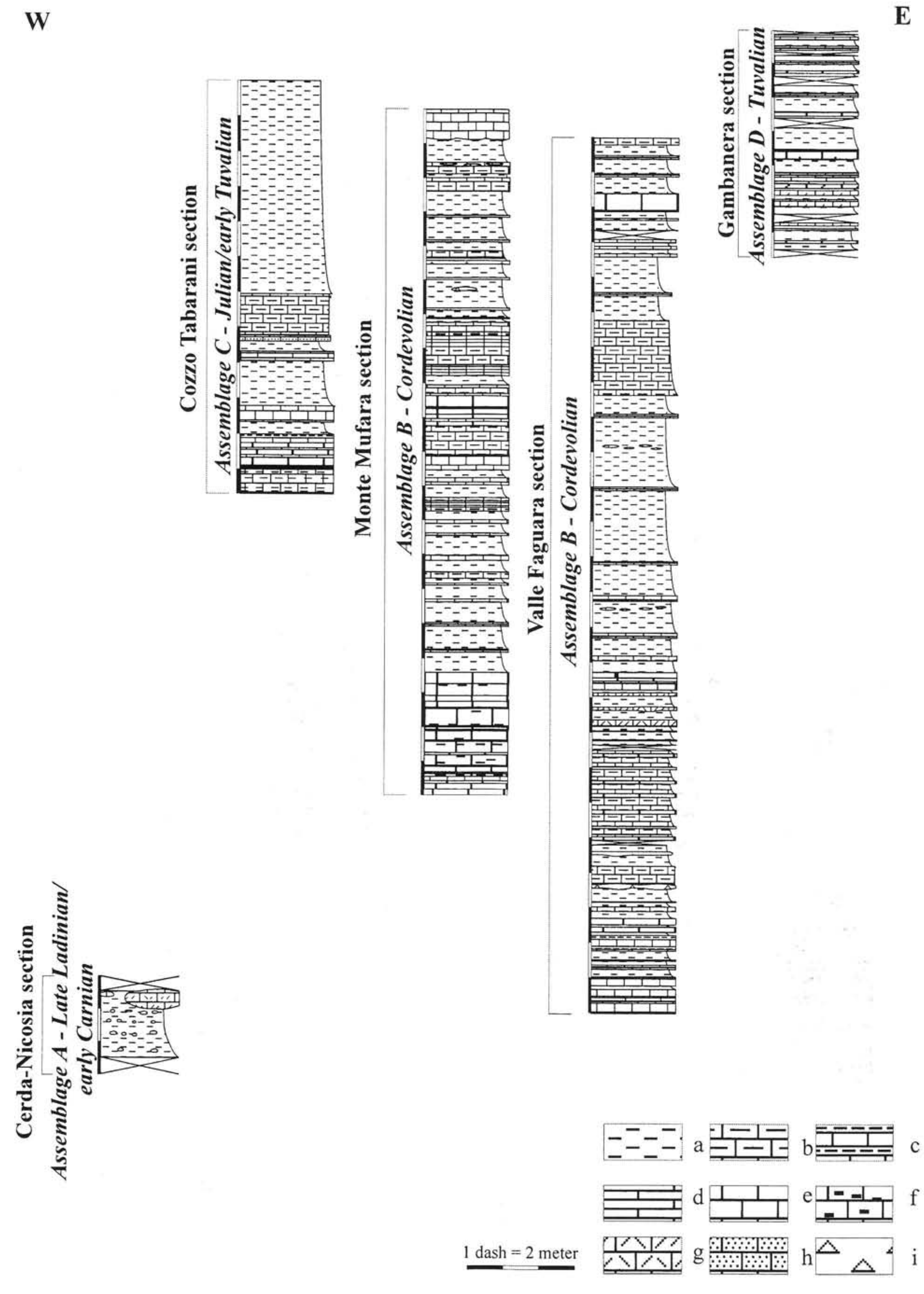


Fig. 3 - Lithological sections of the successions in the Madonie Mountains and in the Caltanissetta Basin (Gambanera section). Litologies: a) marl, b) marly limestone, c) limestone with marly interbeds, d) finely bedded limestone, e) limestone, f) cherty limestone, g) bioclastic limestone, h) silty limestone to calcareous siltstone, i) breccia.

Domain; latitude: 38°00'40"N, longitude: 13°15'17"E) (Figs. 1, 2). It is located north of La Pizzuta (1333 m) and is accessible from a road east of Portella della Paglia. The succession is 15 m thick and is formed, at the base, by marly limestones, followed by marls and, in the upper part, by limestones.

Cozzo Paparina section (Palermo Mountains, Imerese Domain; latitude: 38°01'62"N, longitude: 13°16'43"E) (Figs. 1, 2). The section crops out near the road from Portella della Paglia to Altofonte; it is characterised by a 20 m thick intercalation of yellow marls, silty marls and marly limestones.

Vicari section (Palermo Mountains, Trapanese Domain; latitude: 37°49'51"N, longitude: 13°34'41"E) (Figs. 1, 2). The outcrop is located along the road to the village of Vicari (650 m) before the last curve. It is characterised by a 10 m thick succession of dark marls, marly limestones and calcarenites.

Cerda-Nicosia section (Termini Imerese, Cerda-Roccapalumba unit; latitude: 37°55'59"N, longitude: 13°50'99"E) (Figs. 1, 3). The succession crops out along a dirt a road located on the eastern side of highway A 19. A 4 m thick outcrop shows a large block of bioclastic to brecciated limestone embedded in silty marls.

Cozzo Tabarani section (Western Madonie Mountains, Cerda-Roccapalumba unit; latitude: 37°54'52"N, longitude: 13°51'71"E) (Figs. 1, 3). The outcrop is to the east of highway A 19, along the river Imera and south of Cozzo Bonforti. The section (40 m thick) is dominated by limestone levels, followed by silty marls and calcareous siltstone intervals.

Monte Mufara section (Madonie Mountains, Panormide Domain; latitude: 37°51'80"N, longitude: 14°00'71"E) (Figs. 1, 3). The section crops out on the western flank of Monte Mufara (1865 m). It is a 40 m thick succession characterised by limestones and cherty limestones, intercalated, upwards, with marly intervals. Calcarenites and marly limestones also occur along the section.

Valle Faguara section (Madonie Mountains, Panormide Domain; latitude: 37°51'21"N, longitude: 14°02'84"E) (Figs. 1, 3) . The succession is a few hundred meters south of Rifugio Marini on the road to Petralia, between the first and second bridge. A 40 m thick section crops out showing a base composed mainly by limestones.

Gambanera section (Caltanissetta Basin, Imerese-Sicano Domain; latitude: 37°29'02"N, longitude: 14°46'47"E) (Figs. 1, 3). It crops out in a small quarry, 5 km south of Sferro, in the direction of Castel di Iudica. It consists of a 12 m thick succession of alternating marly clays and marls, with limestones and calcarenites, with increasing carbonates towards the top.

Methods

Standard preparation techniques were used

VICARI SECTION

samples	222	217
Lithology		
age	Late Ladinian/ early Carnian	
Krauselisporites sp.	●	
Minutosaccus sp.	●	
Densosporites sp.	●	
Klausipollenites sp.	●	
Retitriletes sp.	●	
Schizosaccus sp.	●	
Cycadopites sp.	●	
Parillinites sp.	●	
Sellaspora sp.	●	
Pseudoenzonalasporites summus	●	
Protodiploxypinus sp.	●	●
Pityosporites sp.	●	
Lunatisporites acutus	●	
Triadispora sp.	●	●
Gordonispora fossulata	●	
Staurosaccites quadrifidus	●	●
Paracirculina verrucosa	●	●
Platysaccus papilionis	●	
Sellaspora rugoverrucata	●	
Duplicisporites verrucosus	●	
Duplicisporites granulatus	●	●
Deltoidospora minor	●	
Weylandites magmus	●	
Foveosporites visscheri	●	
Enzonalasporites vigens	●	●
Vallasporites ignacii	●	●
Patinasporites densus	●	
Equisetosporites sp.	●	
Ovalipollis pseudoalatus		●
Calamospora sp.		●
Praecirculina granifer		●

10 m

Fig. 4 - Distribution of palynomorphs in the Vicari section.

CERDA-NICOSIA SECTION

Lithology	samples	age	*Lueckisporites* sp.	*Klausipollenites* sp.	*Cuneatisporites cerinus*	*Calamospora mesozoica*	*Ovalipollis pseudoalatus*	*Infernopollenites sulcatus*	*Partitisporites novimundanus*	*Duplicisporites granulatus*	*Patinasporites densus*	*Foveosporites visscheri*	*Vallasporites ignacii*
	82	LateLadinian/ early Carnian		●									●
	81		●	●	●	●	●	●	●	●	●	●	

10 m

Fig. 5 - Distribution of palynomorphs in the Cerda-Nicosia section.

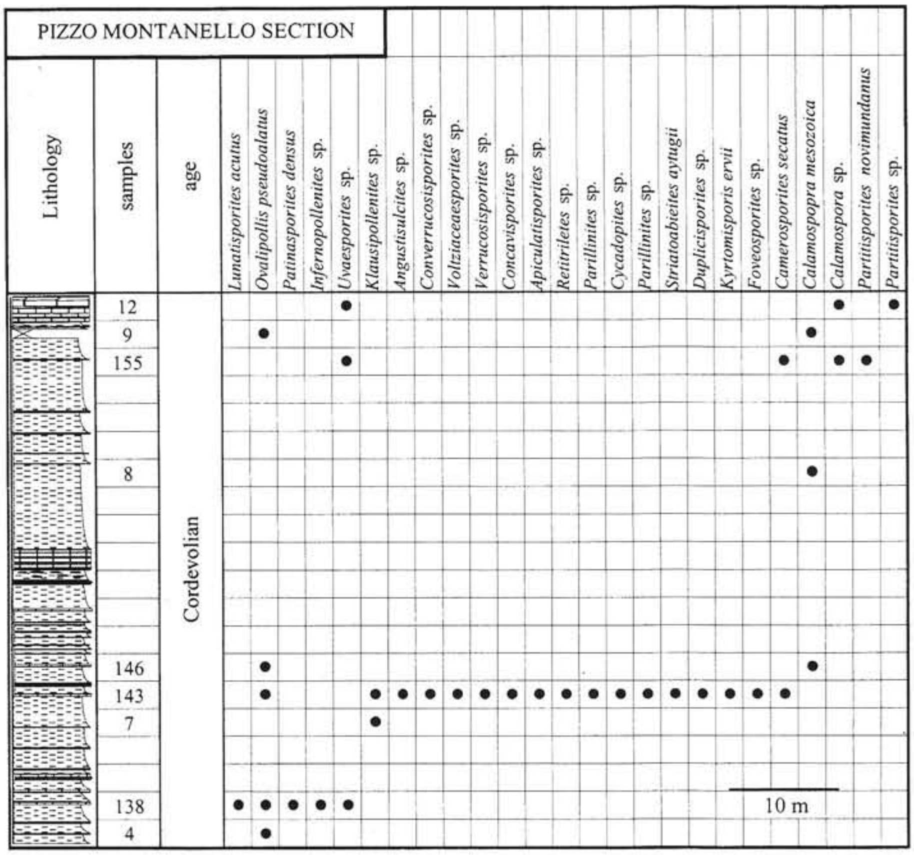


Fig. 6 - Distribution of palynomorphs in the Pizzo Montanello section.

for miospore recovery (Faegri & Iversen 1975; Doher 1980; Heusser & Stock 1984; Wood et al. 1996) and for conodont extraction (Vrielynck 1987).

Upper Triassic chronostratigraphy: historical background

Some current controversies regarding the ammonoid-based subdivision of the Carnian stage must be introduced briefly before discussing the palynological record of the Mufara Formation.

The Carnian stage was introduced by Mojsisovics (1869) for the stratigraphic interval corresponding to the *Trachyceras aonoides* Zone. Later, Mojsisovics et al. (1895) redefined the stage, and divided it into the Cordevolian, Julian and Tuvalian substages, corresponding to the *Trachyceras aon, Trachyceras aonoides,* and *Tropites subbullatus* ammonoid zones, respectively.

Despite a common acceptance of this zonation scheme, objections were raised and alternatives were proposed. For example, after a biostratigraphic study of the Hallstatt Limestones, Krystyn (1978) proposed the subdivision of the Alpine-Mediterranean lower Carnian into four ammonoid subzones which together form two zones that characterise a single substage. He considered the taxonomic difference between *Trachyceras aon* and *T. aonoides* to be insufficient to justify the use of these species in zonal subdivision. He also proposed to use *T. aon* for defining the basal subzone of the Julian substage (Krystyn 1978). Hence the Cordevolian substage would become superfluous and need to be rejected.

As a consequence, of Krystyn's (1978) concept, the lower Carnian can be defined in terms of two zones (Aonoides and Austriacum) and four subzones (Aon, Aonoides, Austriacum, and Sirenites). The proposed rejection of the Cordevolian substage was not accepted by, e.g., Visscher & Brugman (1981), Van der Eem (1983), Bizzarrini et al. (1989) and Urlichs (1994). Regarding the San Cassiano Formation, Van der Eem (1983) argued that the ammonoid faunas with "*Trachyceras aon may justify Urlichs'(1974) proposal of establishing a type-section for the Cordevolian Substage in the type-area of the formation*". Mostly based on the ammonoid biostratigraphy of the Southern Alps, and especially of the Prati di Stuores section (Urlichs 1974), the original zonation of Mojsisovics was thought to be still valid, and consequently Urlichs (1994) retained the Cordevolian substage.

Investigations by Broglio Loriga et al. (1999) in the Prati di Stuores/Stuores Wiesen section suggest that the base of the Carnian Stage should be placed at the FAD (First Appearance Datum) of *Daxatina* cf. *canadensis*. Other considerations support this proposal, among them the fact that the first appearance of the traditional Carnian genus *Trachyceras* with species different from *Trachyceras aon* occurs within the lower *Daxatina* cf. *canadensis* Subzone. Another consideration is that the section is located in the type-area of the Cordevolian substage of Mojsisovics et al. (1895) and of Urlichs (1974; 1994). This last argument may also emphasize the need for redefining and maintaining the Cordevolian substage. In order to facilitate comparisons with previous palynological studies in the Alps, the classic threefold subdivision of the Carnian stage is accepted in the present paper.

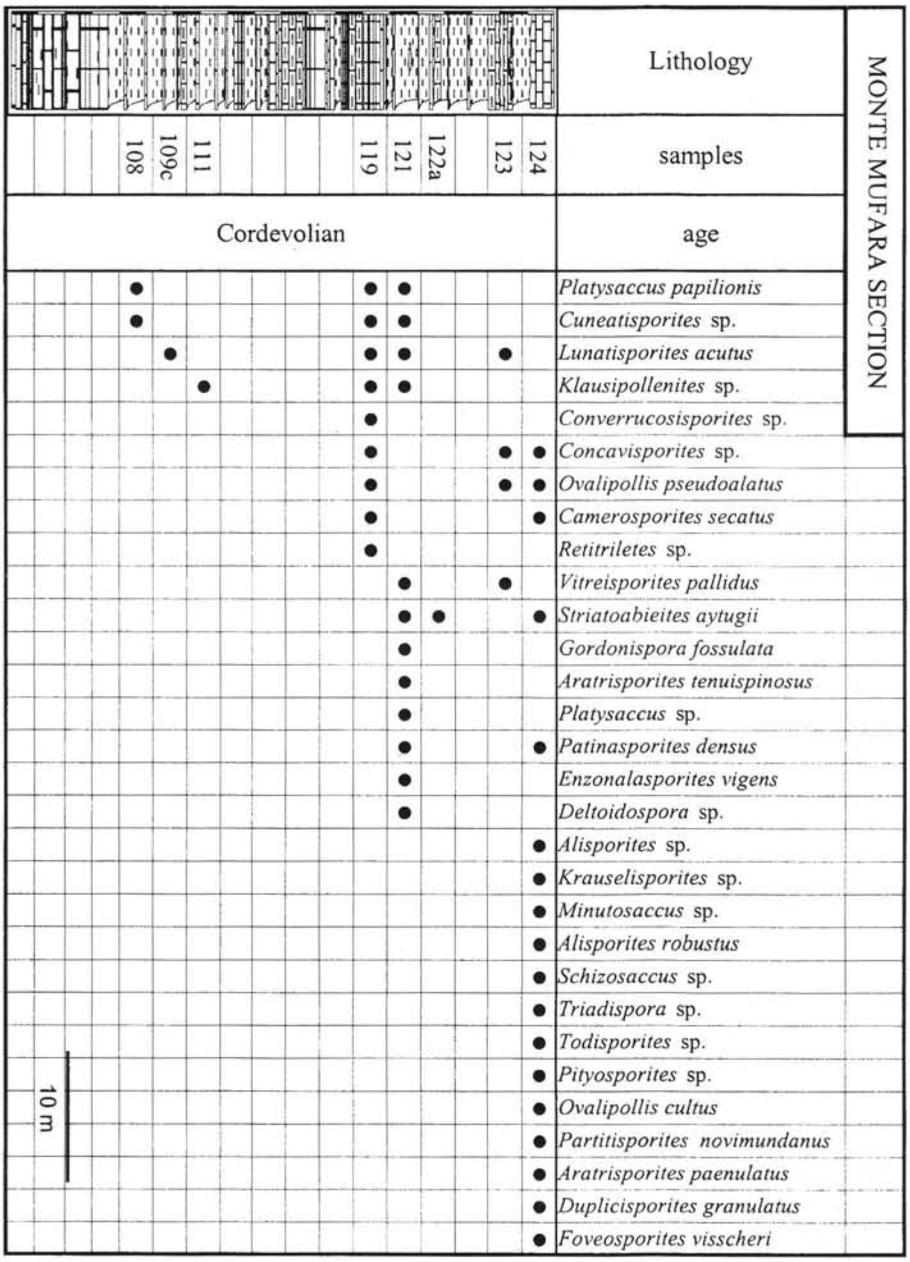


Fig. 7 - Distribution of palynomorphs in the Monte Mufara section.

Palynostratigraphy

Interpretation of the *Camerosporites secatus* phase. Any work on the palynological characterisation of the Carnian stage cannot avoid considering the "*Camerosporites secatus* phase" concept. This was introduced by Visscher & Krystyn (1978), on the basis of Schuurman's (1977; 1979) Phase I, in order to provide a practical palynological tool for correlation. They described this characteristic assemblage as a phase distributed in many paleofloral provinces, reflecting a late Ladinian-Carnian interregional microflora development.

The *Camerosporites secatus* phase (Visscher & Krystyn 1978; Cirilli & Montanari 1994; Cirilli 1995; Warrington 1996) includes a rapid diversification of the Circumpolles group, and is represented by *Praecirculina granifer*, *Camerosporites secatus* and *Duplicisporites granulatus* in association with the vesicate species *Patinasporites densus*, *Enzonalasporites vigens*, *Vallasporites ignacii* and *Pseudoenzonalasporites summus*. The phase was originally considered to be an exclusively Carnian event, but later was extended into the Ladinian (Visscher & Brugman 1981; Van der Eem 1983; Besems 1981a, b, 1983; Besems & Simon 1982; Dolby & Balme 1976; Brugman et al. 1994). Occurrences are also known from early, middle and late Carnian assemblages from well-dated ammonoid-bearing successions, such as the Prati di Stuores section in the Dolomites (Broglio Loriga et al. 1999) in Italy, where *C. secatus* has been recorded from the base of the *Daxatina* cf. *canadensis Subzone* (lower Carnian).

In Austria the occurrence of *C. secatus* is well controlled by a continuous ammonoid zonation which covers the entire Carnian stage (Dunay & Fisher 1978). These authors recorded the appearance of *C. secatus* in the *Trachyceras aon* Zone (Cordevolian substage) and its persistence upwards into the *Halobia rugosa/Carnites floridus* Zone (Julian substage) and *Tropites subbullatus* Zone (Tuvalian substage).

The presence of *C. secatus* in late Carnian assemblages was confirmed by palynostratigraphic data coming from a section in Sicily (Visscher & Krystyn, 1978), where it was recovered from the *Tropites subbullatus* Zone or the "*Anatropites*-Bereich", indicative of the Tuvalian 3 substage (uppermost Carnian). The wide distribution of the *C. secatus* phase is demonstrated by its presence in the Alpine Triassic of Europe (Visscher & Brugman 1981), Italy (Van der Eem 1983; Broglio Lori-

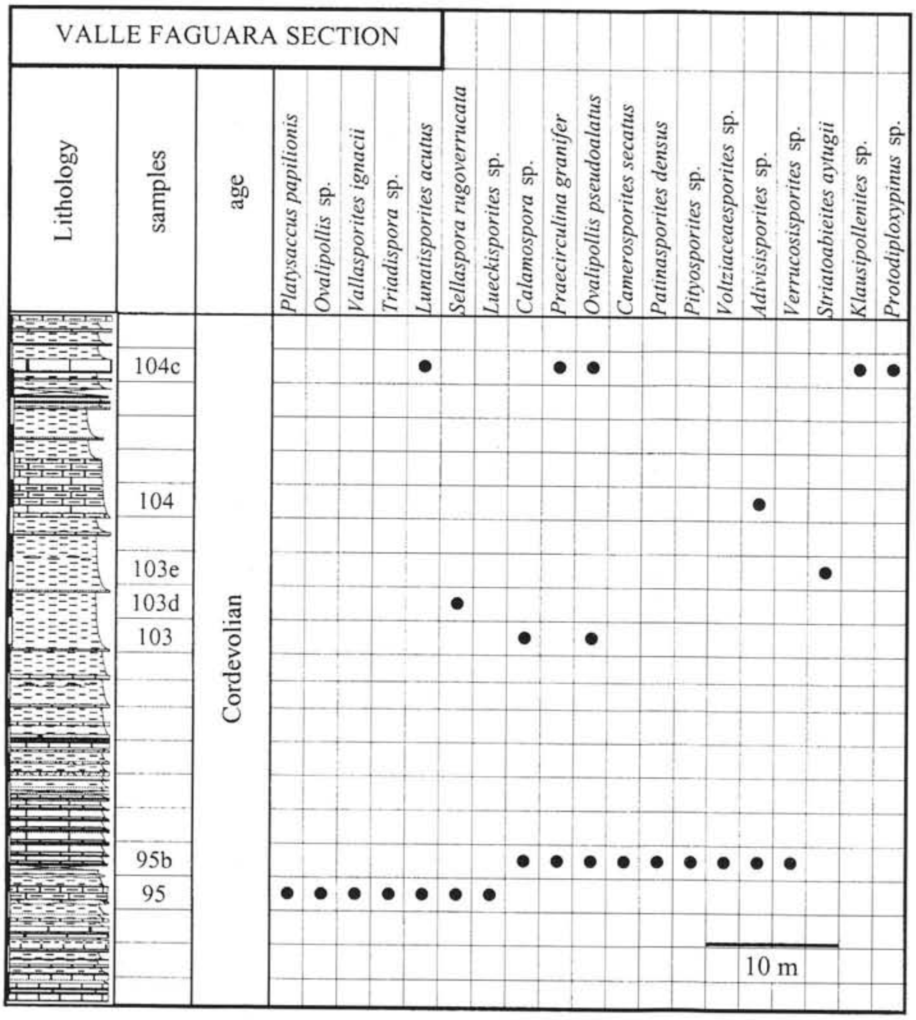


Fig. 8 - Distribution of palynomorphs in the Valle Faguara section.

ga et al. 1999), southern Albania (Cirilli & Montanari 1994), Israel (Cirilli and Eshet 1991), Africa (Bourmouche et al. 1996), the USA (Fisher & Dunay 1984; Litwin & Ash 1993), Arctic Canada (Fisher & Bujak 1975), Australia (Dolby & Balme 1976).

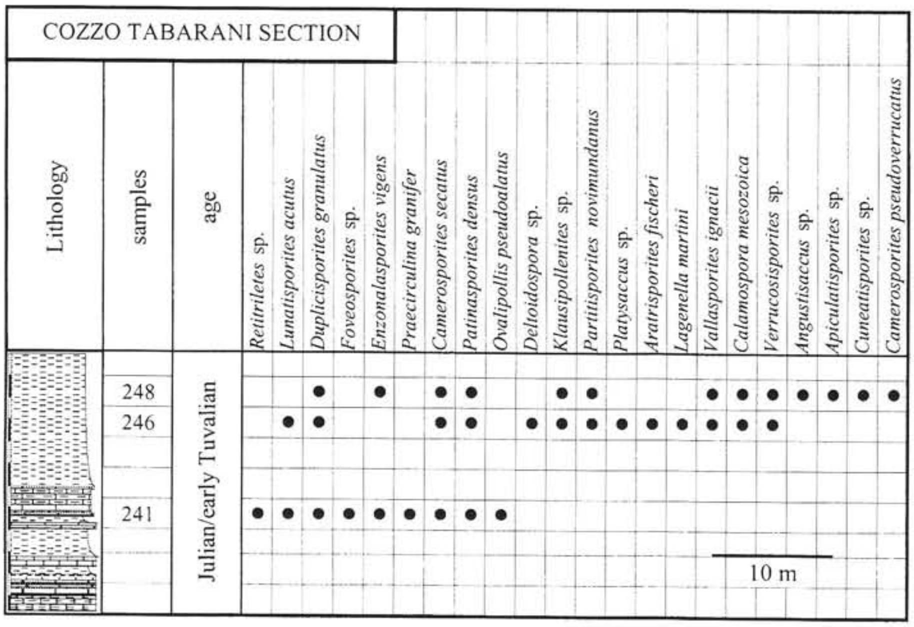
Because *C. secatus* ranges through the Carnian stage, it is unsuitable for a detailed biostratigraphic subdivision of that unit. Many authors (Dolby & Balme 1976; Visscher & Brugman 1981; Van der Eem 1983; Besems 1981a, b; 1983; Besems & Simon 1982; Brugman et al. 1994) tried to recognize compositional trends within the *C. secatus* phase and a subdivision at substage level was attempted, on the basis of a progressive diversification of associated miospore taxa.

The younger part of the phase is recognised by the incoming of taxa such as *Paracirculina quadruplicis* and *Samaropollenites speciosus* in association with *C. secatus* (Visscher et al. 1980), hence the co-occurrences of *C. secatus, Vallasporites ignacii, Enzonalasporites vigens and Patinasporites densus* with *P. quadruplicis* and *Samaropollenites speciosus* is considered indicative of the Tuvalian substage (Visscher & Krystyn 1978; Cirilli et al. 1990; Cirilli & Eshet 1991; Cirilli & Montanari 1994; Cirilli 1995; Warrington 1996).

Palynological assemblages from the Mufara Formation

In the present paper, we attempted to recognize successive qualitative steps in the compositional development of palynological assemblages in the Mufara Formation. Twenty one sections were investigated and 10 proved productive (Fig. 2, 3) yielding four distinctive and highly diversified palynological assemblages. The good preservation of the organic material, together with the abundance and diversity of the assemblages (Pl. 1, 2) allowed useful stratigraphic inferences and a correlation, where possible, with conodont data. The following assemblages are recognised:

Assemblage A. The microflora is characterised (Figs. 4, 5) by the occurrences of *Densosporites* sp., *Infernopollenites sulcatus, Weylandites magmus, Deltoidospora minor, Sellaspora* sp., *Equisetosporites* sp. and *Pseudoenzonalasporites summus* which are exclusive forms of this assemblage. A group of significant species, consisting of *Gordonispora fossulata, Paracirculina verrucosa, Sellaspora rugoverrucata, Duplicisporites granulatus, Foveosporites visscheri, Enzonalasporites vigens, Vallasporites ignacii, Patinasporites densus, Praecirculina granifer*, and *Partitisporites novimundanus* occurs in assemblage A and, sporadically, in some or all the other assemblages. These species are in association with a considerable number of long-ranging sporomorphs dominated by bisaccates. The composition of this assemblage is comparable with many other Tethyan and extra-Tethyan assemblages. *Patinasporites densus, Vallasporites ignacii* and *Enzonalasporites vigens* are considered typical Carnian forms. Their presence was reported from ammonoid-bearing successions in Austria (*Trachyceras aon* Zone; Dunay & Fisher 1978) and northern Italy (*Regoledanus* Zone and early part of the *Daxatina* cf. *canadensis* Subzone; Broglio Loriga et al. 1999; Van der Eem 1983; Blendinger 1988). The association of these forms, together with the occurrences of



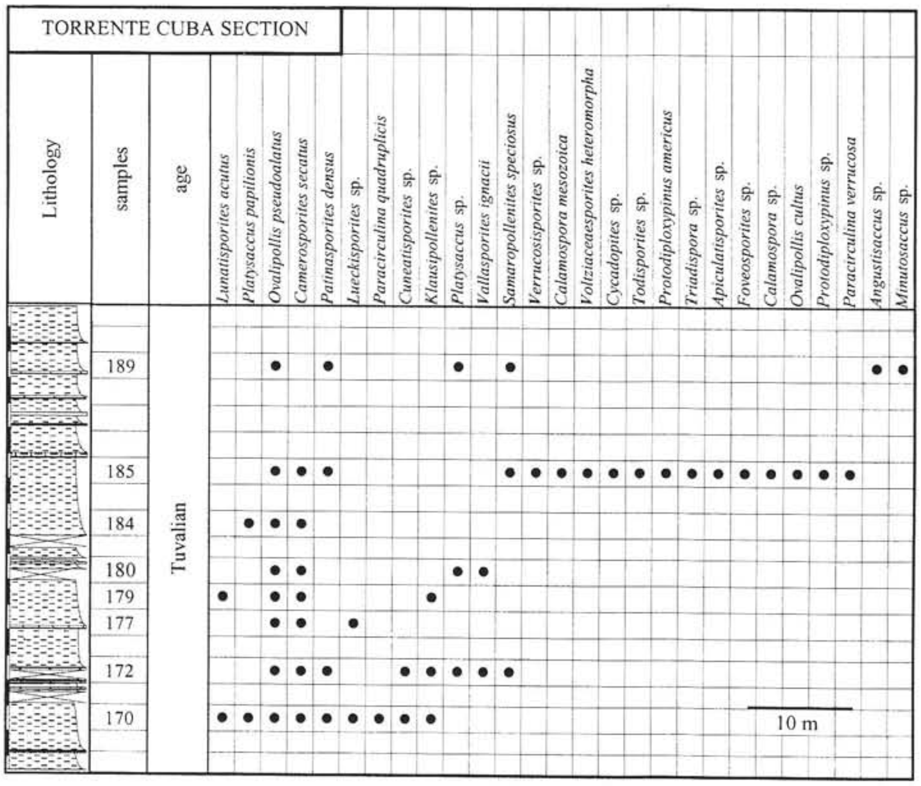


Fig. 9 - Distribution of palynomorphs in the Cozzo Tabarani section.

Fig. 10 - Distribution of palynomorphs in the Torrente Cuba section.

Duplicisporites granulatus, suggests an affinity with the Camerosporites secatus phase. However *Camerosporites secatus* is absent from assemblage A, and the vesicate group (comprising *P. densus*, *E. vigens* and *V. ignacii*) is in association with Ladinian-Carnian boundary elements such as *Foveosporites visscheri*, *Gordonispora fossulata*, *Partitisporites novimundanus*, *Sellaspora rugoverrucata* and *Weylandites magmus*. These Ladinian-Carnian forms have been recognised in Ladinian assemblages (Van der Eem 1983; Broglio Loriga et al. 1999; Blendinger 1988) and their LADs occur in the lower Cordevolian except in the case of *S. rugoverrucata* which seems to reach the upper Cordevolian or lower Julian (Van der Eem 1983; Blendinger 1988).

The main features that allow the grouping of these associations in assemblage A are the absence of *Camerosporites secatus* in combination with the presence of a mixture of upper Ladinian-Carnian and typical Carnian elements. This microfloral composition may reflect a transitional stage in the gradual change from a typical upper Ladinian association to an exclusively Carnian association. Assemblage A was found in the Vicari and the Cerda-Nicosia sections (Figs. 4, 5). These sections are therefore dated as late Ladinian-early Carnian. In the Vicari succession, a conodont association characterised by *Gladigondolella tethydis* (Pl. 3, Fig. 3a, 3b) and *Pseudozarkodina saginata* was found (sample CSI 218). This association ranges from the Illyrian (upper Anisian) to the upper Julian (Vrielynck 1987), which is not in conflict with the palynological data.

Assemblage B. The microflora is characterised by sporadic occurrences of *Camerosporites secatus* in association with many species which persist from the preceding assemblage A. Among these *Gordonispora fossulata*, *Foveosporites visscheri* and *Sellaspora rugoverrucata* disappear in this assemblage. *Striatoabieites aytugii*, *Aratrisporites tenuispinosus*, *A. paenulatus*, and *Kyrtomisporis ervii* occur for the first time in association with many additional elements (Figs. 6, 7, 8).

The composition of the assemblage B has a clear

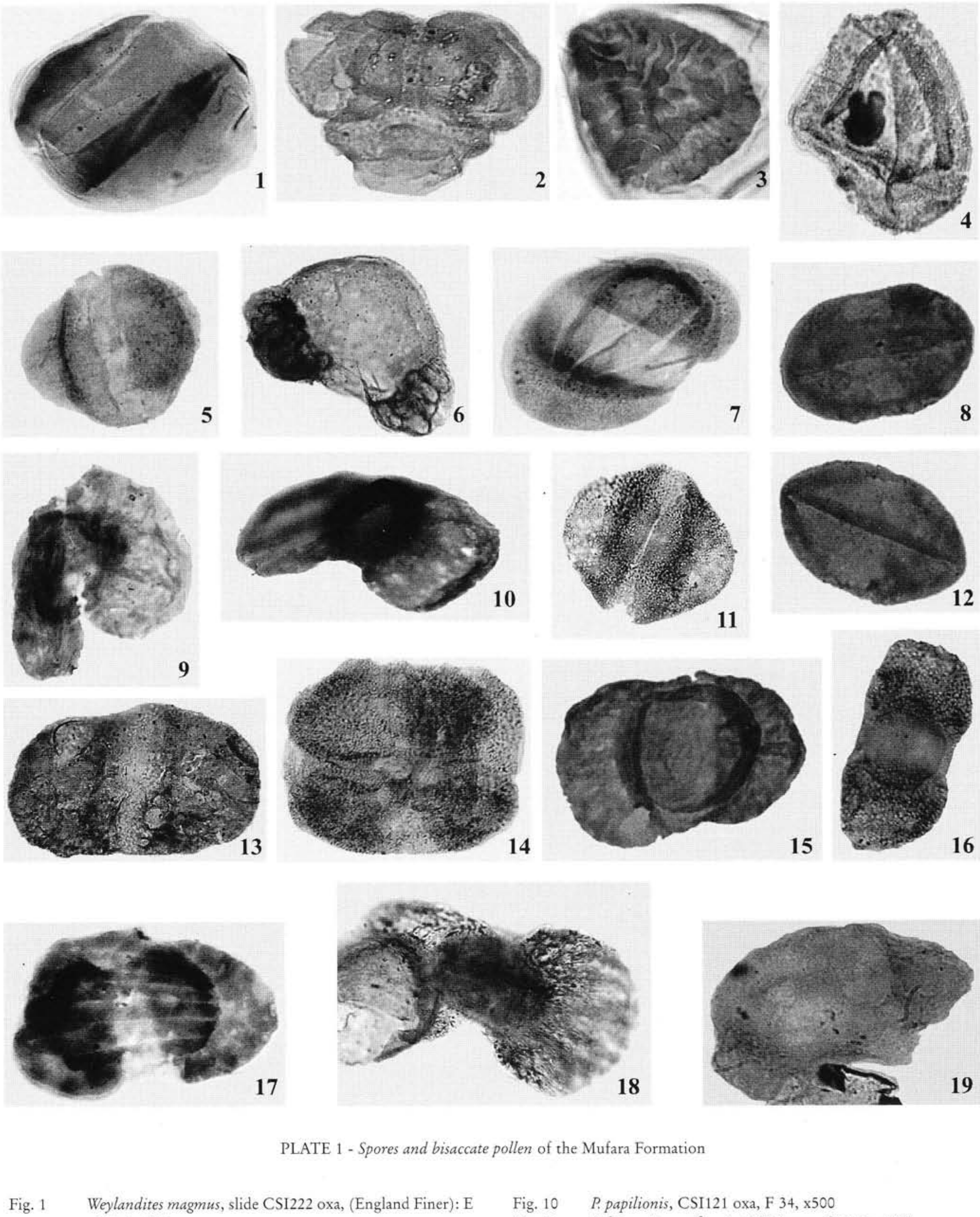


PLATE 1 - *Spores and bisaccate pollen* of the Mufara Formation

Fig. 1 *Weylandites magmus*, slide CSI222 oxa, (England Finer): E 25-4, x900
Fig. 2 *Paracirculina quadruplicis*, CSI31 oxa, E-43, x500
Fig. 3 *Kyrtomisporis ervii*, CSI143 oxa, O 26-2, x700
Fig. 4 *Duplicisporites granulatus*, CSI17 oxa, O-39, x1000
Fig. 5 *Protodiploxypinus americus*, CSI206 oxa, J 29-1, x700
Fig. 6 *Protodiploxypinus fastidiosus*, CSI31 oxa, E 25-1, x600
Fig. 7 *Lunatisporites acutus*, CSI222 oxa, H 29-2/4, x700
Fig. 8 *Ovalipollis pseudoalatus*, CSI195 oxa, E 28-4, x500
Fig. 9 *Platysaccus papilionis*, CSI222, E 28, x300
Fig. 10 *P. papilionis*, CSI121 oxa, F 34, x500
Fig. 11 *Falcisporites oviformis*, CSI56 oxa, G 28-3, x500
Fig. 12 *Ovalipollis pseudoalatus*, CSI195 oxa, F 30, x600
Fig. 13 *Cuneatisporites cerinus*, CSI31 oxa, F 41-4, x600
Fig. 14 *Staurosaccites quadrifidus*, CSI17 oxa, R 30-3, x800
Fig. 15 *Voltziaceaesporites heteromorpha*, CSI185 oxa, F 28-4, x500
Fig. 16 *Vitreisporites pallidus*, CSI19 oxa, N 39-4, x1000
Fig. 17 *Striatoabieites aytugii*, CSI124 oxa, G 38-4, x600
Fig. 18 *Chordasporites chinleanus*, CSI56 oxa, B 39-3, x600
Fig. 19 *Klausipollenites* sp., CSI31 oxa, J 43-2, x900

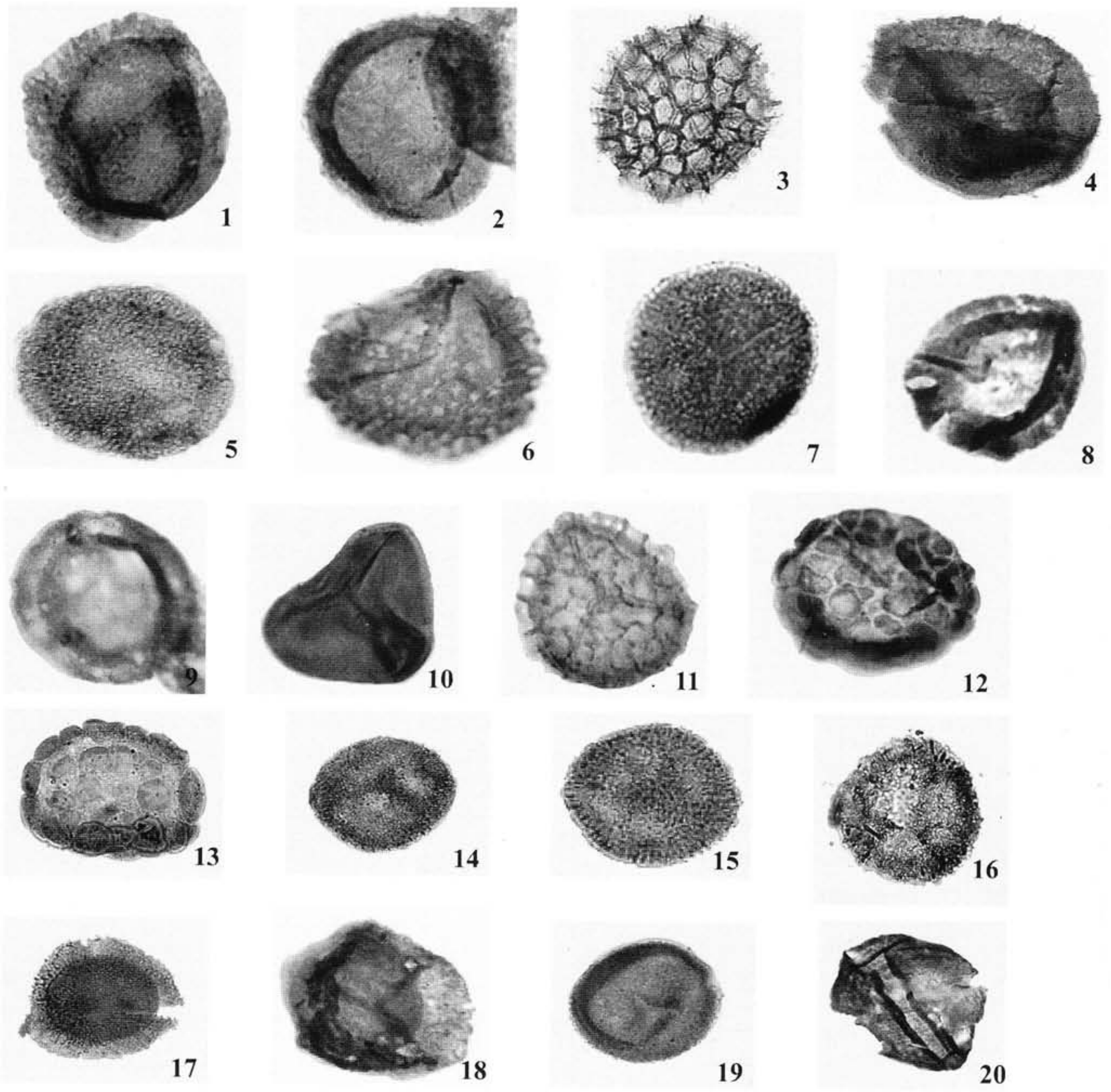
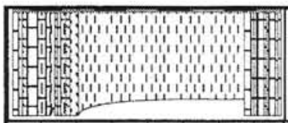


PLATE 2 - Spores and pollen of the Mufara Formation.

Fig. 1 *Paracirculina verrucosa*, CSI222 oxa, F 22-1, x800
Fig. 2 *P. verrucosa*, CSI222 oxa, H 29-4, x800
Fig. 3 *Reticulatisporites dolomiticus*, CSI197 oxa, Q 24-1, x800
Fig. 4 *Aratrisporites tenuispinosus*, CSI121 oxa, T 21-4, x700
Fig. 5 *Enzonalasporites vigens*, CSI19 oxa, S 32-1, x900
Fig. 6 *Foveosporites visscheri*, CSI222 oxa, J 19, x500
Fig. 7 *Pseudoenzonalasporites summus*, CSI222 oxa, H 30-2, x600
Fig. 8 *Duplicisporites granulatus*, CSI246 oxa, S 27-4, x800
Fig. 9 *Partitisporites novimundanus*, CSI124 oxa, J 42, x800
Fig. 10 *Deltoidospora minor*, CSI222 oxa, E 37-3, x800
Fig. 11 *Krauselisporites* sp., CSI222 oxa, H 22-1, x500
Fig. 12 *Camerosporites secatus*, CSI185 oxa, O 46-3, x700
Fig. 13 *C. secatus*, CSI25 oxa, F 23, x700
Fig. 14 *Vallasporites ignacii*, CSI22 oxa, G 42-4, x600
Fig. 15 *Enzonalasporites vigens*, CSI19 oxa, J 37-2, x700
Fig. 16 *Vallasporites ignacii*, CSI22 oxa, R 19-3, x600
Fig. 17 *Patinasporites densus*, CSI22 oxa, M43, x500
Fig. 18 *Gordonispora fossulata*, CSI121 oxa, J 40, x1000
Fig. 19 *Praecirculina granifer*, CSI26 oxa, M 30-2/1, x1000
Fig. 20 *Lagenella martinii*, CSI246 oxa, F 40-4, x900

All the slides are housed in the Département de Geologie et Paléontologie, Univ. de Genève.



LA PIZZUTA SECTION

Lithology						
samples	52	55	56	57	58	59
age	Tuvalian					
Verrucosisporites sp.	●	●	●			●
Klausipollenites sp.	●	●	●	●	●	●
Platysaccus sp.	●					
Aratrisporites sp.	●					
Enzonalasporites vigens	●					
Camerosporites secatus	●	●	●	●	●	●
Ovalipollis pseudoalatus	●	●	●	●	●	●
Chordasporites chinleanus	●		●			
Parillinites sp.	●					
Concavisporites sp.	●					
Duplicisporites verrucosus		●				
Duplicisporites granulatus		●			●	●
Vallasporites ignacii		●			●	
Patinasporites densus		●	●	●	●	
Paracirculina quadruplicis		●	●			
Alisporites sp.		●	●	●		●
Minutosaccus sp.		●				
Converrucosisporites sp.		●				
Lunatisporites acutus			●			
Staurosaccites quadrifidus			●			
Falcisporites oviformis			●			
Lunatisporites noviaulensis			●			
Praecirculina granifer			●			
Apiculatisporites sp.			●			
Cuneatisporites sp.			●		●	●
Schizosaccus sp.			●			
Platysaccus papilionis				●		●
Sellaspora foveorugulata				●		
Pityosporites sp.				●		
Triadispora sp.					●	●
Calamospora sp.					●	
Cycadopites sp.						●
Protodiploxypinus sp.						●
Ovalipollis sp.						●

10 m

Fig. 11 - Distribution of palynomorphs in the La Pizzuta section.

resemblance with Carnian associations (Visscher & Krystyn 1978; Cirilli 1995), on the basis of the presence of circumsulcate (*Camerosporites secatus*) and vesicate forms (*Vallasporites ignacii, Praecirculina granifer, Patinasporites densus*). Some other elements allow a more detailed age assessment. Apparent LADs of *Gordonispora fossulata, Foveosporites visscheri* and *Sellaspora rugoverrucata* and the presence of *Kyrtomisporis ervii* (Van der Eem 1983) confines the age to the early Carnian. Comparison with Van der Eem's (1983) palynological study of Carnian sediments in northern Italy suggests to attribute this assemblage to the *vigens-densus* phase (Cordevolian, lower Carnian). The sporomorph composition of assemblage B is recognised in the Pizzo Montanello, Monte Mufara, and Vallone Faguara section (Figs. 6, 7, 8) dating them as Cordevolian-early Julian.

A conodont assemblage from the Monte Mufara section (sample CSI 105) is composed of specimens of *Gondolella* sp. and *Didymodella alternata* which suggest a pre-Tuvalian age (Vrielynck 1987).

Assemblage C. The microflora is characterised by the more or less continuous presence of *Camerosporites secatus*, together with a significant group of taxa already present in assemblages A and B. The first incoming of *Aratrisporites fischeri, Lagenella martinii, Angustisulacites* sp. and *Camerosporites pseudoverrucatus* was recorded, with the appearance of *A. fisheri* and *L. martinii* being the most remarkable event (Fig. 9). *L. martinii* is known from an ammonoid controlled succession in Austria, where it was recorded in the upper part of the *Halobia rugosa/Carnites floridus* Zone (Dunay & Fisher 1978), and elsewhere in Europe from the basal Cordevolian to the Julian (Van der Eem 1983) and from middle Cordevolian to lower Tuvalian (Visscher & Brugman 1981). On the basis of its biostratigraphic range, assemblage C may be interpreted as transitional between the preceding lower Carnian assemblage B and the succeeding upper Carnian (Tuvalian) assemblage D. Another significant datum is the presence of *Partitisporites novimundanus* which was not noted in assemblage D. The LAD of *P. novimundanus* is in the Julian Substage *densus-maljawkinae* phase (Van der Eem 1983).

The assemblage was recognised in the Cozzo Tabarani section (Fig. 9). The essentially transitional nature is interpreted in terms of a mid-Carnian (Julian)/early Tuvalian age.

No conodonts were found in association with this assemblage.

Assemblage D. The assemblage is characterised by a group of new microfloral elements, including *Paracirculina quadruplicis, Samaropollenites speciosus, Voltziaceaesporites heteromorpha, Protodiploxypinus americus, Reticulatisporites dolomiticus, Sellaspora foveorugulata, Samaropollenites concinnus, Chordasporites chinleanus, Aratrisporites* sp., *Falcisporites oviformis, Lunatisporites noviaulensis, Triadispora vilis, T. aurea, Lycopodiacidites* sp., *Circella splendida, Pyramidosporites traversei* and *Microcachrydites fastidioides*. Many of the additional elements recorded in assemblages A, B and C are still present (Figs. 10, 11, 12, 13). *Camerosporites secatus* is abundant in all the sections but *Patinasporites densus* occurs only sporadically. The combined presence of *Enzonalasporites vigens, Vallasporites ignacii, Duplicisporites granulatus* and *Praecirculina granifer,* already characterising

COZZO PAPARINA SECTION

Lithology

samples	195	197	200	202	206	207	208
age	Tuvalian						
Alisporites sp.	●						●
Deltoidospora sp.	●						
Parillinites sp.	●						
Lunatisporites acutus	●	●					●
Vitreisporites pallidus	●						
Praecirculina granifer	●						
Ovalipollis pseudoalatus	●	●	●		●		●
Vallasporites ignacii	●				●		
Duplicisporites sp.	●				●		
Camerosporites secatus	●	●	●	●	●	●	●
Paracirculina quadruplicis	●				●		
Samaropollenites speciosus	●						
Klausipollenites sp.	●				●		●
Platysaccus sp.		●			●		
Cuneatisporites sp.		●			●		
Angustisaccus sp.		●			●		●
Sellaspora foveorugulata		●					
Reticulatisporites dolomiticus		●					
Verrucosisporites sp.		●			●		
Krauselisporites sp.					●		
Converrucosisporites sp.					●		
Paracirculina verrucosa					●		●
Enzonalasporites vigens					●		
Patinasporites densus					●		●
Protodiploxypinus americus					●		
Concavisporites sp.					●		
Staurosaccites quadrifidus						●	●
Calamospora sp.							●
Calamospora mesozoica							●
Triadispora sp.							●
Ovalipollis cultus							●
Samaropollenites concinnus							●
Ovalipollis sp.							●
Platysaccus papilionis							●
Duplicisporites granulatus							●

10 m

Fig. 12 - Distribution of palynomorphs in the Cozzo Paparina section.

GAMBANERA SECTION

Lithology

samples	13	15	17	19	22	22b	25	26	27c	29	31
age	Tuvalian										
Cuneatisporites cerinus	●	●	●								●
Cuneatisporites sp.	●										●
Triadispora sp.	●	●	●	●	●						●
Ovalipollis cultus	●	●									
Ovalipollis pseudoalatus	●	●		●	●		●	●	●	●	●
Duplicisporites granulatus	●		●		●				●		
Vallasporites ignacii	●	●		●	●		●	●	●		●
Samaropollenites speciosus	●	●	●	●			●			●	●
Camerosporites secatus	●	●	●	●	●	●	●	●	●	●	●
Paracirculina quadruplicis	●	●	●	●	●			●			●
Calamospora sp.	●	●	●	●	●						●
Triadispora vilis		●									●
Enzonalasporites vigens		●	●	●	●				●	●	●
Patinasporites densus		●			●	●	●	●	●	●	●
Calamospora mesozoica		●	●		●		●				
Triadispora aurea			●								
Vitreisporites pallidus			●		●						
Staurosaccites quadrifidus			●								
Platysaccus papilionis			●	●	●		●		●	●	
Alisporites sp.			●	●	●		●			●	●
Praecirculina granifer				●				●			
Angustisulcites sp.				●							
Converrucosisporites sp.					●			●			
Klausipollenites sp.					●		●	●			●
Minutosaccus sp.					●						
Todisporites sp.							●				
Protodiploxypinus sp.							●			●	
Concavisporites sp.							●				
Lycopodiacidites sp.								●			
Verrucosisporites sp.								●		●	
Schizosaccus sp.								●			
Voltziaceaesporites sp.								●			
Paracirculina verrucosa								●			
Pyramisosporites traversei										●	
Lunatisporites acutus										●	
Circella splendida										●	
Protodiploxypinus fastidiosus											●

10 m

Fig. 13 - Distribution of palynomorphs in the Gambanera section.

assemblage C, *the new elements Paracirculina quadruplicis* and *Samaropollenites speciosus*, must be considered as late Carnian (Tuvalian). A late Carnian age appears to be confirmed by the presence of some constituents of the secondary group, *Voltziaceaesporites heteromorpha, Protodiploxypinus americus, Chordasporites chinleanus,* and *Lunatisporites noviaulensis*, which are often recorded in Upper Carnian successions from North America (Dunay & Fisher 1979; Fisher & Dunay 1984; Litwin et al. 1991), and by the absence of *Partitisporites novimundanus*.

The microfloral composition of this assemblage is recorded in many sections of the Mufara Formation, such as Torrente Cuba, La Pizzuta, Cozzo Paparina and Gambanera (Figs. 10, 11, 12, 13) which are therefore referred to the late Carnian (Tuvalian).

A conodont association recovered from the Gambanera succession (samples CSI 23, CSI 30) is distinguished by the presence of *Paragondolella polygnathiformis* (Pl. 3, Fig. 2a, 2b) and *Metapolygnathus abneptis* (Pl. 3, Fig. 1a, 1b); the occurrence of these forms is not in conflict with a late Carnian (Tuvalian) palynological assemblage (Vrielynck 1987; Di Stefano 1988).

Conclusions

This analysis enabled the construction of a palynostratigraphic framework for the Mufara Formation,

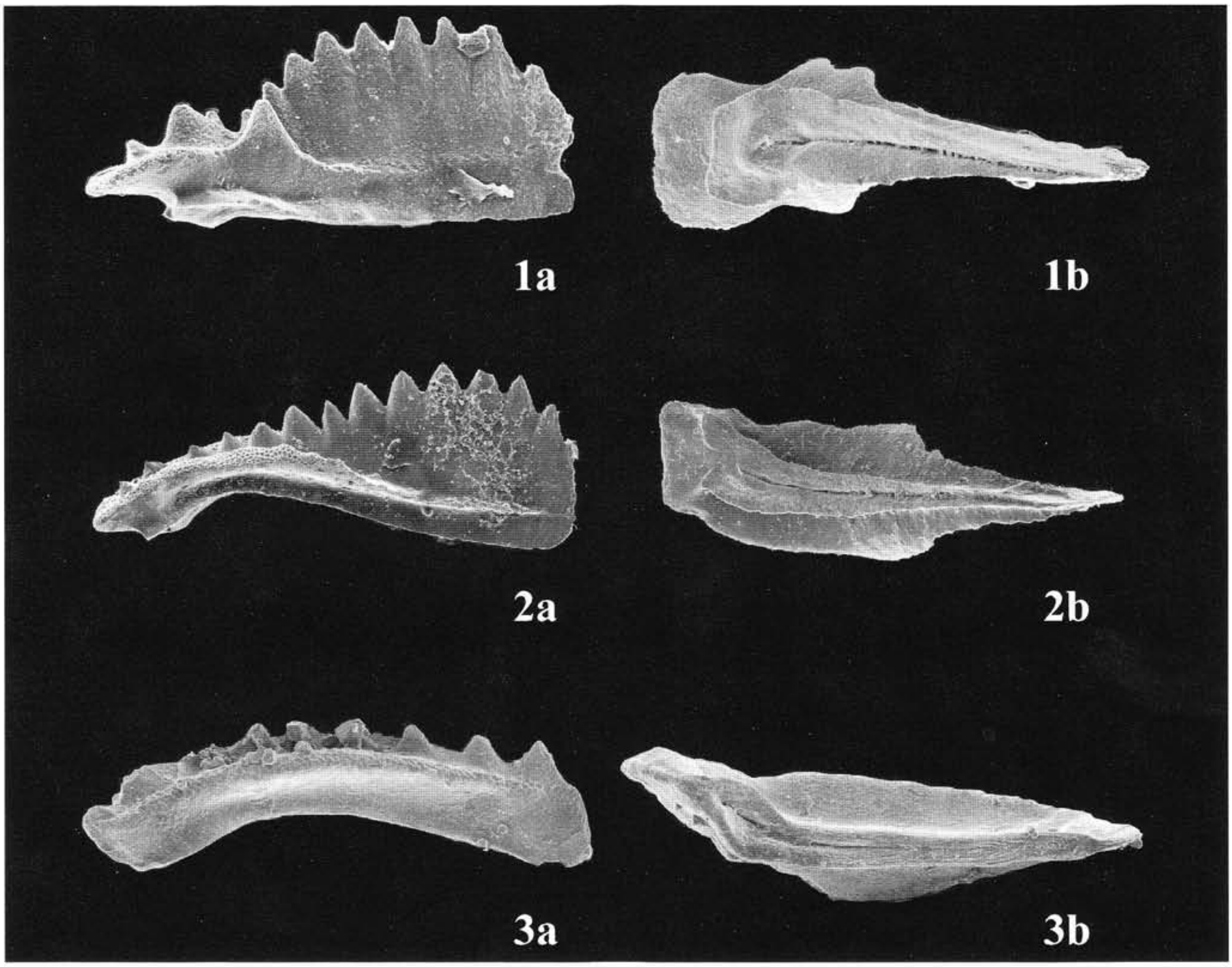


PLATE 3

Fig. 1a	*Metapolygnathus abneptis*, juvenile form (220X, lateral view)
Fig. 1b	*Metapolygnathus abneptis*, juvenile form (220X, aboral view)
Fig. 2a	*Paragondolella polygnathiformis* (150X, lateral view)
Fig. 2b	*Paragondolella polygnathiformis* (150X, aboral view)
Fig. 3a	*Gladigondolella tethydis* (150X, lateral view)
Fig. 3b	*Gladigondolella tethydis* (150X, aboral view)

and provided information on the deposition of the unit from the late Longobardian/early Cordevolian (Ladinian-Carnian boundary) to the late Tuvalian (late Carnian). It represents an important base for successive investigations, helping to understand the development of the Mufara basin and its palaeoenvironmental evolution. Further investigations are needed to assess the exact stratigraphic relationships between successions containing assemblage A (Cerda-Nicosia and Vicari sections), assemblage B (Valle Faguara, Monte Mufara and Pizzo Montanello sections) and D (Torrente Cuba, Cozzo Paparina, La Pizzuta and Gambanera). The construction of a composite section of the Mufara Fm. was attempted on the basis of palynological data and the scheme depicted in Fig. 2 and 3 was drawn to explain the gradual diversification of the associations; however, the hypothesis of possible lateral interfingering cannot be excluded.

Furthermore, the palynological analysis identified a trend in the compositional evolution of the assemblages within the *Camerosporites secatus* phase. This trend is characterised by the successive incoming of new taxa within the *C. secatus* phase, which define four different palynological assemblages.

This new evidence refines the stratigraphic framework for the Mufara Formation providing further perspectives and causing repercussions to the attempts of applying the *C. secatus* phase in previous palynostratigraphic studies (Dolby & Balme 1976; Visscher & Brugman 1981; Van der Eem 1983; Besems 1981a, b, 1983; Besems & Simon 1982; Brugman et al. 1994).

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Species list

A listing of spores and pollen species identified and quoted in the text and illustrated in the figures is given below:

Alisporites robustus Nilsson, 1958
Aratrisporites fischeri (Klaus 1960) Playford & Dettmann, 1965
Aratrisporites paenulatus (Klaus 1960) Playford & Dettmann, 1965
Aratrisporites tenuispinosus Playford, 1965 (Pl. 2, Fig. 4)
Calamospora mesozoica Couper, 1958
Camerosporites secatus Leschik, 1956 (Pl. 2, Figs. 12, 13)
Camerosporites pseudoverrucatus Scheuring 1970
Chordasporites chinleanus (Daugherty) Dunay & Fisher, 1979 (Pl. 1, Fig. 18)
Circella splendida Sukh Dev 1959
Cuneatisporites cerinus Dolby & Balme, 1976 (Pl. 1, Fig. 13)
Deltoidospora minor (Couper, 1953) Pocock, 1970 (Pl. 2, Fig. 10)
Duplicisporites granulatus Leschik, 1956 (Pl. 1, Fig. 4; Pl. 2, Fig. 8)
Duplicisporites verrucosus (Leschik, 1956) emend. Scheuring, 1970
Enzonalasporites vigens Leschik, 1956, (Pl. 2, Figs. 5, 15)
Falcisporites oviformis Dunay & Fisher, 1979 (Pl. 1, Fig. 11)
Foveosporites visscheri Van Erve, 1977 (Pl. 2, Fig. 6)
Gordonispora fossulata (Balme 1970) Van der Eem, 1983 (Pl. 2, Fig. 18)
Infernopollenites sulcatus (Pautsch 1958) Scheuring, 1970
Kyrtomisporis ervii Van der Eem, 1983 (Pl. 1, Fig. 3)
Lagenella martinii (Leschik, 1956) Klaus, 1960 (Pl. 2, Fig. 20)
Lunatisporites acutus Leschik, 1956 (Pl. 1, Fig. 7)
Lunatisporites noviaulensis Leschik 1956
Protodiploxypinus fastidiosus (Jansonius) Warrington 1974 (Pl. 1, Fig. 6)
Ovalipollis cultus Scheuring, 1970
Ovalipollis pseudoalatus (Thiergart 1949) Schuurman, 1976 (Pl. 1, Figs. 8, 12)
Praecirculina granifer Leschik, 1956 Klaus, 1960 (Pl. 2, Fig. 19)
Paracirculina quadruplicis (Scheuring 1970) Van der Eem, 1983 (Pl. 1, Fig. 2)
Partitisporites novimundanus (Leschik, 1956) (Pl. 2, Fig. 11)
Paracirculina verrucosa Praehauser-Enzenberg, 1970 (Pl. 2, Figs. 1, 2)
Patinasporites densus Leschik, 1956 (Pl. 2, Fig. 17)
Platysaccus papilionis Potonié & Klaus, 1954 (Pl. 1, Figs. 9, 10)
Protodiploxypinus americus Dunay & Fisher, 1979 (Pl. 1, Fig. 5)
Pseudoenzonalasporites summus Scheuring 1970 (Pl. 2, Fig. 7)
Pyramidosporites traversei Dunay & Fisher, 1979
Reticulatisporites dolomiticus Blendinger 1988 (Pl. 2, Fig. 3)
Samaropollenites speciosus Goubin, 1965 (Pl. 1, Fig. 19)
Samaropollenites concinnus Fisher & Dunay 1974
Sellaspora rugoverrucata Van der Eem, 1983
Staurosaccites quadrifidus Dolby, in Dolby & Balme, 1976 (Pl. 1, Fig. 14)
Striatoabieites aytugii Visscher, 1966 (Pl. 1, Fig. 17)
Triadispora aurea Scheuring, 1970 emend. Scheuring 1978
Triadispora vilis Scheuring, 1970
Vallasporites ignacii Leschik, 1956 (Pl. 2, Figs. 14, 16)
Voltziaceaesporites heteromorpha Klaus, 1964 (Pl. 1, Fig. 15)
Vitreisporites pallidus (Reissinger) Nilsson, 1958 (Pl. 1, Fig. 16)
Weylandites magnus (Bose & Kar 1966) Van der Eem, 1983 (Pl. 1, Fig. 1)

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