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Palynology (dinoflagellate cysts, spore-pollen) and stratigraphy of the Lower Carnian Raibl Group in the Eastern Swiss Alps

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Key words: Austroalpine Silvretta Nappe, Early Carnian, stratigraphy, palynology, dinoflagellate cysts, spore-pollen, organic matter, maturity

ABSTRACT

Within the almost purely dolomitic units of the Triassic of the Austroalpine realm (Ladinian to Norian), the Cluozza Member is characterized as a conspicuously siliciclastic interval in the upper part of the Raibl Group. It represents a well-defined correlateable event in the Austroalpine Upper Triassic of Graubünden. Based on the present palynological evidence it can be assigned to the Early Carnian (Julian). The composition of the palynological assemblages is closely comparable to those of the upper Lunzer beds in the Alpine realm and to the Schilfsandstein in the Germanic basin. The palynological and lithological evidence indicates that these sediments have been deposited under humid conditions. The data also suggest that the Cluozza Member corresponds to the transgressive phase of an Early Carnian sequence (Car1 or Car2).

The dinoflagellate cysts observed in the studied assemblages are not only the oldest found in the Northern Hemisphere but represent worldwide the oldest dinoflagellate records from low latitude sites.

ZUSAMMENFASSUNG

Innerhalb der dolomitischen Einheiten der Ostalpinen Trias (Ladinian–Norian) ist das Cluozza-Member im oberen Abschnitt der Raibl-Gruppe durch siliziklastische Sedimente charakterisiert. In der Ostalpinen Trias Graubündens stellt es einen eindeutig korrelierbaren Horizont dar. Aufgrund der vorliegenden palynologischen Untersuchungen ist dieses Member dem unteren Carnian (Julian) zuzuweisen. Die Zusammensetzung der palynologischen Assoziationen zeigt auffallende Ähnlichkeit mit jenen der oberen Lunzer Schichten im alpinen sowie mit jenen aus dem Schilfsandstein im germanischen Bereich. Die lithologische und die palynologische Evidenz weisen auf feuchte Klimabedingungen zur Zeit der Ablagerung dieser Schichten hin. Aufgrund der vorliegenden Daten wird das Cluozza-Member als transgressive Phase einer Sequenz des unteren Carnian (Car1 oder Car2) gedeutet.

Die nachgewiesenen Dinoflagellaten-Zysten sind nicht nur die bisher ältesten der Nordhemisphäre, sondern stellen weltweit den frühesten Nachweis in Lokalitäten niedriger Paläobreiten dar.

Introduction

The studied section in the Ducan area is part of the Austroalpine Silvretta nappe (Eastern Alps of Switzerland), which comprises basement and a Mesozoic sediment cover with thick Middle to Late Triassic sections (cf. Fig. 1). Most of this interval consists of shallow marine dolomites. Within this context the Cluozza Member, a sequence with clastic sedimentation, represents a distinct element in the upper part of the Raibl Group (cf. Fig. 2 and 3). The Early Carnian age of the Raibl Group of the Upper Austroalpine nappes is essentially inferred from lamellibranchiata evidence. However, due to the facies dependence of these fossils, the precise age remains a matter of dispute (cf. Frank 1986). The stratigraphic interpretation of the Raibl Group varies depending on different regional concepts. The rather loose biostratigraphic constraints are responsible for the ongoing dispute. Whereas Rüffer & Zühlke (1994) interpret the Raibl Group of the Southern Alps and of the Northern Calcareous Alps as an equivalent event in the Early Carnian (sequence Car2), other authors, such as Gianolla et al. (1998, Fig. 4) assign this unit to the latest Carnian in the Southern Alps and consequently to the uppermost Carnian sedimentary sequence (Car4). According to several lines of evidence, the facies realms of the Eastern Alps and the Northern Calcareous Alps are closely related (for reference see Trümpy 1980). In all the areas considered, the Raibl Group is overlain by the carbonates of the Hauptdolomit Group which is of latest Carnian to Norian age. In the study area there is convincing evidence for a major hiatus between the Raibl Group and the Hauptdolomit (see discussion below).

The palynological results from 6 samples of the siliciclastic Cluozza Member in the profile FZ (Fanezfurgga, cf. Fig. 2 and

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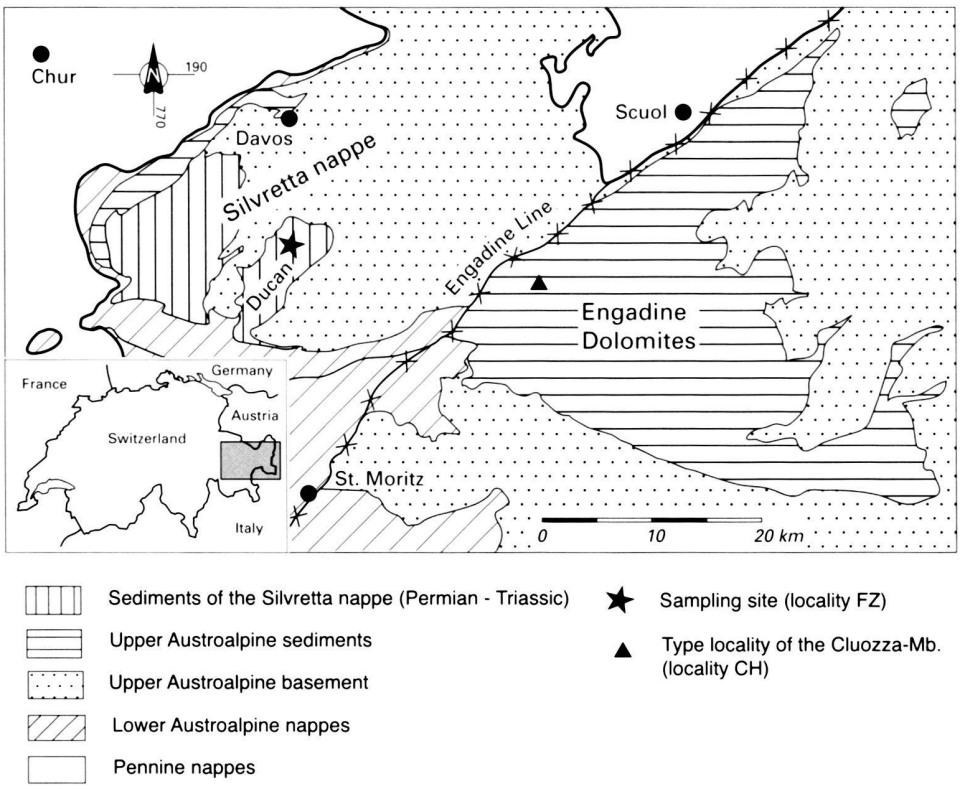

Fig. 1. Sketch map of the western end of the Austroalpine nappes in Graubünden, Switzerland. Location of the Ducan range (Silvretta nappe) and sampling sites.

3) and a few samples from the Engadine Dolomites allows us to position these beds more accurately within the stratigraphic framework. The sedimentary sequences in the Ducan range underwent the lowest grade metamorphose of the whole central Austroalpine nappe pile (Trümpy 1980). Although of brown or black color, most of the palynomorphs of the studied section are sufficiently well preserved to allow specific determination. In contrast to samples from equivalent sections from deeper tectonic positions, most samples contain abundant organic debris, mostly wood and cuticles, and common spore-pollen. Compared to the terrestrial palynomorphs, algal remains of marine to brackish or fresh-water origin are rare. The overall composition of the palynomorph assemblages is relatively homogeneous.

Geological Framework

In the Ducan range situated south of Davos in Eastern Switzerland (cf. Fig. 1) the oldest part of the sedimentary cover of the Central Austroalpine Silvretta nappe (Permian to Rhaetian age) is fully exposed (see overview in Trümpy 1980 and Furrer 1985). For details concerning the tectonic framework of the studied section we refer to Eichenberger (1986) and Froitzheim et al. (1994).

In the Triassic Central Austroalpine sedimentary sequence, five major transgressional-regressionai cycles can be distinguished (Furrer et al. 1992). The topic of the present study is the biostratigraphic calibration of the purely siliciclastic intercalation in the lower part of the Carnian dolomitic sequence. In our view this short-lived and consistently recognizable event is important for correlations in the Triassic of the Central Austroalpine area and the Northern Calcareous Alps (Fig. 2). The Central Austroalpine Raibl Group is defined as a rather heterogeneous accumulation of sediments between the Middle Triassic carbonate complex and the Upper Triassic Hauptdolomit Group (cf. Furrer 1985). Within the Raibl Group two formations have been differentiated by Frank (1986): the Mingèr Formation for the lower part and the overlying Fanez Formation (Fig. 3).

The upper part of the approximately 100 m thick Mingèr Formation is represented by dolomites, often showing fenestral and stromatolitic fabrics. Some layers are characterized by vadose textures (dripstone cements, pisolites, rhizolites). In the measured profile intercalations of up to 1 m thick dark shales occur every 5 to 10 m. These beds represent episodes of high siliciclastic influx from the coastal hinterland probably due to increased rainfall in a monsoon-like climate. The influx of freshwater might be responsible for fast dolomitization and vadose cementation of the carbonate sediments. The studied succession was deposited in an inter- to supratidal sabkha environment. This interpretation is consistent with the absence of fossils of normal marine provenance. Only a few ostracods and

Fig. 2. Outcrop of the Raibl Group at Fanezfurgga (location FZ) viewed from SW with the black sediments of the Cluozza Member in the center, the upper part of the Fanez Formation with Innerchrachen bed to the left, and the underlying Mingèr Formation to the right (Swiss Coordinates: 782'350 / 174'200).

gastropods have been found. The observation of the finest sedimentary structures is obscured by intense recrystallisation. However, yellowish dolomicrites can be regularly observed and are explained as calcretisation phenomena. In some cases they are accompanied by thin green to purple residual shale layers. The complete array of subaerial exposure structures is seldom preserved (cf. Frank 1986). For this reason these sediments probably represent periods of very different duration.

The uppermost bed of the Mingèr Formation consists of yellowish to brownish fine micritic and highly recrystallized peloidal dolomites. Noteworthy are fenestral fabrics outlined by limonitic seams and some hematitic clusters or nets at the contact to the overlying Fanez Formation. Arakel (1982) interpreted identical features as effects of calcretisation, hence subaerial exposure.

In the approximately 1400 m thick, shallow platform carbonate lithologies of Anisian to Norian age in the Ducan range, the Fanez Formation represents the most striking sedimentary sequence. The basal part of this formation, defined as the Cluozza Member, is characterized by an influx of fine siliciclastics (Frank 1986). The studied profile at the Fanezfurgga locality (profile FZ, Fig. 2 and 3) lies in a region of relatively low tectonic activity whereas in neighboring areas the shale layers are often squeezed out or are tectonically thickened. The approximately 2 m thick interval of black shales at the base of the Cluozza Member (cf. samples FZ 1-95, FZ 2-95) are quite rich in mica-detritus on the bedding planes. A first sandstone layer above the shales exhibits intense bioturbation at its base with recognizable trace fossils of the genera *Phycodes* and *Planolites*. The traces are partly filled with phosphatic nodules and are often accompanied by coprolites. The fine-grained sandstones contain abundant white micas and a few plant debris, which are marked by alignments of intensely weathered pyrite crystals. A second shale layer (sample FZ 3-95) is followed by a 5 to 10 cm thick fine-grained sandstone bed, which varies laterally in its composition. It is partly replaced by a brownish sandy dolomite in a section 1.5 km to the southwest. The latter yielded coprolites, fish remains (teeth, ganoid scales), a few bivalves (*Chlamys* sp., and other indeterminable shell fragments) and isolated capitular plates of a lepadomorph crustacean (barnacles) (Furrer *et al.*, in prep.). Comparing the lithostratigraphic sequences, this bed can be correlated with the richest fossil-bearing layer at the type locality of the Cluozza Member in the Engadine Dolomites (locality CH, Fig. 1). There, bivalves such as *Heminajas fissidentata* and *Schafhaeutlia* sp. (possibly *Sch.* cf. *mellingi*) are regularly found. They are considered typical for the lower part of the Carnian (Spitz & Dyhrenfurth 1914, Lieberman 1979). In the Northern Engadine Dolomites a bonebed-like, coarse-grained sand layer, very rich in fish teeth and scales, occurs 2.5 m above the base of the Cluozza Member. The fossil content of this bed provides evidence of marine conditions in all studied sections.

A third, nearly 2 m thick black shale layer is characterized by a very fine granulometry and in parts parallel laminations caused by fine silt or sand intercalations (samples FZ 4-95, FZ 9-83 and FZ 5-95). The overlying sequence is dominated by fine to medium grained arkosic sandstones with cross- and flaser bedding. Compared to the interval below the number and the size of plant remains increases; a few 2–5 cm long, pyritized fragments of *Equisetites* sp. and leaves of the *Ptilophyllum* type were found in different horizons. A color change

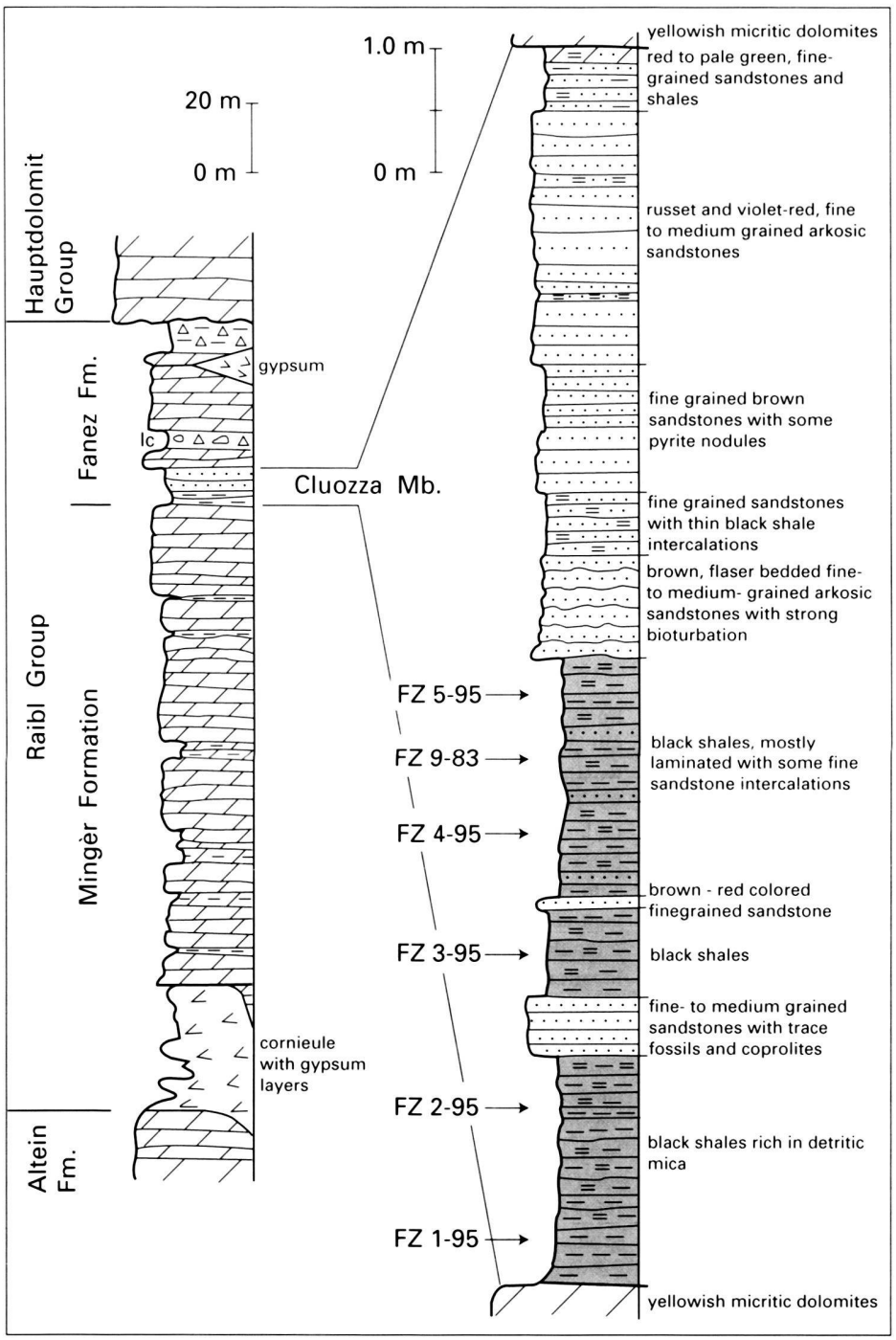

Fig. 3. Profile of the Cluozza Member, overview and detailed lithological section with sampling horizons (FZ). Ic marks the Innerchrachen bed.

from black and brown in the basal, sand-dominated layers, to russet and violet-red in the upper part is a striking feature of this part of the section. This color change varies laterally over a distance of 5 km and obviously depends on the original penetration depths of oxidation into these layers. Typically the Cluozza Member ends with a red to green shale layer.

Generally the overlying dolomites exhibit the same depositional features as the Mingèr Dolomites below the Cluozza Member. In two neighboring profiles, the basal dolomite beds contain common fossil debris such as foraminifera (cf. *Agathamina* sp.), small, cone-shaped gastropods as well as bivalves, dasycladacean algae and ostracods. In the Fanez section it-

self, the 2.5 m thick dolomites at the base of the section are characterized by micritic textures, collapsed tepee structures, redeposited mud clasts and fenestral fabrics. Thin sections exhibit strong diagenetic alteration of the sediments (e.g. microstalactitic cements, vadose silt, partial chertification of fenestral pores). The diagenetic features represent a transition to the Innerchrachen Bed (Frank 1986), which shows even more pronounced postdepositional overprinting due to subaerial exposure. This bed is characterized by a partial lateritisation of the dolomites, with micritic dolomite nodules in red to green shales, pedodes filled with quartz and calcite crystals (cf. Reeves 1976) and with ferruginous, aluminum rich nodules.

Palynology and particulate organic matter

In the studied samples most of the organic matter is strongly affected by biological degradation, damaged by pyritisation and altered by thermal maturation. The specific composition of the originally very rich assemblages is certainly strongly biased by these factors. Numerous thick-walled palynomorphs appearing black and almost opaque in transmitted light microscopy are indeterminable. The dark brown color of the thin walled translucent palynomorphs corresponding to T.A.I. (Thermal Alteration Index) values of about 3 to 4, is evidence for a strong thermal alteration. The organic matter does not show any visible UV fluorescence. These features correspond approximately to vitrinite reflectance values of 1–2 % and indicate a degree of thermal maturation near the limit of the oil window, most likely within the range of wet gas. Thus temperatures in the range of 130 to 160°C can be inferred. The vitrinite values published by Ferreiro Mählmann (1995, 1996) for the Silvretta nappe of the same area indicate considerably higher values (3.2 – 4.9 % RV), and therefore temperature ranges on the order of 180 – 310°C (250 – 270°C). At such a high maturation level no recognizable palynomorphs could be expected. Other data are more in line with our results; namely the temperature range, inferred from the extractable hydrocarbons of the organic rich Prosanto beds underlying the Raibl Group, suggests a maturity level within the oil window (Meister 1999). The elevated vitrinite values can be easily explained by reworking or by the common occurrence of fusinite.

Biostratigraphy

Although biased by selective preservation, several features of the palynomorph assemblages allow a biostratigraphic interpretation. The high abundance and diversity of the *Aratrisporites* group, the frequency of the genus *Lagenella* and the rare occurrence of striate bisaccate pollen grains are characteristic of a Late Triassic age. A number of palynomorphs recorded in the Cluozza Member are known to have their latest occurrence (LAD) in the Julian. The presence of the species *Aulisporites astigmosus, Protodiploxypinus decus* and *Thomsonisporites toralis* is also typical. The regular occurrence of

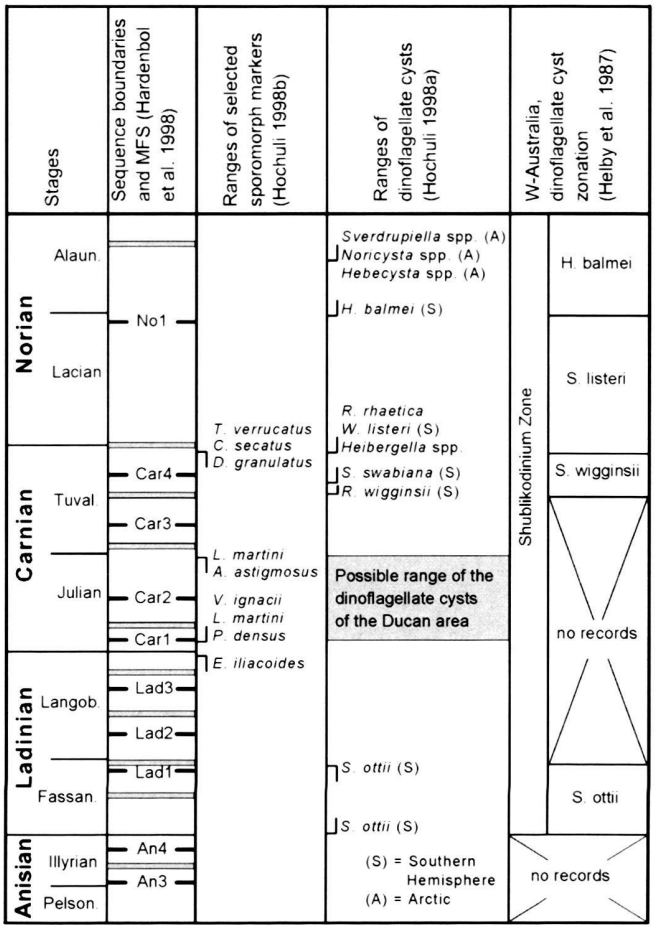

Fig. 4. Stratigraphic framework of the Anisian to Norian interval with sequence boundaries (An3 – No1) and maximum flooding surfaces (MFS) according to Hardenbol et al. (1998) with ranges of sporomorph markers and known distribution of dinoflagellate cysts. The full citations of the marker species included in this figure are listed below:
Spore-pollen: *Aulisporites astigmosus* (Leschik) Klaus 1960, *Camerosporites secatus* Leschik 1955, *Duplicisporites granulatus* Leschik 1955, *Echinitosporites iliacoides* Schulz & Krutzsch 1961, *Lagenella martini* (Leschik) Klaus 1960, *Patinaporites densus* Leschik 1955, *Triadispora verrucata* (Schulz) Scheuring 1970, *Vallasporites ignacii* Leschik 1955.
Dinoflagellate cysts: *Heibergella balmei* Stover & Helby 1987, *Rhaetogonyaulax wigginsii* (Stover & Helby) Lentin & Williams 1989, *Rhaetogonyaulax rhaetica* (Sarjeant) Loeblich & Loeblich 1968, *Sahulidinium otti* Stover & Helby 1987, *Suessia swabiana* Morbey 1975, *Wanneria listeri* (Stover & Helby) Below 1987.

Lagenella martini is restricted to the Early Carnian and gives the most reliable indication for the age of the studied assemblages. A second species – *Lagenella* sp. 1 – is also a potential marker of this interval. The age is further constrained by the first occurrence (FAD) of *Rogalskaisporites cicatricosus* known from the *Schilfsandstein* of Poland (Orlowska-Zwolinska 1983). The palynomorphs of marine origin are essentially

represented by long ranging acritarchs and by some dinoflagellate cysts of suessoid *(Noricysta)* and gonyaulacoid *(Rhaetogonyaulax)* affinity. However, the latter forms cannot be used for our biostratigraphic consideration since no records of similar age are known. In Figure 4 the main biostratigraphic events are shown in the context of the stratigraphic framework.

The Triassic records of dinoflagellate cysts

Although several lines of evidence (e.g. ultrastructure and molecular phylogenetic studies) indicate a Precambrian origin of the dinoflagellates, the organic-walled and calcareous cysts of Triassic age represent the first indubitable fossil records of this group (Fensome *et al.* 1996). So far organic-walled dinoflagellate cysts are known to appear regularly in the upper part of the Late Triassic, essentially in the Norian and Rhaetian. However, the occurrence of calcareous cysts in the lower part of the Carnian of the Southern Alps (Janofske 1992) and the earliest and so far the most complete records of Triassic organic-walled dinoflagellate cysts known from the Southern Hemisphere document an earlier appearance of cyst-forming dinoflagellates. The ranges of the organic-walled cysts have been used by Helby *et al.* (1987) to define a zonation of the Middle and Late Triassic of Australia (cf. Fig. 4). The assemblages described by Brenner (1992) and Brenner *et al.* (1992) from the Wombat Plateau, offshore Northwestern Australia, which are calibrated with ostracods and magnetostratigraphy, confirm the stratigraphic interpretation given by Helby *et al.* (1987).

In the Northern Hemisphere, the dinoflagellate cysts are relatively frequent and widespread in the Late Triassic of the Boreal realm. First occurrences of the groups *Heibergella* and *Rhaetogonyaulax* have been reported from the Late Carnian of Alaska (Wiggins 1973) and from Late Carnian to Norian deposits of the Barents Sea area (Hochuli *et al.* 1989). Well-diversified assemblages are known from the Norian of the Sverdrup Basin of Arctic Canada (Bujak & Fisher 1976). Generally, Rhaetian assemblages are more diversified and are frequently found in marine and estuarine environments (cf. Hochuli 1998a). Considering the widespread early occurrences of the dinoflagellate cysts in the high latitudes of the Boreal Realm and in Australia, it has been argued that species forming organic cysts might have developed under arctic conditions (Stover *et al.* 1996).

The studied material from the Cluozza Member includes a relatively well diversified assemblage of dinoflagellate cysts. Some of the observed forms are tentatively attributed to known taxa, whereas others are too badly preserved to allow a specific determination. However, considering their age and diversity these new records are unique for the Northern Hemisphere. They also suggest that the known concentration of early occurrences in high latitudes may be only related to favorable preservation and thus to more complete records.

Interpretation and discussion

The depositional environment of the Mingèr dolomites underlying the Cluozza Member is characterized by repeated sequences of sub- to supratidal sediments on an extended carbonate platform, promoting early diagenetic dolomitisation and calcretisation. The rare black shale intercalations are interpreted as clastic sedimentary input during exceptional floods in the hinterland. A relative sea-level rise, during a probably more humid climatic phase, led to the establishment of almost normal marine conditions at the base of the Cluozza Member. Due to these changes, medium to coarse grained sands of immature crystalline origin flooded the carbonate platform of the Austroalpine domain. Within the lithostratigraphic context, with dolomites below and above, the lower part of the Cluozza Member is therefore interpreted as a major transgressive phase. This widely recognized event has been defined as *Reingrabener Wende* by Schlager & Schöllnberger (1974) and was later defined by Rüffer & Zülke (1995) as the transgressive and early highstand phase of their sequence Car2. Hardenbol *et al.* (1998, chart 8) attributed the maximum flooding event in the middle part of the Julian to the first Carnian sequence (Car1) whereas Gianolla *et al.* (1998) interpreted a transgressive event at the same level as part of sequence Car2. According to Gianolla *et al.* (1998) the flooding event of the first Carnian sequence coincides with the Ladinian/Carnian boundary. Hence the event reflected in the Cluozza Member, dated as Julian, can be interpreted as part of the first Carnian sequence (Car1) following Hardenbol *et al.* (1998), or according to the concept of Gianolla *et al.* (1998), as the second Carnian sequence (Car2). The sandstones in the upper part of the Cluozza Member with terrestrial cementation (authigenic K-feldspar) and oxidation (reddening) reflects the regressive phase of this sequence (late highstand). In the Ducan area, as well as in several coeval sections of the Engadine Dolomites, this regression is also documented by caliche nodules inside the red sandstones and parallel bedding caused by calcrete layers. The strong oxidation recognizable at the top of the Cluozza Member, the lithological evidence in the overlying Innerchrachen Bed and the red colored polymictic breccias below the Hauptdolomit Group correspond to various phases of emersion. Following Gaetani *et al.* (1998) the basal part of the Hauptdolomit is interpreted as the uppermost sequence in the Carnian (Car4). Hence, the interval of non-deposition or erosion could be of considerable duration and comprise the sequences Car2 and/or Car3.

A marginal marine depositional environment in the lower part of the Cluozza Member can be inferred from the palynological content including abundant terrestrial palynomorphs and phytoclasts, relatively rare marine forms (acritarchs, dinoflagellate cysts) as well as spores of fresh water algae of zygnematalean affinity (*Schizosporis* and *Tetraporia*). The abundance and diversity of pteridophyte spores suggests, at least locally, humid conditions in the nearby terrestrial environment. Within the Carnian spore-pollen assemblages the

representatives of the lycopod group *Aratrisporites*, several types of trilete pteridophyte spores, and monosulcate pollen grains including the genus *Lagenella* are considered hygrophytic elements (cf. Visscher & van der Zwan 1981, Heunisch 1999). These groups dominate all the studied assemblages. Generally they represent over 50% and in some cases up to 85% of the terrestrial palynomorphs. In contrast, xerophytic elements, including the striate bisaccates, as well as the representatives of the *Triadispora* and the *Circumpolles* group, are relatively rare. In their overall composition the studied assemblages compare best with those of the Carnian Lunzer beds from Austria (Klaus 1960; Visscher & van der Zwan 1981) and with those from the Schilfsandstein of the Germanic realm (Leschik 1955, Scheuring 1970, Orlowska-Zwolinska 1983, Heunisch 1986). The palynological data suggest a correlation between the above mentioned units, although independent stratigraphic evidence is weak and similarities due to analogue facies development cannot be excluded completely. Recently the correlation of the above mentioned units have been confirmed by detrital zircon fission track data (Köppen & Carter 2000).

Thus, the palynological and the sedimentological evidence suggest that the siliciclastic sediments correspond to an increased runoff under more humid climatic conditions or to a flooding event in the Western Tethys area. Based on similar evidence from the *Schilfsandstein* and the equivalent formations in the British Triassic, Simms and Ruffell (1989) postulated a "pluvial event" for the middle and upper part of the Carnian. This concept has been contested by Visscher *et al.* (1994) who found no palynological evidence for such an event. However, these authors state that the floral assemblages of the Schilfsandstein reflect "widespread but local humid environmental conditions" related to water saturated substrates with high groundwater tables in a fluvial depositional setting. They related the dominance of hygrophytic elements and the local formation of coal to increased water supply of extensive river systems rather than to increased precipitation.

The correlation of the Raibl Group with the above mentioned units, and thus the occurrence of contemporaneous assemblages representing similar climatic conditions in the Alpine realm, suggest that hydrographic conditions affected floral assemblages of a very wide area. In this way our results support the concept of a "pluvial event" as postulated by Simms and Ruffell (1989).

Annotated species list

Below the recorded palynomorphs are listed alphabetically within three groups – spore-pollen, marine algae and other palynomorphs. For most species comments on their relative abundance, stratigraphic and ecological significance are added. The stratigraphic ranges indicated below are based on a compilation of published data (Hochuli 1998b and unpublished data). Other important references are mentioned in the text. The most important species recorded in the samples from the Cluozza Member are figured on plates 1 and 2.

Spore-pollen

Acanthotriletes spp.

Long ranging group. A few specimens occur in the studied material.

Annulispora spp.

Annulispora represents a long-ranging group that occurs frequently in Late Triassic to Early Jurassic sections. The presence of a few specimens is typical for Carnian and Norian assemblages.

Apiculatisporites spp.

Representatives of this long-ranging spore group are regularly recorded.

Aratrisporites spp.

Indeterminable specimens of the *Aratrisporites* group, associated to lycopods, are very common in most of the studied samples. Together with the species mentioned below it represents the dominant hygrophytic element (Visscher & van der Zwan 1981) or as Heunisch (1999) states, typical elements of coastal marshes.

Aratrisporites fimbriatus (Klaus) Mädler 1964

This species, known to be common in the Late Triassic, is regularly observed.

Aratrisporites fischeri (Klaus) Playford & Dettmann 1965
Plate 1, Fig. 12

A. fischerii, most common in the Alpine and Germanic Carnian, is present throughout the studied section.

Aratrisporites laevigatus (Thiergart) Mädler 1964
Plate 1, Fig. 2

As in most Late Triassic sections *A. laevigatus* occurs regularly in the present material.

Aratrisporites parvispinosus / paraspinosus group
Plate 1, Fig. 6

In this study *A. parvispinosus* Leschik 1955 and *A. paraspinosus* Klaus 1960 are regarded as representatives of the same group. In the studied material these forms are quite frequent.

Aratrisporites scabratus Klaus 1960
Plate 1, Fig. 10

Regularly recorded.

Aratrisporites saturni (Thiergart) Mädler 1964

This relatively long-ranging species occurs regularly. So far it has been reported as common element of the interval between the Anisian and the Early Carnian (Orlowska-Zwolinska 1983).

Asseretospora gyrata (Playford & Dettmann) Schuurman 1977
Plate 1, Fig. 23

This long-ranging species is regularly recorded.

Aulisporites astigmosus (Leschik) Klaus 1960
Plate 2, Fig. 3

A. astigmosus has been reported as common element in the assemblages of the Schilfsandstein and the Lettenkohle (cf. Orlowska-Zwolinska 1983) and other Lower Carnian sites (Hochuli 1998b). In the studied material most specimens are difficult to recognize due to the thick, almost opaque wall.

Baculatisporites spp.

These long-ranging pteridophyte spores are common in all the samples of the Cluozza Member.

Bisaccate pollen grains

Indeterminable forms of bisaccate pollen grains are common. In most cases the state of preservation does not allow to differentiate alete and trilete forms (see also *Triadispora*).

Calamospora sp.
Plate 1, Fig. 1

These trilete spores of equisetalean affinity have a long stratigraphic range. Despite the fact that most specimens of these relatively thin-walled spores are severely damaged, they can be recognized as one of the prominent elements in the studied samples.

Camarozonosporites spp.

This essentially Late Triassic spore group is regularly recorded. Specific determination is hampered by the poor preservation.

Chasmatosporites sp.
Plate 1, Fig. 16

This group of gymnosperm pollen grains appears as a rare element in the Middle Triassic. It is known to occur more regularly in the Carnian and is a common element in latest Triassic and Early Jurassic assemblages (cf. Hochuli 1998b).

Circumpolles group
Plate 1, Fig. 19

The representatives of the *Circumpolles* group such as *Duplicisporites* (Plate 1, Fig. 19), *Partitisporites* and *Paracirculina* are usually quite frequent in Ladinian and Carnian assemblages. Their sporadic occurrence in the present material may be explained by the state of preservation, since many specimens are indeterminable. Alternatively, this group, representing xerophytic elements, may be rare for ecological reasons (Visscher & van der Zwan 1981). The absence of *Camerosporites secatus*, which is unusual for Early Carnian assemblages could also be due to preservation.

Cohaculatisporites spp.

Long ranging pteridophyte spores. Regularly recorded.

Cycadopites spp.

Long ranging monocolpate gymnosperm pollen grains. Rare.

Deltoidospora / Dictyophyllidites group.

These long ranging trilete pteridophyte spores dominate most of the studied assemblages.

Ephedripites sp.
Plate 1, Fig. 15

Polyplicate gymnosperm pollen grains of gnetalean affinity occur sporadically.

Gibeosporites spp.

Generally, representatives of this genus are common in assemblages from the lower part of the Carnian. In the present material they are rare, although regularly present.

Gordonispora fossulata (Balme) Van der Eem 1983
Plate 1, Fig. 5, 9

This species occurs regularly in the studied samples.

Kraeuselisporites dentatus Leschik 1955

The LAD of *K. dentatus is* considered typical for the top of the Carnian (cf. Orlowska-Zwolinska 1983). In the studied material this species is rare.

Lagenella martini (Leschik) Klaus 1960
Plate 1, Fig. 18, 22

L. martini the main marker of the stratigraphic range of the studied samples (cf. Fig. 4) is quite common. It is considered part of the hygrophytic element (Visscher & van der Zwan 1981).

Lagenella sp.1
Plate 1, Fig. 17, 21

This form can be consistently differentiated from *Lagenella martini* based on its coarse sculpture. It occurs in all the studied samples.

Lueckisporites sp.
Plate 2, Fig. 2

A few representatives of this group such as *L. singhii* are known from the Late Triassic (cf. van der Eem 1983). In the present material they are also very rare.

Ovalipollis sp.
Plate 2, Fig. 1

Most of the specimens assigned to the *Ovalipollis* group are too poorly preserved to allow specific determination. The range of the genus covers the Ladinian and the Late Triassic. The representatives of this genus are relatively rare. They are interpreted as xerophytic elements.

Patinasporites spp.

Patinasporites densus Leschik 1955 has its lowest occurrence near the base of the Carnian. The observed specimens are too poorly preserved to allow a specific determination.

Protodiploxypinus decus Scheuring 1970
Plate 1, Fig. 14

In the Alpine and the Germanic realm *P. decus* is known mostly from the upper part of the Ladinian and from the lower part of the Carnian.

Punctatosporites walkomi De Jersey 1962
Plate 1, Fig. 3

P. walkomi is usually common in Late Triassic assemblages (Orlowska-Zwolinska 1983). It is regularly recorded in the samples from the Cluozza Member

Rogalskaisporites cicatricosus (Rogalska) Danzé-Corsin & Laveine 1963
Plate 1, Fig. 4

The oldest records of this species are known from the *Schilfsandstein* (Orlowska-Zwolinska, 1983). In the studied material it occurs sporadically.

Striate bisaccates

As in most Late Triassic assemblages striate bisaccate pollen grains are very rare in all the studied samples. Only the species *Striatoabietites aytugii* occurs regularly (see below). The striate bisaccates are considered part of the xerophytic elements.

Striatoabietites aytugii Visscher 1966
Plate 1, Fig. 20, 24

The LAD of *St. aytugii* is considered typical for the Carnian. This species has its main distribution in the Carnian and older Triassic sections (van der Eem 1983). It occurs in all the studied samples.

Thomsonisporites toralis Leschik 1955
Plate 1, Fig. 7

Only a few specimens of this species have been found; its LAD is considered typical for the Julian.

Triadispora spp.

Due to the state of preservation, most of the pollen grains belonging to the *Triadispora* group are indeterminable on a specific level.

Triadispora verrucata (Schulz) Scheuring 1970
Plate 1, Fig. 13

Ranging from the Ladinian to the Carnian (cf. Fig. 4) the LAD of *T. verrucata* is generally considered a distinct event at or near the top of the Carnian (Hochuli 1998b). In the samples from the Cluozza Member this species is rare.

Trilete spores (indeterminate forms)

Many of the commonly occurring trilete spores are indeterminable due to opaqueness of the thick spore walls. For most specimens the ambitus and traces of the trilete marks are the only recognizable features.

Zebrasporites spp.

The representatives of this genus are most regularly represented in Late Triassic sections (Orlowska-Zwolinska 1983); they are very rare in the studied samples.

Marine algae

Dinoflagellate cysts
Rhaetogonyaulax cf. *wigginsii* (Stover & Helby) Lentin & Williams 1989
Plate 2, Fig. 4, 5, 6

Although poorly preserved, several specimens recorded from the Cluozza Member are comparable to *R. wigginsii*. The specimen illustrated in Fig. 4, 5 is comparable to this taxon by its overall shape with one distinct and one reduced antapical lobe and its large posterior part of the sulcus. Some of the plate boundaries recognizable on the epicyst probably correspond to the intercalary series. The ornamentation of this species consists of linearly arranged verrucae and distinct ridges along the cingulum and bordering the sulcus. The specimen shown in Fig. 6 is compressed and folded. Some of the fine grana on the surface of the cyst seem to be aligned along plate boundaries. The isolated lobe in the upper part of Fig. 6 probably represents one single (?apical) plate.

Rhaetogonyaulax sp.
Plate 2, Fig. 7, 12,

The overall shape of the partly broken specimen (Fig. 7) is typical for the genus *Rhaetogonyaulax*. Clearly visible are the cingulum, the archeopyle and one of the antapical lobes. The state of preservation precludes a specific attribution.

The fragment illustrated in Fig. 12 is interpreted as an apical view of the detached operculum. Its outline is compatible with the tabulation of *Rhaetogonyaulax wigginsii* as presented by Stover & Helby (1987, Fig. 17A).

cf. *Noricysta pannucea* Bujak & Fisher 1976
Plate 2, Fig. 8, 9, 10, 11

Several specimens with an oval shape, a relatively fine granular sculpture and low, poorly developed crest show some similarities to *Noricysts pannucea*, described from the Norian of the Arctic (Bujak & Fisher 1976). The numerous small plates visible on the epicyst of the specimens illustrated in Fig. 8 and 9 are compatible with the tabulation of the genus *Noricysta* and show the suessoid affinity of this genus (cf. Fensome *et al.* 1993). The crests are best developed along the cingulum and the sulcus, although folds, recognizable on all the figured specimens, partly mask the original tabulation.

cf. *Noricysta fimbriata* Bujak & Fisher 1976
Plate 2, Fig. 18, 19

This specimen is characterized by an oval shape with a slightly protruding apical part and two asymmetrically arranged antapical lobes of different sizes. The wall of the cyst is clearly double layered. The surface shows irregularly formed crests and a granular to spinose ornamentation without a clearly recognizable tabulation pattern. Except for its small size – 34 µm compared to 45 µm for the holotype – it is comparable to *N. fimbriata*.

? Noricysta sp.
Plate 2, Fig. 17

The rounded sub-rhomboidal shape and the partly double layered wall of this specimen suggest an affinity to the genus *Noricysta*. The ornamentation of the wall is comparable to that of *N. pannucea*. However, the plate boundaries are masked by folds.

Dinoflagellate cyst, type 1
Plate 2, Fig. 13, 14

The overall oval shape of this specimen with a broad triangular apical part and two asymmetrical antapical lobes represent essential features of dinoflagellate cysts. The very thin wall is ornamented by very fine granules. The presence of a tabulation is suggested by a few breaks in the wall near the apex and by some alignments of granules. The sparser ornamentation and the slight constriction in the middle part of the figured specimen can be interpreted as the cingular area. To our knowledge no comparable forms have be recorded from the Triassic.

? Horologinella sp.
Plate 2, Fig. 15

The form of this specimen implies an affinity to the genus *Horologinella*; its asymmetry and the faint indications of a tabulation represent features of dinoflagellate cysts. However, the differentiation of the genera *Horologinella* of dinophycean origin and *Tetraporina* of zygnematalean affinity is not straightforward for untabulated forms. Since *Tetraporina* occurs in the same samples this specimen could also represent a deformed spore of this group of green algae.

Indeterminate palynomorphs, ?dinoflagellate cysts
Plate 2, Fig. 16, 20, 21, 26

Quite a few specimens observed in the studied material resemble dinoflagellate cysts in their overall shape and aspect. However, the state of preservation precludes a definite assignation of these forms.

Palynomorph of uncertain affinity
Plate 2, Fig. 22

The body of this form is obviously consists of several plates. This feature suggests an affinity to dinoflagellate cysts. However, flattening and the relatively bad preservation hinder the interpretation of the plate relationship.

Acritarchs (undifferentiated)

Regular records of acritarchs of the genera *Veryhachium* and *Micrhystridium* document a marine influence in all the studied samples.

Other palynomorphs

Celyphus aff. *rallus* Batten 1973
Plate 2, Fig. 23, 24

Specimens similar to *Celyphus rallus* have been observed in one of the studied samples (FZ 9-83-A). In contrast to the typical *C. rallus* they show a faint longitudinal striation which is clearly developed on the specimen shown in Fig. 23. Originally described from non-marine or marginal marine sediments of the British Wealden (Batten 1973) these forms are regarded as remains of cyanobacteria (Batten 1996). In the studied material these forms are rare.

Schizosporis spp.

Spores of zygnematalean affinity are rare but regularly present in most of the samples. The presence of *Schizosporis* spp. and *Tetraporina* spp. (see below) documents freshwater influx.

Tetraporina sp.
Plate 2, Fig. 25

A second type of zygnematalean spores is represented by the genus *Tetraporina*. These forms occur regularly in the studied material.

Fungal remains

Together with the rather poor preservation of the palynomorphs the common occurrence of different types of fungal remains provides evidence for the severe biological degradation of the organic matter.

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Plate 1

The measures indicate the longest diameter of the specimens. The coordinates after the sample number refer to the „England Finder".

Figure 1: *Calamospora* sp.
FZ-2-95 A, O29 (56 µm)

Figure 2: *Aratrisporites laevigatus* (Thiergart) Mädler 1964
FZ-2-95 A, K53/4 (59 µm)

Figure 3: *Punctatosporites walkomi* De Jersey 1962
FZ-9-83-A, U25/3 (27 µm)

Figure 4: *Rogalskaisporites cicatricosus* (Rogalska) Danzé-Corsin & Laveine 1963
FZ-9-83 A, P15/2 (25 µm)

Figure 5: *Gordonispora fossulata* (Balme) Van der Eem 1983
FZ-2-95 A, S27/1 (37 µm)

Figure 6: *Aratrisporites parvispinosus* Leschik 1955
FZ-4-95 KX, J37/3 (47 µm)

Figure 7: *Thomsonisporites toralis* Leschik 1955
FZ-2-95 A, O30 (44 µm)

Figure 8: *Aratrisporites parvispinosus* Leschik 1955
FZ-9-83, P16/1 (40 µm)

Figure 9: *Gordonispora fossulata* (Balme) Van der Eem 1983
FZ-5-95 A, R36/1 (39 µm)

Figure 10: *Aratrisporites scabratus* Klaus 1960
FZ-9-83, L11/4 (52 µm)

Figure 11: *Aratrisporites parvispinosus* Leschik 1955
FZ-2-95 A, M18/4 (58 µm)

Figure 12: *Aratrisporites fischeri* (Klaus) Mädler 1964
FZ-2-95 A, Q51/4 (100 µm)

Figure 13: *Triadispora verrucata* (Schulz) Scheuring 1970
FZ-4-95 KX, N41/2 (55 µm)

Figure 14: *Protodiploxypinus decus* Scheuring 1970
FZ-4-95 KX, O34/2 (60 µm)

Figure 15: *Ephedripites* sp.
FZ-9-83 A, U25/3 (33 µm)

Figure 16: *Chasmatosporites* sp.
FZ-9-83, L49/3 (31 µm)

Figure 17: *Lagenella* sp. 1
FZ-2-95 A, J25/3 (50 µm)

Figure 18: *Lagenella martini* (Leschik) Klaus 1960
FZ-2-95, X26/1 (38 µm)

Figure 19: *Duplicisporites* sp.
FZ-5-95 A, Q25 (38 µm)

Figure 20, 24: *Striatoabietites aytugii* Visscher 1966
FZ-2-95 A, D44/3 (48 µm)

Figure 21: *Lagenella* sp. 1
FZ-4-95 KX, R37/4 (48 µm)

Figure 22: *Lagenella martini* (Leschik) Klaus 1960
FZ-9-83-A, W26/1 (38 µm)

Figure 23: *Asseretospora gyrata* (Playford & Dettmann) Schuurman 1977
FZ-2-95 A, O25 (53 µm)

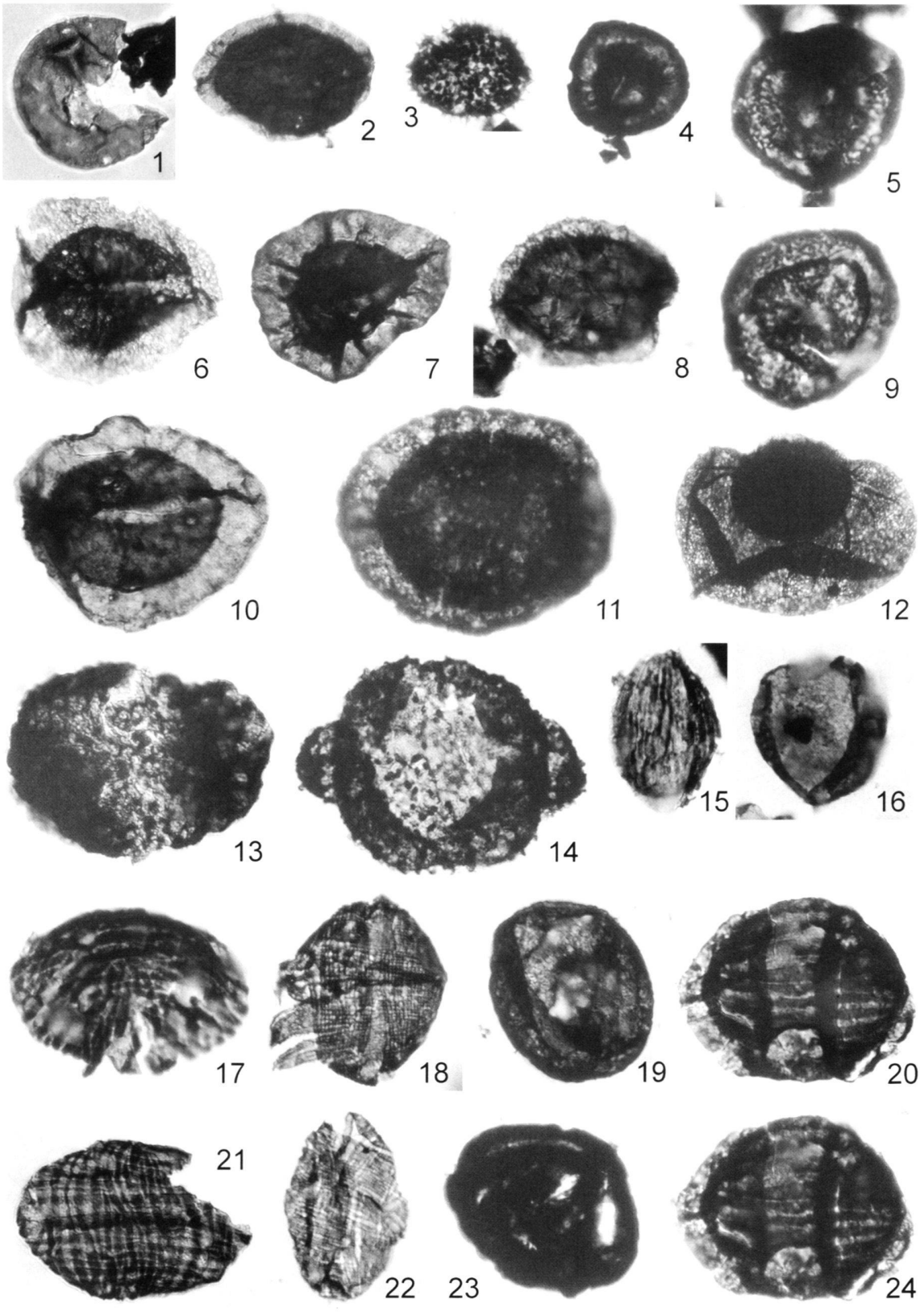
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Plate 2

Figure 1: *Ovalipollis* sp.
FZ-2-95-A, N46/1 (57 µm)

Figure 2: *Lueckisporites* sp.
FZ-4-95 Y, O21 (64 µm)

Figure 3: *Aulisporites astigmosus* (Leschik) Klaus 1960
FZ-4-95-X, K33/2 (60 µm)

Figure 4, 5: *Rhaetogonyaulax* cf. *wigginsii* Stover & Helby 1987
FZ-4-95 KX, O28 (50 µm)

Figure 6: *Rhaetogonyaulax* cf. *wigginsii* Stover & Helby 1987
FZ-9-83-A, X13 (45 µm)

Figure 7: *Rhaetogonyaulax* sp.
FZ-2-95-A, P43 (50 µm)

Figure 8, 9: cf. *Noricysta pannucea* Bujak & Fisher 1976
FZ-4-95, KX, L45/4 (36 µm)

Figure 10: cf. *Noricysta pannucea* Bujak & Fisher 1976
FZ-4-95 KX, J36/4 (36 µm)

Figure 11: cf. *Noricysta pannucea* Bujak & Fisher 1976
FZ-9-83, M9/1 (41 µm)

Figure 12: *Rhaetogonyaulax* sp., Operculum
FZ-9-83, L11/3 (31 µm)

Figure 13, 14: Dinoflagellate cyst, type 1
FZ-2-95-A, F30/3 (32 µm)

Figure 15: ? *Horologinella* sp.
FZ-4-95-A, J57/1 (46 µm)

Figure 16, 20: Indeterminate palynomorphs, ?dinoflagellate cysts
FZ-4-95 K1, N39 (38 µm)

Figure 17: ? *Noricysta* sp.
FZ-5-95-A, N20 (36 µm)

Figure 18, 19: cf. *Noricysta fimbriata* Bujak & Fisher 1976
FZ-2-95-A, P19 (34 µm)

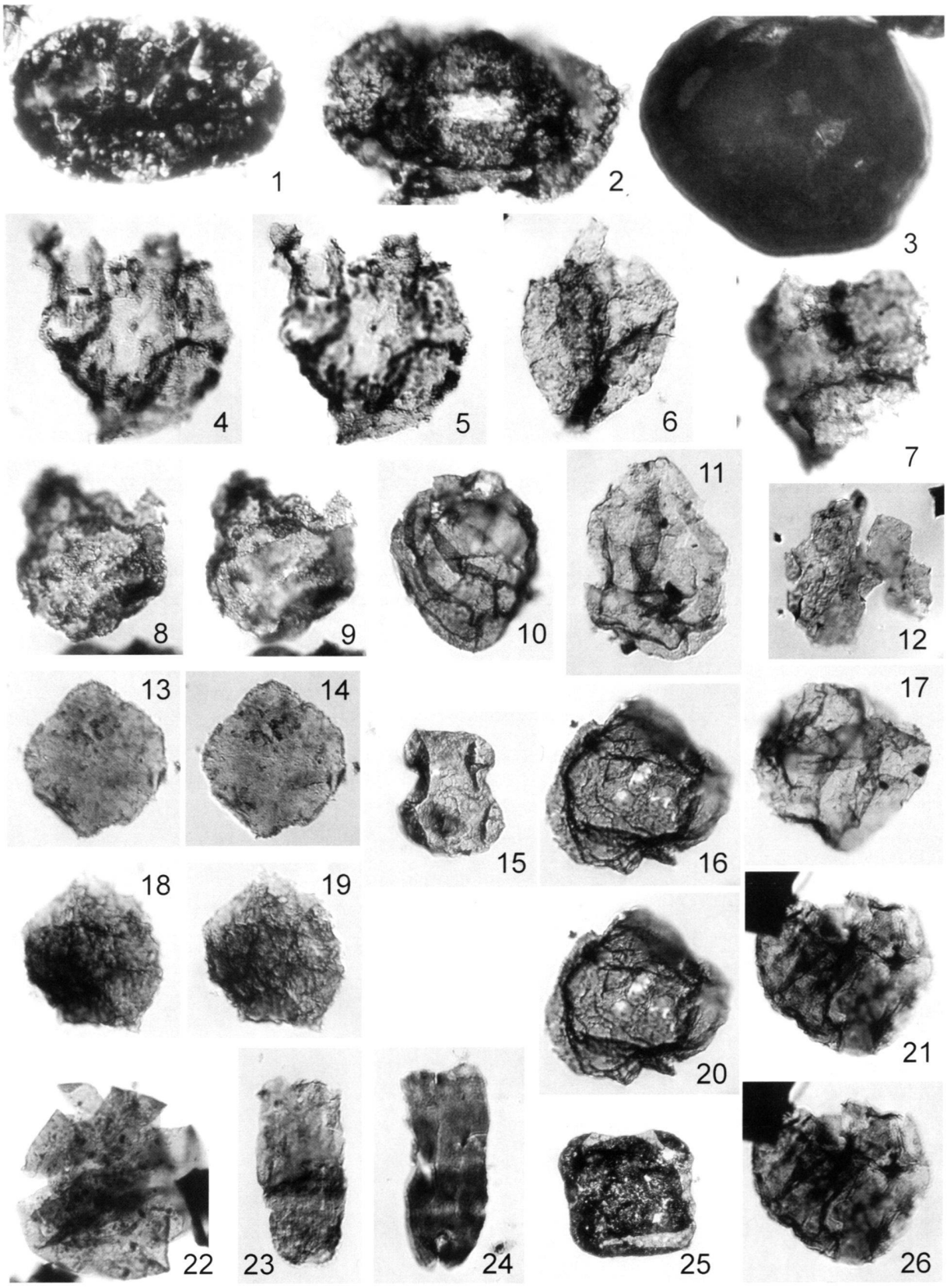
Figure 21, 26: Indeterminate palynomorphs, ?dinoflagellate cysts
FZ-4-95-KX, F20 (37 µm)

Figure 22: Palynomorph of uncertain affinity
FZ-9-83, R10/4 (44 µm)

Figure 23: *Celyphus* aff. *rallus* Batten 1973
FZ-9-83-A, X27-3 (38 µm)

Figure 24: *Celyphus* aff. *rallus* Batten 1973
FZ-9-83-A, T20/2 (36 µm)

Figure 25: *Tetraporina* sp.
FZ-9-83-A, L42/2 (47 µm)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