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Organic-walled dinoflagellate cyst biostratigraphy of the Well Höflein 6 in the Cretaceous–Paleogene Rhenodanubian Flysch Zone (Vienna Basin, Austria)

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Abstract: Palynological analysis of the Rhenodanubian Flysch Zone section recovered from Well Höflein 6 north of Vienna allows the successful application of non-calcareous dinoflagellate biostratigraphy to the deep-water sediments of the Greifenstein Nappe. All 62 cuttings samples contained organic-walled dinoflagellate cysts (dinocysts) and some of them allow age-assessment. The results corroborated the presence of two thrust slices. The upper thrust unit A comprises a Campanian to Lower Eocene succession including, from old to young, the Röthenbach Subgroup, Perneck Formation, Altlengbach Formation and Greifenstein Formation. The lower thrust unit B contains in addition a pre-Campanian base, probably the Wolfpassing Formation of Early to mid-Cretaceous age.

Key words: Cretaceous, Paleogene, Vienna Basin, Rhenodanubian Flysch Zone, biostratigraphy, organic-walled dinoflagellate cysts.

Introduction

The intramontane Vienna Basin has produced by far the largest volumes of hydrocarbons and also provided Austria's earliest petroleum production (Hamilton et al. 2000). Oil and gas production in the Vienna Basin has come from Neogene basin-fill sandstones (termed the 'First Floor') and from underlying allochthonous Triassic dolomites of the Northern Calcareous Alps and units of the Rhenodanubian Flysch Zone (RFZ, 'Second Floor'). Reservoirs within the underlying subthrust zone comprise mainly Jurassic carbonates and Cretaceous-Paleogene sandstones ('Third Floor'). Some exploration of deep, autochthonous, mainly Jurassic-age, subthrust reservoirs below the Neogene of the Vienna Basin has also been conducted (Hamilton et al. 2000). A commercial gas field (Höflein NW of the city of Vienna, Fig. 1), reservoired in Middle Jurassic cherty sandstones, has been discovered in autochthonous units below the RFZ (e.g. Hamilton et al. 2000). The stratigraphy of the RFZ within one of the wells (Höflein 6 of OMV) at the gas field Höflein is the topic of this paper.

The RFZ, which constitutes a 500-km-long, imbricated thrust pile, trends E-W to ENE-WSW, parallel to the northern margin of the Eastern Alps. To the south of Lake Chiemsee, it is interrupted for a short distance and consequently it has been subdivided into eastern and western parts (e.g. Egger & Schwerd 2008). Investigations of this study concentrated on the easternmost part of the RFZ, the Wienerwald area near Vienna, and the subcrop in the Vienna Basin.

The sedimentary succession of the RFZ consists of deep-water deposits, which have been considered a lithostratigraphic supergroup (Mattern 1999; Wortmann et al. 2004) or group (Egger & Schwerd 2008). It is subdivided into a number of formations, from the Lower Cretaceous up to the

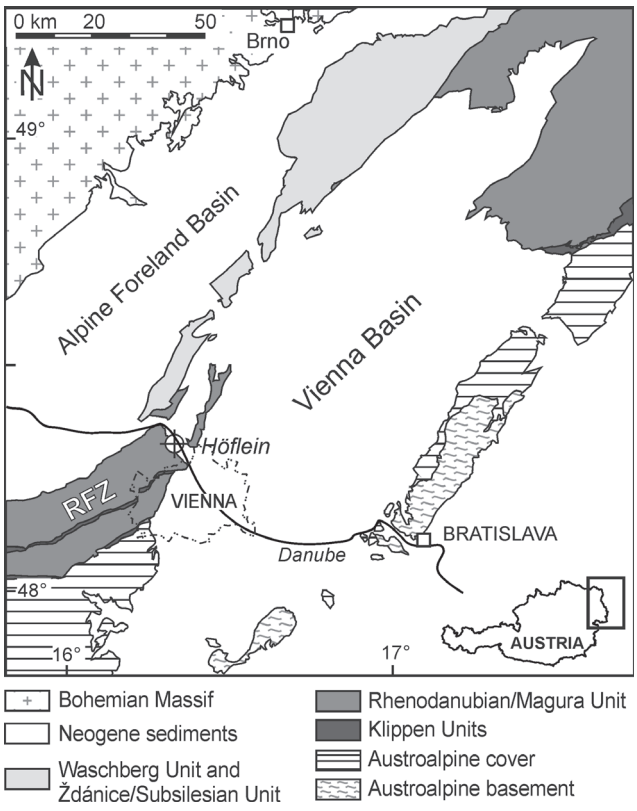

Fig. 1. Simplified geological map of the study area at the eastern margin of the Eastern Alps, showing the location of the Höflein area including Well Höflein 6 within the Rhenodanubian Flysch Zone (RFZ).

Eocene. Classically, biostratigraphy in these deep-water clastic flysch deposits is hindered by the fact that deposition was mainly below the calcite compensation depth (e.g. Egger & Schwerd 2008; Wagreich 2008). Consequently, stratigraphically useful macrofossils are missing almost completely, and planktonic foraminifera are very rare. Calcareous nannoplankton and agglutinated foraminifera are the main sources so far for biostratigraphic subdivision of the RFZ. Organic-walled microplankton such as dinoflagellates have been used only rarely (e.g. Kirsch 2000, 2003).

Planktonic foraminifera and calcareous nannoplankton are rare in the Paleocene and Eocene successions in the Wienerwald area, such as the flysch units of the Höflein gas field. Therefore, a reassessment of a well within the Höflein area, Höflein 6, was carried out in the present study using organic dinoflagellate cysts (dinocysts). Dinocysts provide a high resolution chronostratigraphic framework for this part of the RFZ. Tectonic interpretations regarding thrust units, hitherto largely based on heavy mineral studies, can be confirmed by dinoflagellate biostratigraphy. This paper presents the first palynological study of Well Höflein 6, illustrating the distribution of the dinocysts and their relative abundances. Thus, dinocysts are useful means for the solution of stratigraphic problems in flysch sediments despite problems of reworking and borehole downfall.

Stratigraphy

The OMV Höflein 6 Well, situated at the longitude of E 16°18′38.13″ and latitude N 48°19′43.77″ (Fig. 1), was analysed stratigraphically using cuttings samples by OMV in-house lab based on a few biostratigraphic data by benthic foraminifera and rare nannoplankton beside sediment-petrographic methods. The total thickness of the Rhenodanubian Flysch sediments within Well Höflein 6 measures ca. 2565 m. Studies of heavy minerals from the well have identified different contents especially of zircon and garnet, on the basis of which several lithostratigraphic units can be distinguished. According to unpublished OMV in-house data (R. Sauer, pers. comm. 2010), the RFZ section of Höflein 6 can be divided into two thrust units, an upper thrust unit A and a lower thrust unit B (Table 1). The upper thrust unit A is composed from top to bottom by the Greifenstein Formation (zircon-dominated heavy mineral assemblages), Altlengbach Formation (garnet-dominated heavy mineral assemblages), Perneck Formation (characteristic red shaly interval) and the Röthenbach Subgroup (garnet-dominated heavy mineral assemblages). The lower thrust unit B is composed by a succession, from top to bottom, by again the Greifenstein Formation (zircon-dominated heavy mineral assemblages), Altlengbach Formation (garnet-dominated heavy mineral assemblages) and Wolfpassing Formation (zircon-dominated or mixed heavy mineral assemblages). The Wolfpassing Formation may form a separate thrust unit below thrust unit B (e.g. Schnabel 1992) but is herein regarded as stratigraphically connected to thrust unit B.

The modern lithostratigraphic subdivision of the RFZ is based on Schnabel (1992), Faupl (1996), Wagreich (2008) and Egger & Schwerd (2008). Biostratigraphic data from outcrops in the Wienerwald and wells apart from Well Höflein 6 indicate in general a Late Paleocene to Early Eocene age of the Greifenstein Formation (Thanetian–Ypresian, NP9–NP13, see Schnabel 1992), although a significant diachronism was noted already by Hekel (1968). The Altlengbach Formation ranges from Late Campanian–Maastrichtian up to the Paleocene (CC22–NP8; Schnabel 1992; Egger & Schwerd 2008). The Perneck Formation (former "Oberste Bunte Schiefer", e.g. Sauer et al. 1992) has a Late Campanian age to the west of the Wienerwald area (CC21–22a; Egger & Schwerd 2008). The Röthenbach Subgroup (former Zementmergelserie and partly Kahlenberg Formation, e.g. Sauer et al. 1992) is mainly Campanian in age (CC18–CC21/22; Egger & Schwerd 2008). For the Wolfpassing Formation a Barremian to Aptian and questionable Albian age was reported by Grün et al. (1972; see also Sauer et al. 1992).

Table 1: Lithostratigraphic units of the RFZ and their inferred ages in Well Höflein 6 based on OMV internal reports (see also Sauer et al. 1992). Originally, the Perneck Formation was termed "Bunte Schiefer" and the Röthenbach Subroup was termed "Kahlenberg Formation".

Depth [m]	Lithologic units	Age	
10–322	Greifenstein Formation	Late Paleocene–Early Eocene	Upper thrust unit (A)
322–785	Altlengbach Formation	Late Campanian–Early Paleocene	
785–ca.1017	Perneck Formation	Late Campanian	
1017–1210	Röthenbach Subgroup	Campanian	
1210–1520?	Greifenstein Formation	Late Paleocene–Early Eocene	Lower thrust unit (B)
1520–2480	Altlengbach Formation	Late Campanian–Early Paleocene	
2480–2561	Wolfpassing Formation	Early Cretaceous?	

Material and methods

A total of 62 cuttings samples was selected on the basis of variation in lithology and to sample especially formation boundaries for palynological analysis from the Well Höflein 6, giving a mean sample interval of ca. 50 m for the 2565 m thick well section.

30 grams of dry sediment were crushed and treated with cold 35% HCl for one day in order to remove carbonates. Adding water and subsequent decantation was carried out twice with a minimum interval of six hours. Then, the samples were treated with 38% HF for 1–2 days to remove silicates. Adding water and decantation twice with a minimum interval of seven hours followed the HF treatment. A small amount of 35% HCl was added again to the samples to remove gel which may have formed during the previous step. Water was added to samples for the last time and the samples were put in an ultrasonic device for 10–30 seconds and then sieved over 15 and 30 μm nylon meshes. A part of the residue was mounted in glycerin jelly on 2 or 3 microscope slides after extensive mixing to obtain homogeneity and then covered by a slide cover (20×40 mm). One of these slides holds the residue particles over 15 μm and the other slides

hold the residue particles over 30 μm. The slides are stored at the Department of Geodynamics and Sedimentology, Center for Earth Sciences, University of Vienna, Austria.

All samples were scanned for dinocyst taxa and were counted for allowing identification of acmes, better correlations within units, and to get some information on reworking and/or downhole contamination. Taxonomy of dinocysts is generally based on Fensome et al. (1993) and dinocyst nomenclature follows Fensome et al. (2008) — see Appendix A. Most of biostratigraphically significant dinocyst taxa are documented in Figs. 3 to 12. The relative abundances of dinocysts are shown in electronic Appendix B and C.

Flysch sediments, comprising turbidites and other deep-water mass-flow deposits, are prone to ample reworking of older sediments, thus last occurrences of species have to be used with caution. In addition, using cuttings samples also involves possible downhole contamination of younger strata into older cuttings, making first occurrences questionable and hard to interpret. Thus, stratigraphic interpretation is done with care, using assemblage counts and acmes, and also lithostratigraphic correlations to evaluate and corroborate stratigraphic results. In the following, first occurrence (FO) and last occurrence (LO) are used in the connotation from old to young as used for stratigraphic (outcrop) sections (and not as it may be used for a borehole drilled from young to old), so that FO denotes the stratigraphic base and LO denotes the top of the stratigraphic range of a taxon.

Results

Dinocyst preservation

Of the 62 samples from the Well Höflein 6 most samples were productive yielding dinocysts; only 9 samples were low productive and yielded less than 50 specimens. Marine palynomorphs dominate most samples, while the sporomorph component is composed mainly of bisaccate pollen and spores with a very low relative abundance in all samples (electronic Appendix B, C). Preservation of dinocysts is moderate to good in most productive samples. The dinocysts show a high diversity in most samples, with up to 82 species per sample at the depth of 300 m. A total of 292 dinocyst species and subspecies have been identified from the Well Höflein 6 and are listed in Appendix A.

Dinocyst bioevents

In the upper thrust unit A, the FO of *Trithyrodinium evittii* (Fig. 8.13,14) is recorded at the depth of 1210 m, the biostratigraphically lowest event within the Röthenbach Subgroup. The FOs of *Chatangiella granulifera* (Fig. 7.2,3), *Palynodinium grallator* (Fig. 3.7,8) and *Cannosphaeropsis utinensis* (Fig. 4.14,15) are present at the depth of 1170 m. The FO of *Membranilarnacia*? *tenella* (Fig. 11.1–3) and *Odontochitina operculata* (Fig. 10.3,4) are recorded at the depth of 1120 m. The FOs of *Alterbidinium acutulum* (Fig. 9.9,10), *Corradinisphaeridium horridum* (Fig. 5.1,2), *Chatangiella robusta* (Fig. 7.1), *Xenascus gochtii* and *Trabeculidium quinquetrum* (Fig. 11.9) occur at the depth of 1070 m. The LOs of *Odontochitina porifera* (Fig. 10.1,2) and *Chatangiella granulifera* occur at the depth of 1120 m. *Pervosphaeridium pseudhystrichodinium* (Fig. 12.7) and *Palaeoperidinium pyrophorum* (Fig. 8.6) acmes are present at the depths of 1120 m and 1070 m respectively (Fig. 2). The FO of *Xenascus sarjeantii* (Fig. 10.10–12) is recorded at the depth of 1020 m, still within the Röthenbach Subgroup.

At the base of the overlying Perneck Formation *Xenascus gochtii* and *Palynodinium grallator* have their LOs at the depth of 1010 m. Within the Perneck Formation, the FO of *Diphyes colligerum* (Fig. 6.1,2) and *Manumiella seelandica* (990 m) (Fig. 9.5) and the LO of *Odontochitina operculata*, *Florentinia mayi* (Fig. 5.11) and *Trabeculidium quinquetrum* are recorded (890 m).

Eisenackia circumtabulata (Fig. 6.7–9) first occurred at the base of the overlying Altlengbach Formation (780 m). The LOs of *Alterbidinium acutulum* and *Xenascus sarjeantii* are recorded at the depth of 790 m (Fig. 2). The FOs of *Carpatella cornuta* (Fig. 5.3–6) and *Senoniasphaera inornata* (Fig. 5.7–9) are recorded at the depth of 680 m and *Damassadinium californicum* (Fig. 5.12) first occurred at the depth of 630 m, within the Altlengbach Formation. The FO of *Glaphyrocysta exuberans* (Fig. 6.12–15) occurs at the depth of 430 m. *Cerodinium diebelii* (Fig. 8.1) and *Riculacysta amplexa–Glaphyrocysta semiticta* acmes (Fig. 11.11–12; Fig. 6.11) are recorded at the depth of 680 m and 430 m respectively (Fig. 2).

Within the Greifenstein Formation, the FO of *Apectodinium homomorphum* (Fig. 3.5,6), *Diphyes ficusoides* (Fig. 6.3,4) and *Deflandrea phosphoritica* (Fig. 8.7,8) and the last occurrence of *Membranilarnacia*? *tenella*, *Eisenackia circumtabulata* and *Manumiella seelandica* are recorded in the sample at the depth of 300 m (Fig. 2). Particularly high abundances of certain taxa, namely the *Areoligera coronata–Areoligera senonensis* acme (Fig. 3.9–11), *Glaphyrocysta exuberans–Glaphyrocysta ordinate* acme and *Paralecaniella indentata* acme (Fig. 11.13–15), are recorded at 250, 200 and 100 m depth respectively.

In the lower thrust unit B, the LOs of *Muderongia extensive* (Fig. 10.5), *Muderongia australis* (Fig. 10.6), *Leberidocysta*? *laticaudata* and *Pseudoceratium pelliferum* (Fig. 10.8) are recorded at the depth of 2530 m, within the Wolfpassing Formation. A *Surculosphaeridium longifurcatum–Oligosphaeridium complex* acme (Fig. 12.1–2) was found at the same depth (Fig. 2). The FOs of *Areoligera coronata*, *Chatangiella ditissima* (Fig. 7.4,6), *Alterbidinium acutulum*, *Cannosphaeropsis utinensis* and *Cerodinium diebelii* are present at the depth of 2480 m, at the boundary of the Wolfpassing Formation to the overlying Röthenbach Subgroup.

Near the base of the Röthenbach Subgroup of the lower thrust unit, the FOs of *Areoligera senonensis*, *Trithyrodinium evittii* and *Hystrichosphaeropsis obscura* are recorded at the depth of 2380 m. The FOs of *Xenascus sarjeantii* and *Corradinisphaeridium horridum* are recorded at the depth of 2130 m and 2080 m respectively. The LO of *Corradinisphaeridium horridum* is recorded at the depth of 2030 m. The LO of *Odontochitina porifera*, *Alterbidinium acutulum*, *Xenascus sarjeantii* and *Palaeohystrichophora infusorioides*

Fig. 2. Stratigraphic distribution of selected dinocyst species and bioevents in the Well Höflein 6.

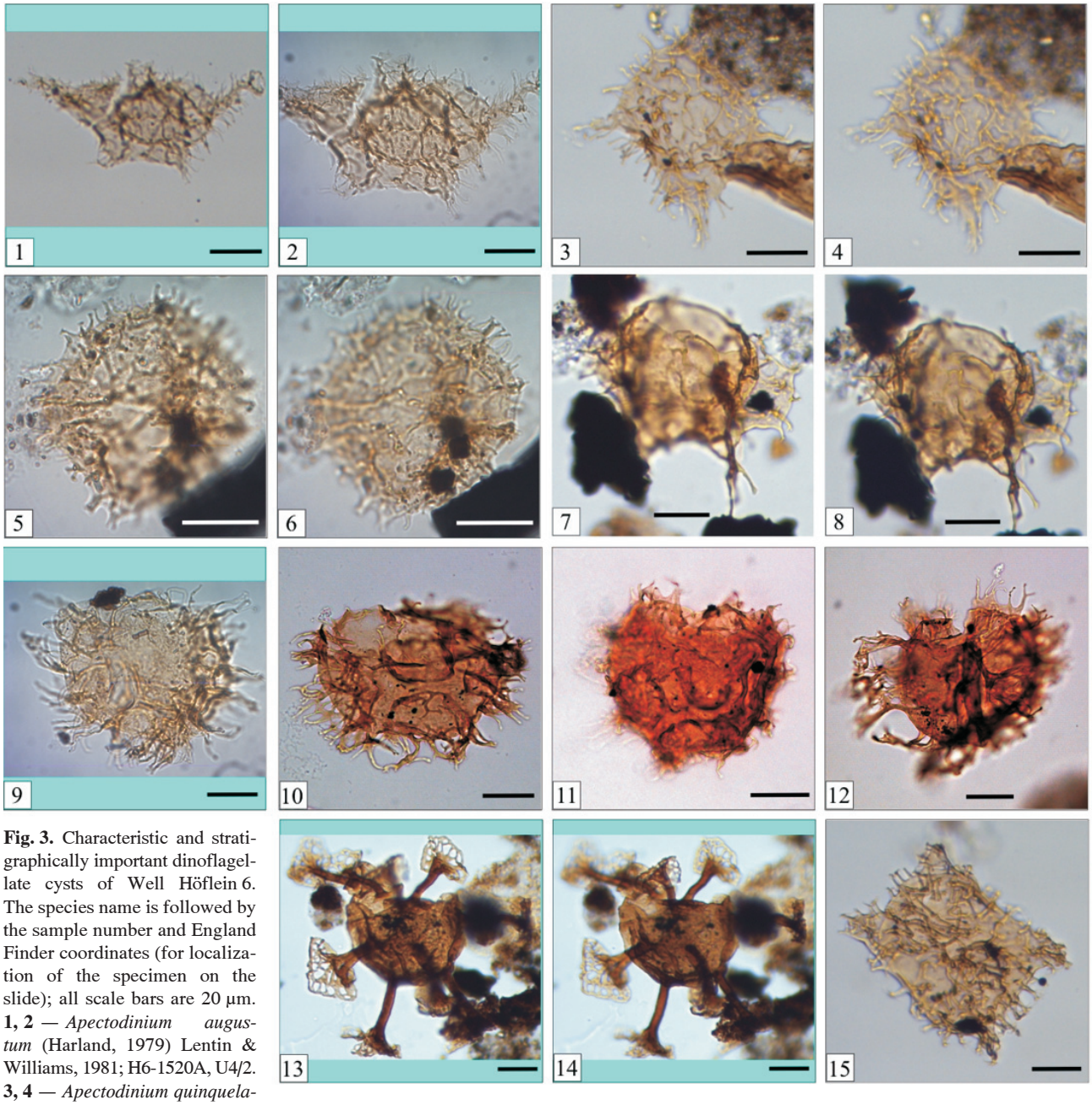

Fig. 3. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1, 2** — *Apectodinium augustum* (Harland, 1979) Lentin & Williams, 1981; H6-1520A, U4/2. **3, 4** — *Apectodinium quinquelatum* (Williams & Downie, 1966) Costa & Downie, 1979; H6-2180A, F33/1. **5, 6** — *Apectodinium homomorphum* (Deflandre & Cookson, 1955) Lentin & Williams, 1977; emend. Harland, 1979; H6-300B, Q42. **7, 8** — *Palynodinium grallator* Gocht, 1970; H6-1170A, K2. **9** — *Areoligera senonensis* Lejeune-Carpentier, 1938; H6-1520A, P19/1. **10** — *Areoligera coronata* (Wetzel, 1933b) Lejeune-Carpentier, 1937; H6-1470A, S30/3. **11** — *Areoligera guembelii* Kirsch, 1991; H6-250A, V29. **12** — *Areoligera coronata* (Wetzel, 1933b) Lejeune-Carpentier, 1937; H6-1470A, Q33/3. **13, 14** — *Areosphaeridium diktyoplokum* (Klumpp, 1953) Eaton, 1971; emend. Eaton, 1971; H6-2530B, F7/4. **15** — *Wetzeliella symmetrica* Weiler, 1956; H6-1830A, K33.

(Fig. 9.20) occur at the depth of 1930 m. The *Areoligera senonensis–Trithyrodinium evittii* acme and *Hystrichodinium pulchrum* acme are recorded at the depth of 2130 and 1930 respectively (Fig. 2). Within the Altlengbach Formation, the FOs of *Membranilarnacia*? *tenella* and *Diphyes colligerum* occur at the depth of 1880 m, followed by the FOs of *Manumiella seelandica* and *Manumiella druggii* (Fig. 9.6) at 1780 m and the *Glaphyrocysta exuberans* acme and *Cerodinium diebelii* acme at the depth of 1730 m and 1680 m respectively (Fig. 2). The FO of *Damassadinium californicum* and *Senoniasphaera inornata* are recorded at the depth of 1630 m and 1580 m respectively.

The base of the Greifenstein Formation of the lower thrust unit is characterized by the FO of *Apectodinium augustum* (Fig. 3.1,2) at the depth of 1520 m. *Manumiella druggii* last occurred at the depth of 1520 m. An acme of *Palaeoperidinium pyrophorum* is recorded at the depth of 1580 m (Fig. 2). The LO of *Damassadinium californicum* is recorded at the depth

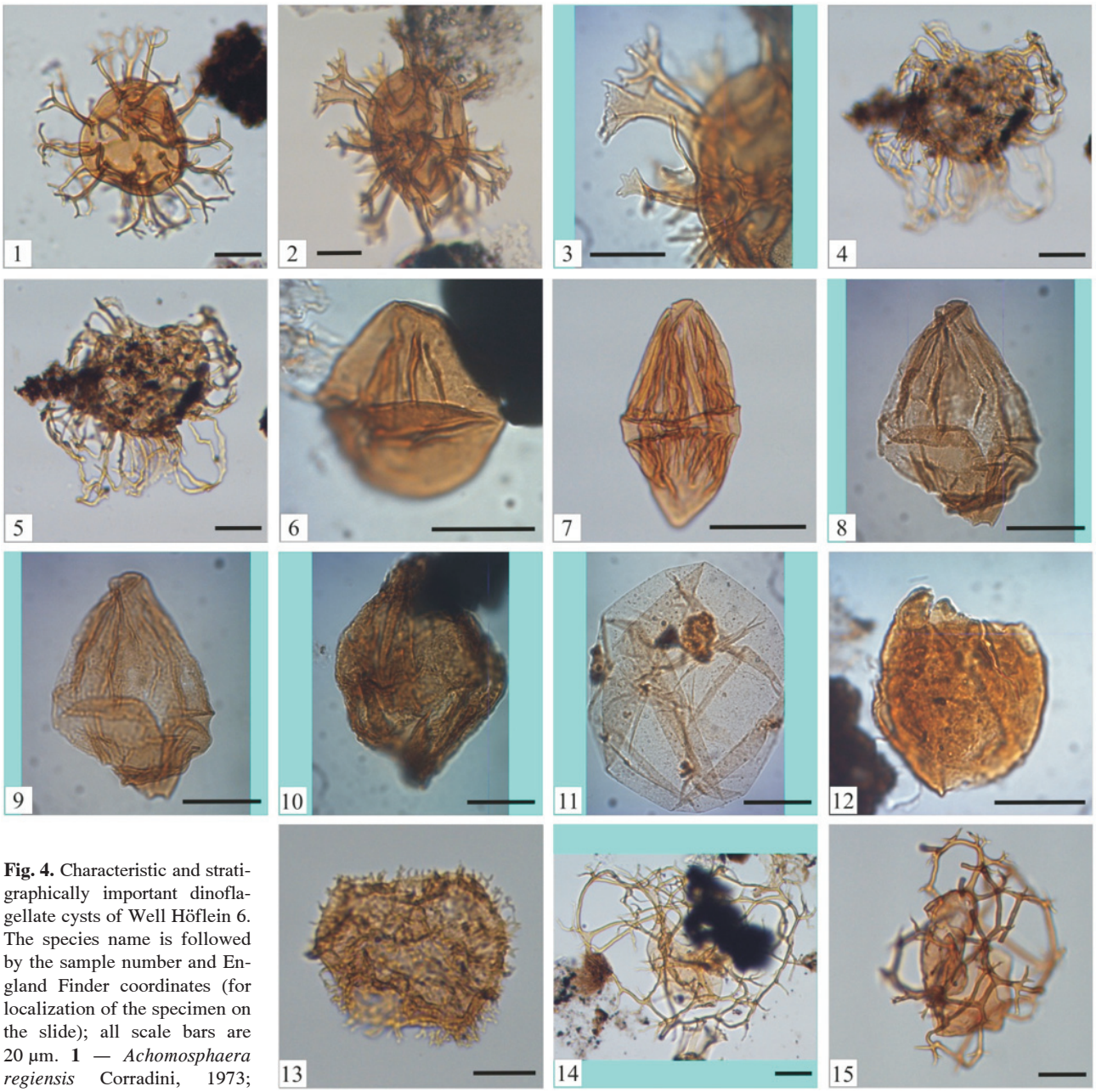

Fig. 4. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1** — *Achomosphaera regiensis* Corradini, 1973; H6-1120A, G24/4. **2, 3** — *Achomosphaera* cf. *alcicornu* (Eisenack, 1954) Davy & Williams, 1966; H6-300A, B16/1. **4, 5** — *Adnatosphaeridium tutulosum* (Cookson & Eisenack, 1960) Morgan, 1980; H6-20B, J9/4. **6** — *Alisogymnium euclaense* (Cookson & Eisenack, 1970) Lentin & Vozzhennikova, 1990; H6-990B, J11. **7** — *Dinogymnium acuminatum* Evitt et al., 1967; H6-480B, B19. **8, 9** — *Dinogymnium denticulatum* (Alberti, 1961) Evitt et al., 1967; H6-890B, Q15/4. **10** — *Dinogymnium* sp.; H6-1220B, L31. **11** — *Batiacasphaera micropapillata* Stover, 1977; H6-1220A, A6. **12** — *Batiacasphaera* sp.; H6-300B, B16/3. **13** — *Canningia reticulata* Cookson & Eisenack, 1960; emend. Below, 1981; H6-1020A, D33/2. **14** — *Cannosphaeropsis utinensis* Wetzel, 1933; emend. May, 1980; H6-1170A, D3. **15** — *Cannosphaeropsis utinensis* Wetzel, 1933; emend. May, 1980; H6-790A, H22.

of 1470 m, *Membranilarnacia*? *tenella* at 1370 m, *Apectodinium homomorphum* and *Diphyes colligerum* at 1270 m, and *Senoniasphaera inornata*, *Diphyes colligerum* and *Manumiella seelandica* at 1220 m. The *Areoligera coronata–Areoligera senonensis* and *Palaeoperidinium pyrophorum* acmes are recorded at the depth of 1470 m, and the *Glaphyrocysta exuberans–Glaphyrocysta ordinate* acme at 1420 m. A *Paralecaniella indentata* acme is present at the depth of 1320 m and 1270 m (Fig. 2), within the Greifenstein Formation.

Interpretation

According to the above results, dinocysts provide a useful tool for biostratigraphic studies in RFZ sediments. In the

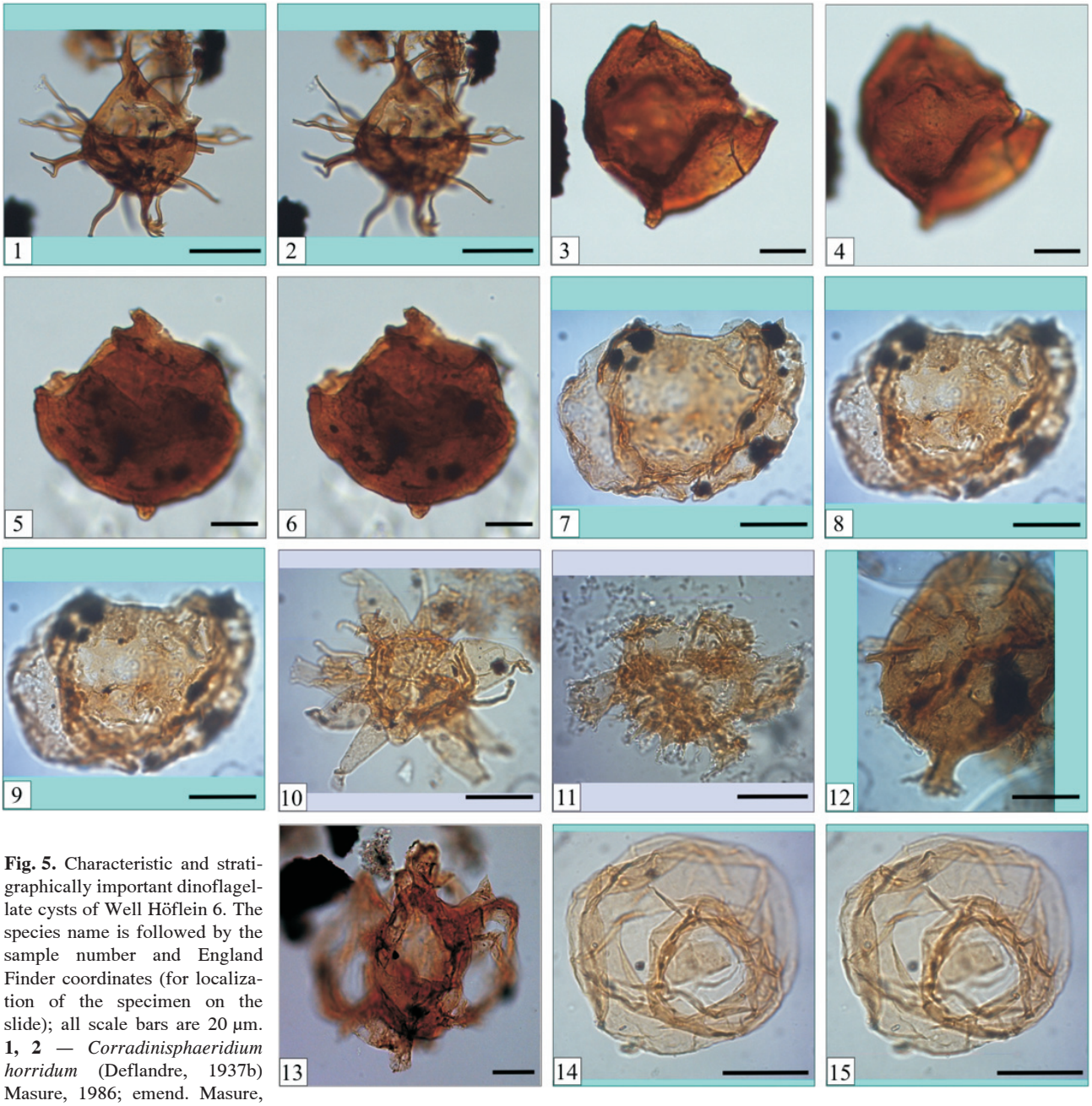

Fig. 5. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1, 2** — *Corradinisphaeridium horridum* (Deflandre, 1937b) Masure, 1986; emend. Masure, 1986; H6-2080B, N38. **3, 4** — *Carpatella cornuta* Grigorovitch, 1969; emend. Fechner & Mohr, 1986; H6-580A, B15. **5, 6** — *Carpatella cornuta* Grigorovitch, 1969; emend. Fechner & Mohr, 1986; H6-580A, K31/1. **7–9** — *Senoniasphaera inornata* (Drugg, 1970) Stover & Evitt, 1978; H6-20A, C22/2. **10** — *Hystrichokolpoma bulbosum* (Ehrenberg, 1838) Morgenroth, 1968; emend. Morgenroth, 1968; H6-2530A, J2. **11** — *Florentinia mayi* Kirsch, 1991; H6-1010A, V8. **12** — *Damassadinium californicum* (Drugg, 1967) Fensome et al., 1993; H6-320B, A18/2. **13** — *Disphaerogena carposphaeropsis* Wetzel, 1933; emend. Sarjeant, 1985; H6-1470B, Y6/3. **14, 15** — *Turnhosphaera hypoflata* (Yun Hyesu, 1981) Slimani, 1994; emend. Slimani, 1994; H6-1020A, G17/2.

Well Höflein 6, despite the problems of reworking and downfall contamination, ages and stage boundaries can be indicated with some confidence by a combination of the first (earliest) and last (latest) stratigraphic occurrences (FOs, LOs) of some selected marker species based on comparisons with world wide dinocyst studies.

The FOs of *Apectodinium homomorphum*, *Diphyes ficusoides* and *Deflandrea phosphoritica* are biostratigraphically important species that are found at the depth of 300 m within the Greifenstein Formation (Fig. 2). Previously, *Apectodinium homomorphum* was recorded in the Upper Paleocene to Lower Eocene in New Zealand (Wilson 1988) and in St. Pankraz, Austria (Hofmann et al. 2011), in the Lower Eocene of northern Spain (Caro 1973), Belgium (N) (de Coninck et al. 1983), Germany (Fechner & Mohr 1988; Köthe & Piesker 2007), north Egypt (El-Beialy & Shahin 1990), English Channel

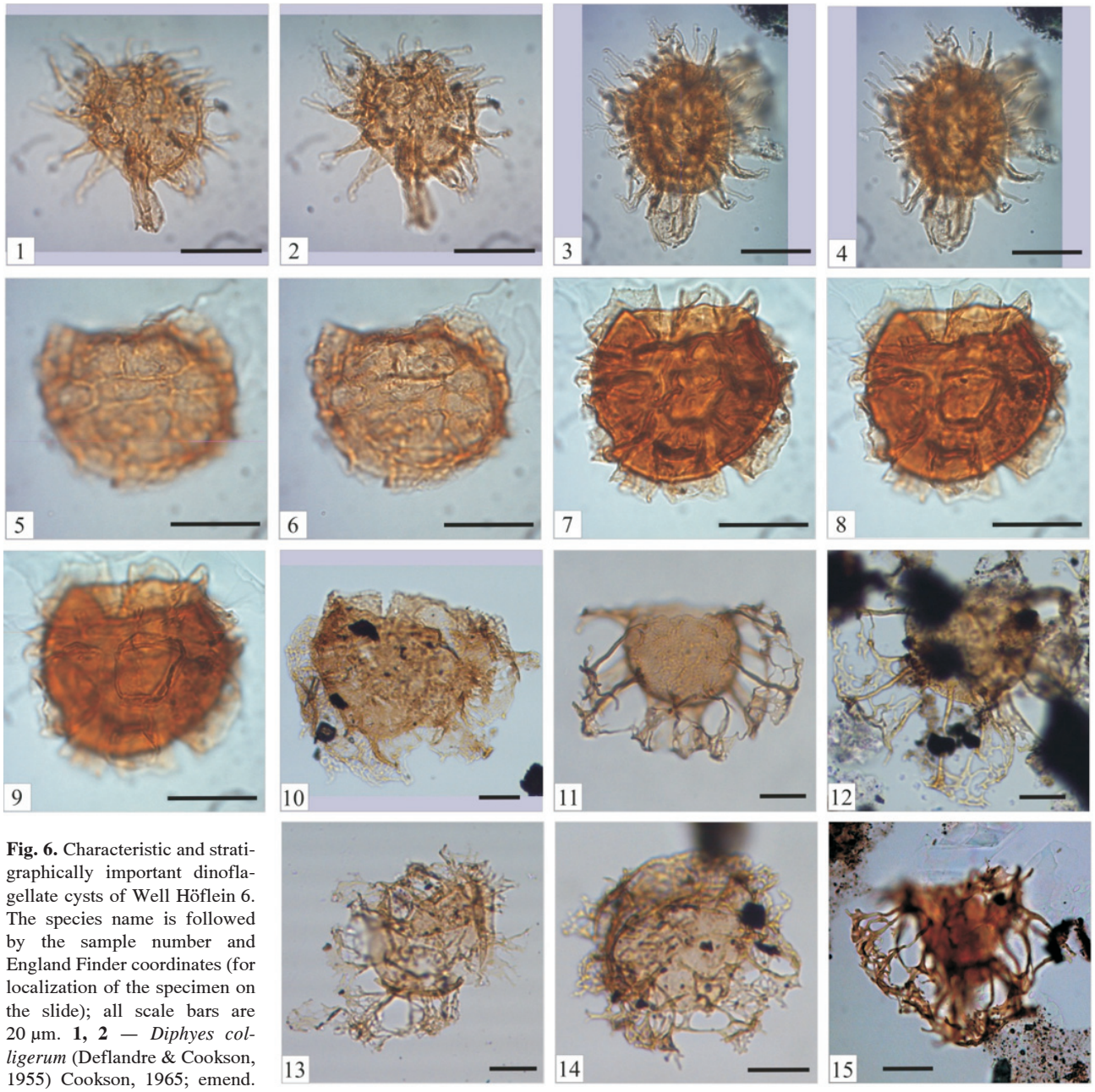

Fig. 6. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1, 2** — *Diphyes colligerum* (Deflandre & Cookson, 1955) Cookson, 1965; emend. Cookson, 1965; H6-300B, B16/3. **3, 4** — *Diphyes ficusoides* Islam, 1983; H6-300A, B16/1. **5, 6** — *Eisenackia margarita* (Harland, 1979) Quattrocchio & Sarjeant, 2003; H6-790B, L1/2. **7–9** — *Eisenackia circumtabulata* Drugg, 1967; H6-780A, D17. **10** — *Glaphyrocysta perforata* Hultberg & Malmgren, 1985; H6-2130A, U6. **11** — *Glaphyrocysta semiticta* (Bujak in Bujak et al., 1980) Lentin & Williams, 1981; H6-1930A, M37/4. **12** — *Glaphyrocysta exuberans* (Deflandre & Cookson, 1955 ex Eaton, 1976) Stover & Evitt, 1978; emend. Sarjeant, 1986; H6-1170A, E29. **13** — *Glaphyrocysta exuberans* (Deflandre & Cookson, 1955 ex Eaton, 1976) Stover & Evitt, 1978; emend. Sarjeant, 1986; H6-1420A, X5. **14** — *Glaphyrocysta exuberans* (Deflandre & Cookson, 1955 ex Eaton, 1976) Stover & Evitt, 1978; emend. Sarjeant, 1986; H6-1420A, G3. **15** — *Glaphyrocysta exuberans* (Deflandre & Cookson, 1955 ex Eaton, 1976) Stover & Evitt, 1978; emend. Sarjeant, 1986; H6-1470B, Y5/4.

(Auffret & Gruas-Cavagnetto 1975) and in the Middle to Upper Eocene of northern Germany (Costa & Martini 1981), northern France (Châteauneuf 1980). Williams & Bujak (1985) documented that *Apectodinium homomorphum* ranges from the Upper Paleocene to the Middle Eocene. *Diphyes ficusoides* is recorded in the Lower Eocene in Virginia (Edwards 1989), Lower to Middle Eocene in Germany (Heilmann-Clausen & Costa 1989; Köthe & Piesker 2007) and in southern England (Islam 1983), and ranges from the Middle to the Upper Eocene according to Stover et al. (1996). *Deflandrea phosphoritica* is recorded in the Lower Eocene in Germany (Köthe & Piesker 2007). The co-occurrence of *A. homomorphum*, *D. ficusoides* and *D. phosphoritica* in Well Höflein 6 at the depth of 300 m indicates a stratigraphic posi-

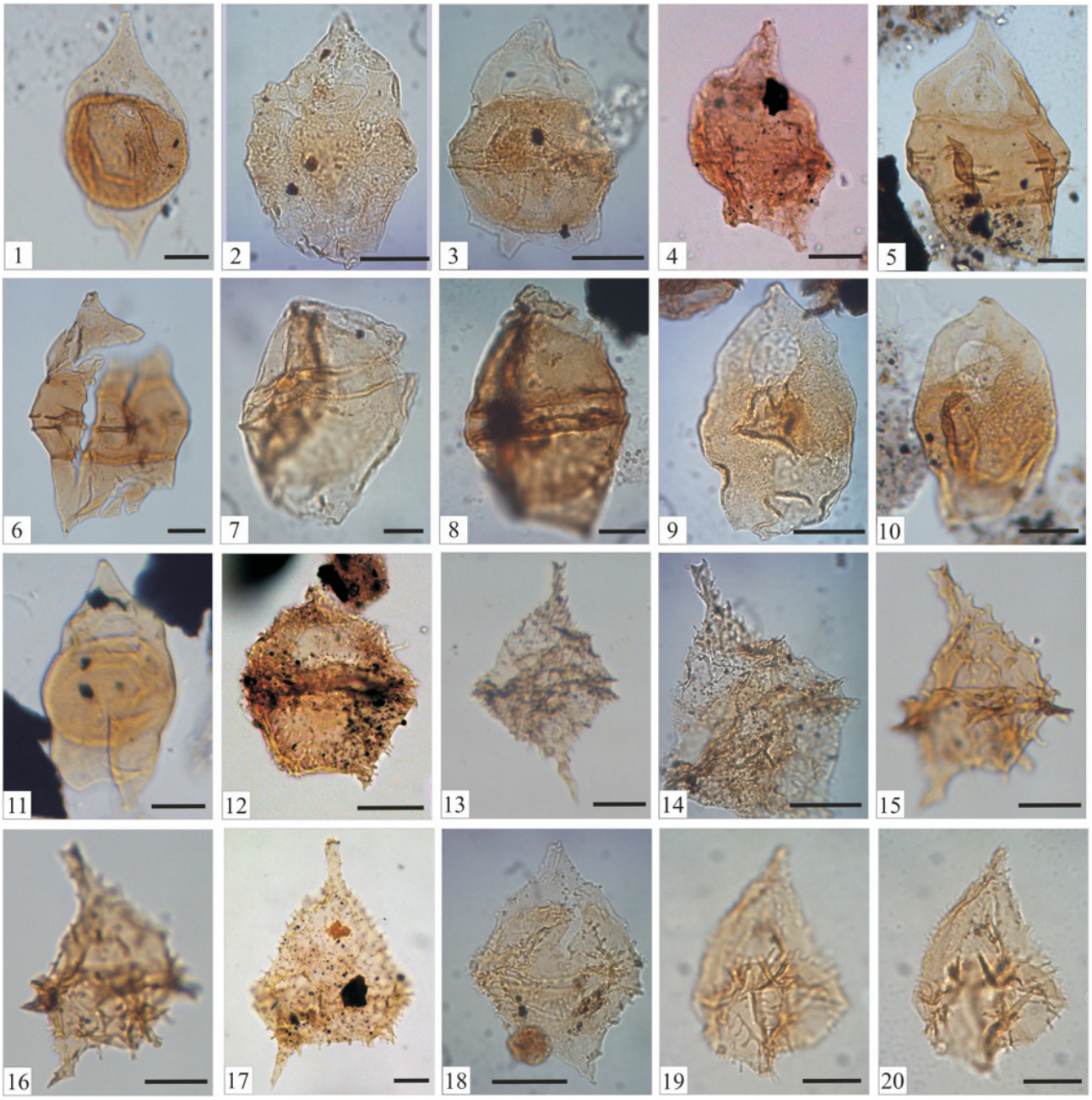

Fig. 7. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1** — *Chatangiella*? *robusta* (Benson, 1976) Stover & Evitt, 1978; H6-1070A, U31/4. **2** — *Chatangiella granulifera* (Manum, 1963) Lentin & Williams, 1976; H6-1730A, T23. **3** — *Chatangiella granulifera* (Manum, 1963) Lentin & Williams, 1976; H6-1170A, B17. **4** — *Chatangiella ditissima* (McIntyre, 1975) Lentin & Williams, 1976; H6-250A, H7. **5** — *Chatangiella hexacalpis* Harker & Sarjeant in Harker et al., 1990; H6-1930C, K18. **6** — *Chatangiella ditissima* (McIntyre, 1975) Lentin & Williams, 1976; H6-1120A, G27. **7** — *Subtilisphaera terrula* (Davey, 1974) Lentin & Williams, 1976; emend. Harding, 1986; H6-1120A, O11/1. **8** — *Subtilisphaera perlucida* (Alberti, 1959) Jain & Millepied, 1973; H6-300B, L9/2. **9** — *Isabelidinium* sp.; H6-890B, V8. **10** — *Isabelidinium cooksoniae* (Alberti, 1959) Lentin & Williams, 1977; H6-1120A, U16/4. **11** — *Isabelidinium cooksoniae* (Alberti, 1959) Lentin & Williams, 1977; H6-840B, B19/1. **12** — *Magallanesium densispinatum* (Stanley, 1965) Quattrocchio & Sarjeant, 2003; H6-1470A, X13. **13, 14** — *Magallanesium macmurdoense* Wilson, 1967; H6-300A, A9. **15, 16** — *Spinidinium* sp.; H6-1930A, L14. **17** — *Magallanesium macmurdoense* Wilson, 1967; H6-250A, V29. **18** — *Spinidinium echinoideum* (Cookson & Eisenack, 1960) Lentin & Williams, 1976; emend. Sverdlove & Habib, 1974; H6-1170B, F13. **19, 20** — *Spinidinium echinoideum* subsp. *rhombicum* (Cookson & Eisenack, 1974) Lentin & Williams, 1976; H6-2080B, T12/4.

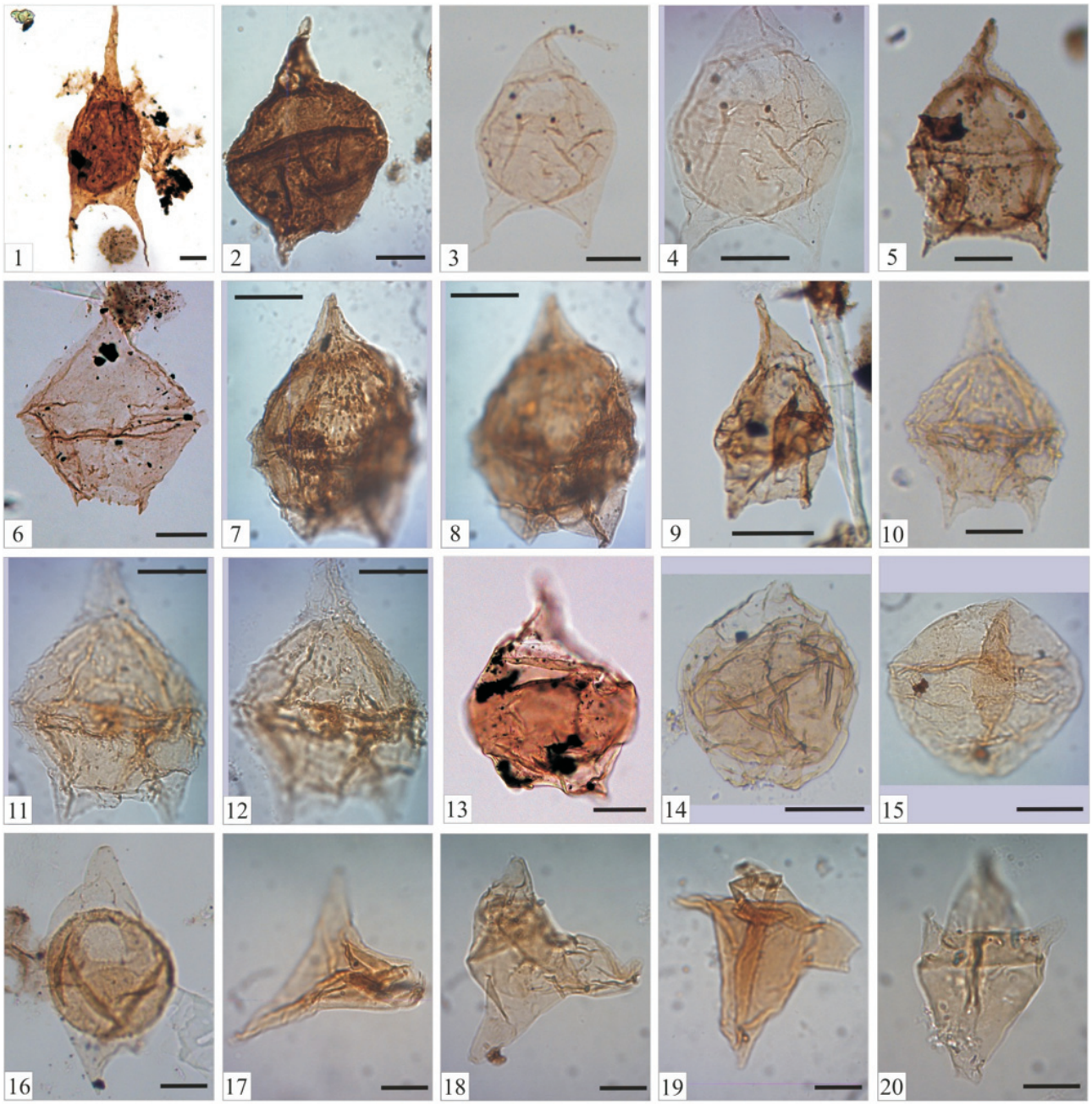

Fig. 8. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1** — *Cerodinium diebelii* (Alberti, 1959) Lentin & Williams, 1987; H6-1220B, B21. **2** — *Cerodinium obliquipes* (Deflandre & Cookson, 1955) Lentin & Williams, 1987; H6-153B, T21/4. **3, 4** — *Cerodinium speciosum* subsp. *glabrum* (Gocht, 1969) Lentin & Williams, 1987; H6-730A, D15. **5** — *Cerodinium speciosum* (Alberti, 1959) Lentin & Williams, 1987; H6-1220C, P30. **6** — *Palaeoperidinium pyrophorum* (Ehrenberg, 1838 ex Wetzel, 1933) Sarjeant, 1967; emend. Sarjeant, 1967; H6-1470B, V5/1. **7, 8** — *Deflandrea phosphoritica* Eisenack, 1938; H6-300A, E22/3. **9** — *Deflandrea antarctica* Wilson, 1967; H6-50A, B8/2. **10–12** — *Deflandrea cygniformis* Pöthe de Baldis, 1966; H6-300A, E23. **13** — *Trithyrodinium evittii* Drugg, 1967; H6-1220B, C34/2. **14** — *Trithyrodinium evittii* Drugg, 1967; H6-300A, E2/1. **15** — *Trithyrodinium* cf. *evittii* Drugg, 1967; H6-1120A, U15. **16** — *Trithyrodinium robustum* Benson, 1976; H6-2480A, H20/3. **17** — *Trigonopyxidia ginella* (Cookson & Eisenack, 1960) Downie & Sarjeant, 1965; H6-320B, J7. **18** — *Trigonopyxidia ginella* (Cookson & Eisenack, 1960) Downie & Sarjeant, 1965; H6-300B, W11/2. **19** — *Palaeotetradinium silicorum* Deflandre, 1936; emend. Deflandre & Sarjeant, 1970; H6-320B, A11/3. **20** — *Palaeotetradinium silicorum* Deflandre, 1936; emend. Deflandre & Sarjeant, 1970; H6-320B, O42.

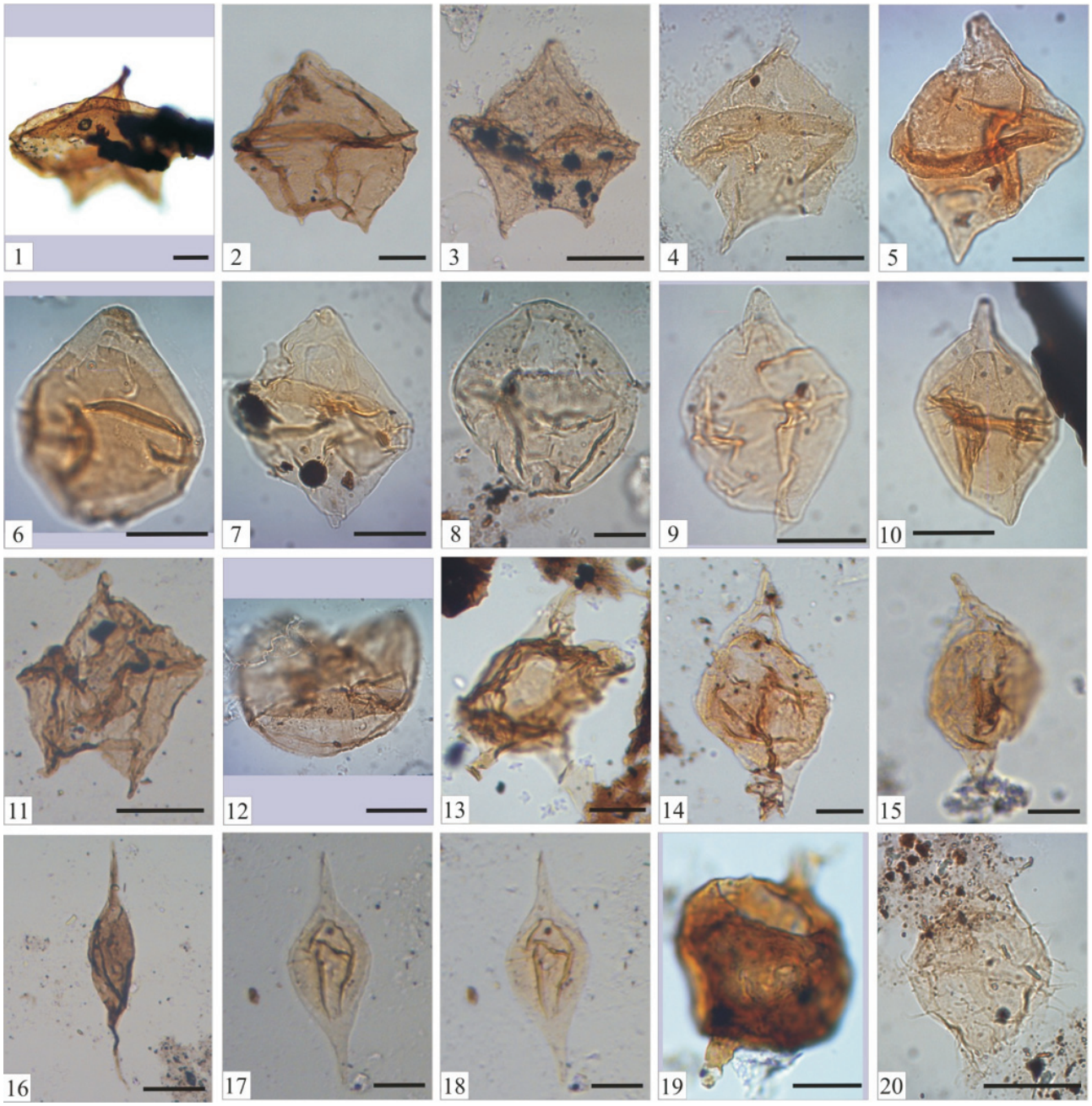

Fig. 9. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1** — *Lejeunecysta communis* Biffi & Grignani, 1983; H6-1220B, E36. **2** — *Lejeunecysta hyalina* (Gerlach, 1961) Artzner & Dörhöfer, 1978; emend. Sarjeant, 1984; H6-2130A, W33. **3** — *Lejeunecysta hyalina* (Gerlach, 1961) Artzner & Dörhöfer, 1978; emend. Sarjeant, 1984; H6-300A, B35. **4** — *Lejeunecysta hyalina* (Gerlach, 1961) Artzner & Dörhöfer, 1978; emend. Sarjeant, 1984; H6-2480A, C5/3. **5** — *Manumiella seelandica* (Lange, 1969) Bujak & Davies 1983; emend. Firth, 1987; H6-790A, E29/2. **6** — *Manumiella druggii* (Stover, 1974) Bujak & Davies, 1983; H6-300B, Q40/3. **7** — *Manumiella*? *hemmoorensis* Marheinecke, 1992; H6-1680A, O27/1. **8** — *Manumiella*? cf. *cretacea* (Cookson, 1956) Bujak & Davies, 1983; H6-300B, A12/4. **9** — *Alterbidinium acutulum* (Wilson, 1967) Lentin & Williams, 1985; H6-790B, A13. **10** — *Alterbidinium acutulum* (Wilson, 1967) Lentin & Williams, 1985; H6-1020B, U31/1. **11** — *Phelodinium magnificum* (Stanley, 1965) Stover & Evitt, 1978; H6-300B, K25/2. **12** — *Phelodinium magnificum* (Stanley, 1965) Stover & Evitt, 1978; H6-300A, C11/3. **13** — *Phelodinium tricuspe* (Wetzel, 1933) Stover & Evitt, 1978; emend. Lejeune-Carpentier & Sarjeant, 1981; H6-2030B, D20. **14** — *Andalusiella polymorpha* (Malloy, 1972) Lentin & Williams, 1977; H6-680B, L4. **15** — *Andalusiella polymorpha* (Malloy, 1972) Lentin & Williams, 1977; H6-1120B, G3. **16** — *Palaeocystodinium golzowense* Alberti, 1961; H6-300A, D24/3. **17, 18** — *Biconidinium reductum* (May, 1980) Kirsch, 1991; emend. Kirsch, 1991; H6-1120B, B32/1. **19** — *Kenleyia lophophora* Cookson & Eisenack, 1965; H6-300B, J11/4. **20** — *Palaeohystrichophora infusorioides* Deflandre, 1935; H6-1930B, Q36/4.

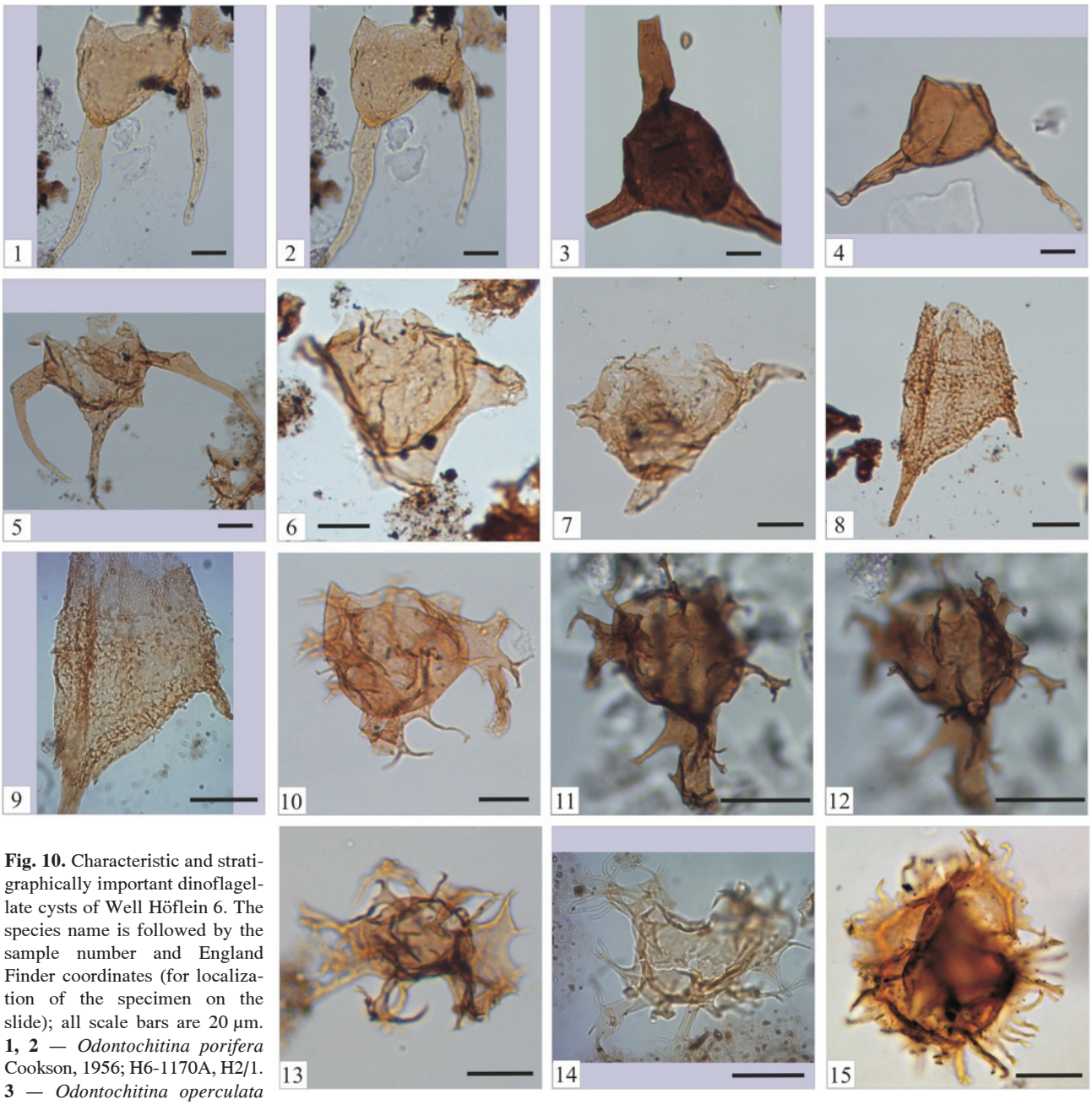

Fig. 10. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1, 2** — *Odontochitina porifera* Cookson, 1956; H6-1170A, H2/1. **3** — *Odontochitina operculata* (Wetzel, 1933) Deflandre & Cookson, 1955; H6-990A, A19. **4** — *Odontochitina operculata* (Wetzel, 1933) Deflandre & Cookson, 1955; H6-890A, B11/4. **5** — *Muderongia extensiva* Duxbury, 1977; H6-2530A, M20. **6** — *Muderongia australis* Helby, 1987; emend. Monteil, 1991; H6-2530B, W20. **7** — *Muderongia* sp.; H6-1120A, G10. **8, 9** — *Pseudoceratium pelliferum* Gocht, 1957; emend. Dörhöfer & Davies, 1980; H6-2530A, J23. **10** — *Xenascus sarjeantii* (Corradini, 1973) Stover & Evitt, 1978; H6-790A, R5/1. **11, 12** — *Xenascus sarjeantii* (Corradini, 1973) Stover & Evitt, 1978; H6-1020B, B18. **13** — *Xenascus* sp.; H6-1930B, O14/2. **14** — *Xenascus* cf. *asperatus* Stover & Helby, 1987; H6-1930B, O14/2. **15** — *Xiphophoridium alatum* (Cookson & Eisenack, 1962) Sarjeant, 1966; emend. Sarjeant, 1966; H6-20A, Y28.

tion not lower than Lower Eocene and the Paleocene/Eocene boundary probably may be present below 300 m depth (Fig. 2). Associated with the Paleocene-Eocene thermal maximum (PETM) warming is a >2.5 ‰ negative carbon isotope ($\delta^{13}C$) excursion (CIE) measured on terrestrial and marine sedimentary carbon (Kennett & Stott 1991; Koch et al. 1992; Thomas et al. 2002; Pagani et al. 2006). The position of the CIE termination is correlated to the concomitant LO of the dinocyst species *Apectodinium augustum*, which has only been recorded from the CIE (Bujak & Brinkhuis 1998; Steurbaut et al. 2003; Sluijs et al. 2007; Hofmann et al. 2011; Speijer et al. 2012). In Well Höflein 6, *Apectodinium augustum* occurs at the depth of 1520 m which indicates equivalence to the uppermost Paleocene PETM-interval for this horizon directly below the Paleocene/Eocene boundary in the lower thrust unit B at the base of the Greifenstein Formation (Fig. 2).

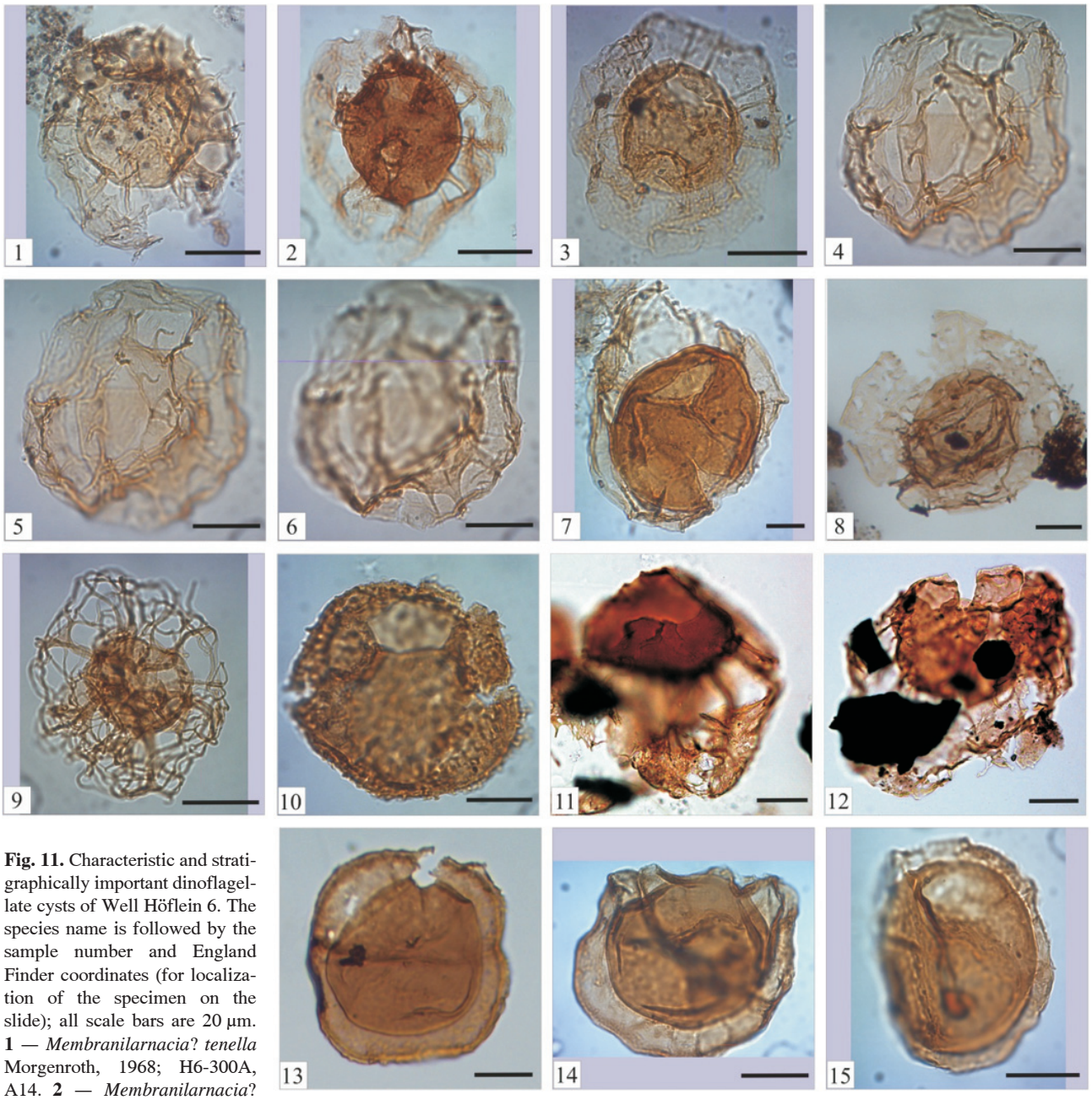

Fig. 11. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1** — *Membranilarnacia*? *tenella* Morgenroth, 1968; H6-300A, A14. **2** — *Membranilarnacia*? *tenella* Morgenroth, 1968; H6-940A, P11/3. **3** — *Membranilarnacia*? *tenella* Morgenroth, 1968; H6-1120A, D16/2. **4–6** — *Thalassiphora delicata* Williams & Downie, 1966; emend. Eaton, 1976; H6-1370A, N9. **7** — *Thalassiphora pelagica* (Eisenack, 1954) Eisenack & Gocht, 1960; emend. Benedek & Gocht, 1981; H6-300B, C4/1. **8** — *Thalassiphora inflata* Heilmann-Clausen in Thomsen & Heilmann-Clausen, 1985; H6-2530B, S14/3. **9** — *Trabeculidium quinquetrum* Duxbury, 1980; H6-1020A, E32/3. **10** — *Trichodinium ciliatum* (Gocht, 1959) Eisenack & Klement, 1964; H6-2530B, Q32/2. **11** — *Riculacysta amplexa* Kirsch, 1991; H6-1470B, M20/4. **12** — *Riculacysta amplexa* Kirsch, 1991; H6-1470B, J35/3. **13** — *Paralecaniella indentata* (Deflandre & Cookson, 1955) Cookson & Eisenack, 1970; emend. Elsik, 1977; H6-1270A, T40/2. **14** — *Paralecaniella indentata* (Deflandre & Cookson, 1955) Cookson & Eisenack, 1970; emend. Elsik, 1977; H6-1270B, N20. **15** — *Paralecaniella indentata* (Deflandre & Cookson, 1955) Cookson & Eisenack, 1970; emend. Elsik, 1977; H6-1420A, D31.

Carpatella cornuta is a typical Danian dinoflagellate species (e.g. Williams et al. 2004). In the Northern Hemisphere at the El-Kef GSSP (Global Boundary Stratotype Section and Point) section, Brinkhuis et al. (1998) documented that the lowest global occurrence of *Carpatella cornuta* is slightly above the Cretaceous/Paleogene (K/Pg) boundary. In the Southern Hemisphere, *Carpatella cornuta* is recorded above the K/Pg boundary, two sporadic occurrences of *Carpatella cornuta* below the boundary are interpreted as the result of intense bioturbation (Ferrow et al. 2011). This Danian species and *Senoniasphaera inornata* are reported to occur slightly above the boundary both in the Northern and Southern Hemi-

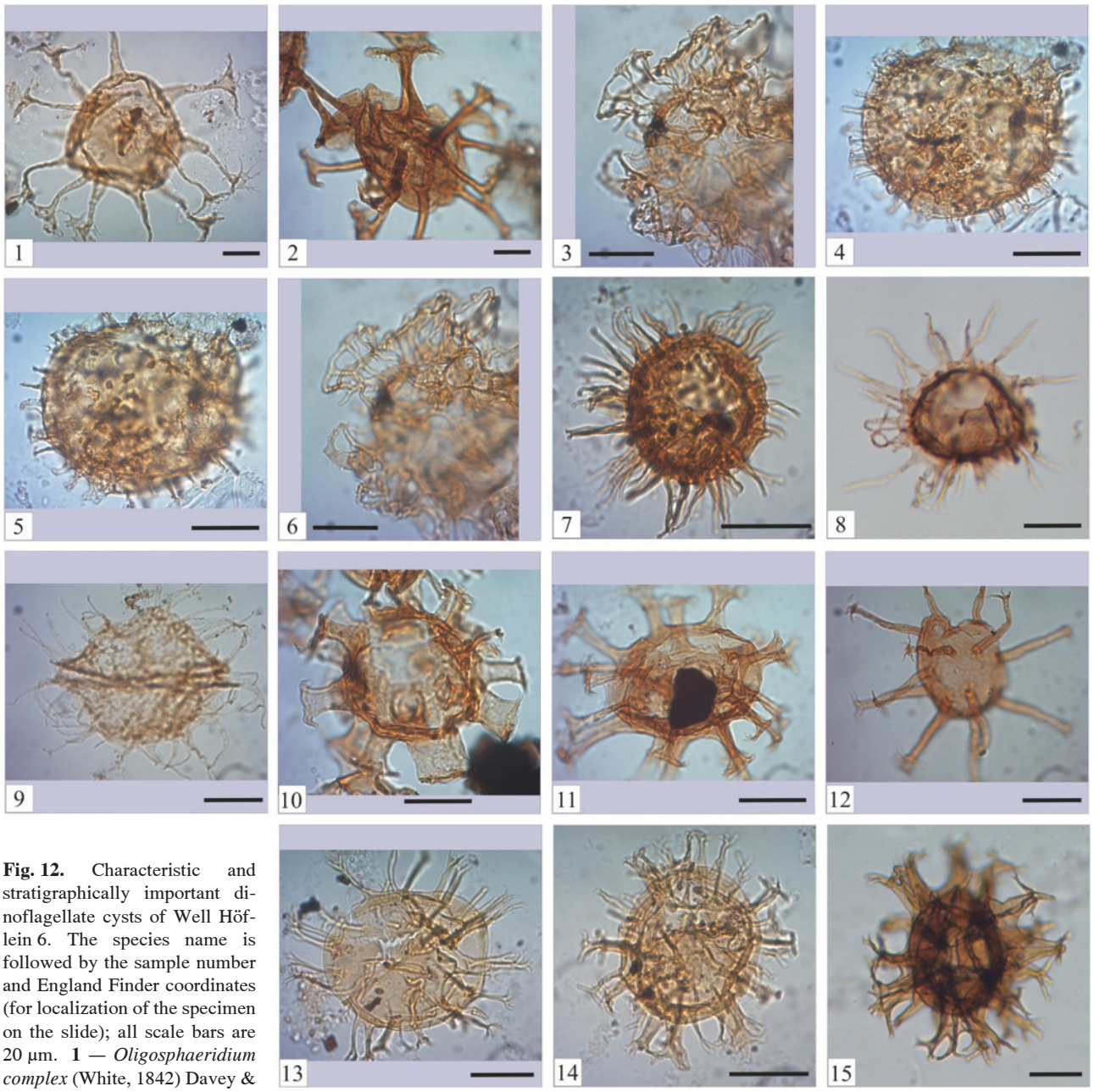

Fig. 12. Characteristic and stratigraphically important dinoflagellate cysts of Well Höflein 6. The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide); all scale bars are 20 µm. **1** — *Oligosphaeridium complex* (White, 1842) Davey & Williams, 1966; H6-300B, Q42. **2** — *Oligosphaeridium complex* (White, 1842) Davey & Williams, 1966; H6-2530B, F7. **3, 6** — *Hystrichosphaerina schindewolfii* Alberti, 1961; H6-1170B, E12. **4, 5** — *Circulodinium distinctum* (Deflandre & Cookson, 1955) Jansonius, 1986; H6-300A, C27. **7** — *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937) Yun Hyesu, 1981; emend. Davey, 1969; H6-300A, D27/3. **8** — *Hystrichodinium pulchrum* Deflandre, 1935; H6-790A, H18/1. **9** — *Hystrichodinium pulchrum* subsp. *areatum* Marheinecke, 1992; H6-1730A, W35/1. **10** — *Hystrichosphaeridium tubiferum* subsp. *brevispinum* (Davey & Williams, 1966) Lentin & Williams, 1973; emend. Marheinecke, 1992; H6-790B, A4/2. **11** — *Hystrichosphaeridium tubiferum* (Ehrenberg, 1838) Deflandre, 1937; emend. Davey & Williams, 1966; H6-790B, R32. **12** — *Hystrichosphaeridium recurvatum* (White, 1842) Lejeune-Carpentier, 1940; H6-940A, W25. **13** — *Surculosphaeridium*? *basifurcatum* Yun Hyesu, 1981; H6-1010B, F15/2. **14** — *Spiniferites* cf. *bulloideus* (Deflandre & Cookson, 1955) Sarjeant, 1970; H6-200A, Q23. **15** — *Spiniferites membranaceus* (Rossignol, 1964) Sarjeant, 1970; H6-890B, L37.

spheres by Williams et al. (2004). In West Greenland, Nøhr-Hansen & Dam (1997) recognized the LO of *Senoniasphaera inornata* in the K/Pg boundary clay layer. In the Gams Basin, Austria, *Senoniasphaera inornata* and *Damassadinium californicum* occur first directly above the K/Pg boundary and *Carpatella cornuta* occurs 30 cm above (Mohamed et al. 2012). In the upper thrust unit A of Well Höflein 6, the FO of *Damassadinium californicum*, also typical for the Danian (e.g. Williams et al. 2004), is recorded at the depth of 630 m. Both, *Carpatella cornuta* and *Senoniasphaera inornata* are recorded at the depth of 680 m suggesting the presence of the K/Pg boundary directly below the

depth of 680 m (Fig. 2), within the Altlengbach Formation. In the lower thrust unit B, *Carpatella cornuta* is not recorded. The FOs of *Damassadinium californicum* and *Senoniasphaera inornata* are recorded at the depth of 1630 m and 1580 m respectively, suggesting the position of the K/Pg boundary directly below the depth of 1630 m (Fig. 2).

The FO of *Manumiella seelandica* is recorded at the Campanian-Maastrichtian boundary in the southern mid latitudes and in the Upper Maastrichtian in the northern mid latitudes (e.g. Williams et al. 2004). In Well Höflein 6, the FO of *Manumiella seelandica* occurs at the depth of 990 m in the upper thrust unit A (Perneck Formation) and at 1780 m depth in the lower thrust unit B (Altlengbach Formation) (Fig. 2). The occurrence of this species at this level indicates a stratigraphic position not lower than Maastrichtian. The highest occurrence of *Palaeohystrichophora infusorioides* is recorded directly above the Campanian-Maastrichtian boundary in the southern mid latitudes and occurs at the depth of 1930 m in Well Höflein 6. The most significant biostratigraphic event within this interval is the LO of *Odontochitina porifera*. The highest occurrence of this species is restricted to the Campanian in the northern mid latitudes (e.g. Williams et al. 2004). Kirsch (1991) reported this species from the Lower–Middle Campanian in the Helvetic and Ultrahelvetic realm of Germany and Austria. In Well Höflein 6 the LO of *Odontochitina porifera* is recorded at the depth of 1120 m in the upper thrust unit A (Röthenbach Subgroup) and 1930 m in the lower thrust unit B (Altlengbach Formation?). Therefore, a Campanian age can be inferred for these depth intervals, and formations are either diachronous or formation interpretation of the lower thrust unit has to be refined. *Corradinisphaeridium horridum* occurs in three samples (depth of 1070, 2030, 2080 m) (Fig. 2). This species was originally reported by Corradini (1973) from the Campanian of northern Italy, from the type Campanian (Charente, France) by Masure (1986) and from mid-Campanian strata in southern Germany by Kirsch (1991). Schiøler & Wilson (2001) regard this species as an important Middle–Upper Campanian marker with a LO close to the Campanian-Maastrichtian boundary. Based on these data the Campanian-Maastrichtian boundary can be positioned above the depth of 1070 m and 1930 m in the Well Höflein 6.

Further biostratigraphically important events are recorded at the boundary of the Röthenbach Subgroup (Altlengbach Formation according to OMV internal report) to the underlying Wolfpassing Formation, namely the LOs of *Muderongia extensiva*, *Muderongia australis*, *Leberidocysta*? *laticaudata* and *Pseudoceratium pelliferum* at 2530 m depth, and the FOs of *Areoligera coronate*, *Chatangiella ditissima* and *Cerodinium diebelii* at 2480 m depth (Fig. 2). Kirsch (1991) reported the FO of *Areoligera coronata* from the Lower Campanian in southern Germany. Previous studies demonstrated that the FO of the genus *Areoligera* is not recorded below the Campanian (e.g. Williams & Bujak 1985; Williams et al. 2004). The FO of *Cerodinium diebelii* was recorded as a Maastrichtian event in central and northern Europe by Górka (1963), Wilson (1974), Kirsch (1991) and Smelror & Riegraf (1996), from the Lower Maastrichtian of West Greenland (Nøhr-Hansen 1996) and NW Germany (Marheineck 1992), and from the Upper Campanian in the North Sea area by Costa & Davey (1992). *C. diebelii* was also found in the Maastrichtian of the Outer Carpathian Flysch Zone by Skupien & Mohamed (2008), and probably occurs before in the Late Campanian (see Skupien et al. 2009). Schiøler & Wilson (2001) interpreted this species as an important biostratigraphic marker situated directly below the Campanian-Maastrichtian boundary. *Leberidocysta*? *laticaudata* was recorded in the Santonian of the USSR (Vozzhennikova 1967) and NW Germany (Yun Hyesu 1981). Thus, in the Höflein 6 Well the lower boundary of the Campanian occurs between 2480 and 2530 m depth.

The succession of the Wolfpassing Formation below the Lower Campanian part of thrust unit B in Well Höflein 6 is regarded as older than Santonian, although the age evidence is not straightforward and rather contradictory. *Muderongia extensiva* was recorded in the Lower Valanginian–Lower Hauterivian in England (Duxbury 1977), Valanginian-basal Hauterivian in Denmark (Heilmann-Clausen 1987), Valanginian/Hauterivian–Upper Aptian in Norway (Thusu 1978), Upper Berriasian–Upper Valanginian in the Gulf of Mexico (Riley & Fenton 1984) and Upper Barremian in France (Srivastava 1984). *Muderongia australis* was recorded in the Hauterivian–Barremian in Australia (Helby 1987), basal Hauterivian in NW Germany (Prauss 1990) and Lower Barremian in east Greenland (Nøhr-Hansen 1993). Stover et al. (1996) documented that the range of this species is Hauterivian–Aptian. On the other hand, the species *Palaeoperidinium pyrophorum* and *Palaeotetradinium silicorum* (sample 2530; Fig. 8.19–20) have their FO probably in the Cenomanian, and *Surculosphaeridium longifurcatum* (samples 2560, 2530) has its FO in the Middle Albian according to some authors (e.g. Skupien et al. 2009), however, it was also recorded in older sediments, e.g. Gedl (2007) in the Aptian to Early Campanian in Poland. Thus, in the Well Höflein 6 the interval from 2530 m to 2565 m can most probably be correlated to the interval from the Hauterivian to the Cenomanian. Because of the presence of the genus *Muderongia*, a Hauterivian–Barremian to Aptian age is most likely, which is in accordance with the general age assignment for this formation (e.g. Sauer et al. 1992).

Reworking and downfall materials

A few specimens of Cretaceous species such as *Florentinia aculeata*, *Tanyosphaeridium xanthiopyxides*, *Cannosphaeropsis utinensis*, *Chatangiella* spp., *Palaeotetradinium silicorum* and *Surculosphaeridium longifurcatum* are recorded in the Paleocene samples indicating a high rate of reworking (electronic Appendix B, C). The presence of single specimen of *Areosphaeridium diktyoplokum* (Fig. 3.13,14) and *Cerodinium diebelii* at 2530 m depth are probably downfall from the upper succession. A few specimens of Cretaceous species such as *Cannosphaeropsis utinensis*, *Chatangiella* spp., *Tanyosphaeridium xanthiopyxides*, *Palaeotetradinium silicorum*, *Surculosphaeridium*? *basifurcatum* and *Xenascus sarjeantii* are recorded in the Paleocene samples at the depth of ca. 1520 m indicating again increased reworking (electronic Appendix B, C). The occurrence of one damaged specimen of

Odontochitina porifera at the depth of 890 m indicates a reworking from older sediments.

The FO of *Glaphyrocysta exuberans* at the depth of 1730 m may be due to downhole contamination since this species is only known from the Paleocene and Eocene (e.g. Köthe & Piesker 2007). The LO of the Paleocene taxa *Carpatella cornuta*, *Damassadinium californicum* are recorded at the depth of 250 m and the LO of *Senoniasphaera inornata* is recorded in 20 m depth, indicating a reworking of Paleocene into Eocene strata. A few specimens (one or two per sample) of Cretaceous species such as *Chatangiella ditissima*, *Chatangiella madura*, *Chatangiella* spp., *Cannosphaeropsis utinensis*, *Florentinia aculeata*, *Manumiella*? cf. *cretacea*, *Surculosphaeridium longifurcatum*, *Dinogymnium denticulatum*, *Tanyosphaeridium xanthiopyxides*, *Palaeotetradinium silicorum*, *Trigonopyxidia ginella*, *Stanfordella fastigiata* and *Xiphophoridium alatum* are present in the Eocene samples of the lower and upper thrust units indicating a high degree of reworking (electronic Appendix B, C).

Stratigraphic correlations of Flysch units from borehole to outcrop

The dinoflagellate-based ages as interpreted from the cuttings samples of the Höflein 6 Well compare well with age data derived from the corresponding lithostratigraphic units from the succession of the Wienerwald area. The Wolfpassing Formation at the base of the lower thrust unit B in Höflein 6 (2490–2530 m) gives indications for a Hauterivian to Aptian age, in accordance with published data from the type section of the Wolfpassing Formation of the Wienerwald area (mainly Barremian–Aptian; Grün et al. 1972). Stratigraphically, a gap between Aptian and overlying Campanian strata may indicate another thrust or fault plane separating the Wolfpassing Formation from the overlying younger strata. The Röthenbach Subgroup from the upper thrust unit A (1017–1210 m) ranges from the Campanian up to the basal Maastrichtian according to our dinocyst data. Similar Campanian ages are reported from Egger & Schwerd (2008) from Bavaria, Germany. The Perneck Formation from the upper thrust unit A (785–1017 m) has an Early Maastrichtian age according to our data in contrast to the Late Campanian age reported from Upper Austria and Bavaria (Egger 1993; Egger & Schwerd 2008). Further biostratigraphic data is needed to evaluate whether the formation is diachronous from west to east within the RFZ, or if dinoflagellate biostratigraphic datums and problems due to reworking and downfall result in an imprecise biostratigraphic result for Well Höflein 6. Some uncertainties probably also exist with the lithostratigraphic interpretation of the Höflein 6 borehole as the Perneck Formation, normally only up to 50 m thick, attains a (non-dip corrected) thickness of 120 m.

The Altlengbach Formation is present both in the upper unit A (322–785 m) and in the lower unit B (1520–2470 m). Within the upper unit, dinoflagellate ages compare well with the known stratigraphic ages of Maastrichtian to Paleocene of the Altlengbach Formation (up to NP9; Schnabel 1992; Egger 1995). In the lower unit B, some ambiguity seems to exit about the attribution of the lower part of the interval, mainly the Campanian part, to the Altlengbach Formation as is also indicated by the high thickness of 940 m. At least the lower part of this Campanian section interval from 2470 to 1930 m may be alternatively attributed to the Röthenbach Subgroup (and the Perneck Formation on top) in accordance with the succession within the upper thrust unit A.

The Greifenstein Formation of Well Höflein 6 straddles the Paleocene-Eocene boundary and ranges up into the Lower/Middle Eocene. This correlates well with data from Hekel (1968: NP9 to NP13, Thanetian–Ypresian) and chronostratigraphic ages summarized by Schnabel (1992) and Faupl (1996) for the Greifenstein Formation of the Greifenstein Nappe.

Conclusions

Despite the fact that only cuttings samples from Well Höflein 6 within the Rhenodanubian Flysch Zone have been investigated a concise and detailed biostratigraphic succession and zonation based on organic-walled dinoflagellates is possible.

In the upper thrust unit A, an Eocene age is indicated in the upper part of the Greifenstein Formation. A Paleocene age is indicated for the upper part of the Altlengbach Formation (and in the overlying lowermost Greifenstein Formation) between the depths of ca. 680 m and ca. 322 m. A Maastrichtian age is interpreted for the uppermost Röthenbach Subgroup, the Perneck Formation (Oberste Bunte Schiefer of OMV internal reports) and the lowermost Altlengbach Formation, between the depths of ca. 1020 m and ca. 730 m. A Campanian age is inferred for the Röthenbach Subgroup, between the depths of ca. 1210 m and ca. 1017 m.

In the lower thrust unit B, an Eocene age is inferred for the upper part of the Greifenstein Formation. A Paleocene age is recorded in the uppermost Altlengbach Formation and in the lowermost Greifenstein Formation between the depths of ca. 1630 m and ca. 1520 m. A Maastrichtian age is inferred for the Altlengbach Formation between the depths of ca. 1880 m and ca. 1680 m. A Campanian age is inferred between the depths of ca. 2480 m and ca. 1930 m (corresponding mainly to the lowermost part of the Altlengbach Formation and probably parts of the Röthenbach Subgroup).

The Wolfpassing Formation of inferred Early Cretaceous age is only reported from the lower thrust unit B (see Table 1), between the depths of ca. 2561 m and 2470 m. A stratigraphic gap probably indicates the presence of a thrust or fault between the Wolfpassing Formation and the overlying Campanian strata.

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Appendix A. Species list

List of dinocyst taxa encountered in this study, arranged in alphabetical order of genus name. The references to species' authors are given by Fensome et al. (2008) and the taxonomy of dinocyst taxa is generally based on Fensome et al. (1993).

Achilleodinium biformoides (Eisenack, 1954) Eaton, 1976
Achomosphaera cf. *alcicornu* (Eisenack, 1954) Davy & Williams, 1966
Achomosphaera neptuni (Eisenack, 1958) Davey & Williams, 1966; emend. Duxbury, 1983
Achomosphaera ramosasimilis (Yun Hyesu, 1981) Londeix et al., 1999
Achomosphaera ramulifera (Deflandre, 1937) Evitt, 1963
Achomosphaera ramulifera subsp. *ramulifera* Deflandre, 1937
Achomosphaera regiensis Corradini, 1973
Achomosphaera spp.
Actinotheca aphroditae Cookson & Eisenack, 1960
Adnatosphaeridium filiferum (Cookson & Eisenack, 1958) Williams & Downie, 1969
Adnatosphaeridium multispinium Williams & Downie, 1966
Adnatosphaeridium tutulosum (Cookson & Eisenack, 1960) Morgan, 1980
Alisogymnium euclaense (Cookson & Eisenack, 1970) Lentin & Vozzhennikova, 1990
Alterbidinium acutulum (Wilson, 1967) Lentin & Williams, 1985
Alterbidinium longicornutum Roncaglia et al., 1999
Alterbidinium spp.
Alterbidinium? *distinctum* (Wilson, 1967) Lentin & Williams, 1985
Andalusiella polymorpha (Malloy, 1972) Lentin & Williams, 1977
Apectodinium augustum (Harland, 1979) Lentin & Williams, 1981
Apectodinium homomorphum (Deflandre & Cookson, 1955) Lentin & Williams, 1977; emend. Harland, 1979
Apectodinium quinquelatum (Williams & Downie, 1966) Costa & Downie, 1979
Apectodinium spp.
Apteodinium deflandrei (Clarke & Verdier, 1967) Lucas-Clark, 1987
Apteodinium granulatum Eisenack, 1958; emend. Sarjeant, 1985
Areoligera coronata (Wetzel, 1933) Lejeune-Carpentier, 1937
Areoligera gippingensis Jolley, 1992
Areoligera guembelii Kirsch, 1991
Areoligera medusettiformis Wetzel, 1933 ex Lejeune-Carpentier, 1938
Areoligera senonensis Lejeune-Carpentier, 1938
Areoligera spp.
Areoligera volata Drugg, 1967
Areosphaeridium diktyoplokum (Klumpp, 1953) Eaton, 1971; emend. Eaton, 1971
Avellodinium? *hauteriviense* Prössl, 1990
Batiacasphaera grandis Roncaglia et al., 1999
Batiacasphaera micropapillata Stover, 1977
Batiacasphaera spp.
Biconidinium reductum (May, 1980) Kirsch, 1991; emend. Kirsch, 1991
Canningia reticulata Cookson & Eisenack, 1960; emend. Below, 1981
Canningia senonica Clarke & Verdier, 1967
Cannosphaeropsis hughesii Harding, 1990 ex Harding in Williams et al., 1998
Cannosphaeropsis utinensis Wetzel, 1933; emend. May, 1980
Carpatella cornuta Grigorovitch, 1969; emend. Fechner & Mohr, 1986
Cassidium fragile (Harris, 1965) Drugg, 1967
Cauveridinium membraniphorum (Cookson & Eisenack, 1962) Masure in Fauconnier & Masure, 2004
Cerodinium diebelii (Alberti, 1959) Lentin & Williams, 1987
Cerodinium obliquipes (Deflandre & Cookson, 1955) Lentin & Williams, 1987
Cerodinium speciosum (Alberti, 1959) Lentin & Williams, 1987
Cerodinium speciosum subsp. *glabrum* (Gocht, 1969) Lentin & Williams, 1987
Cerodinium spp.
Chatangiella ditissima (McIntyre, 1975) Lentin & Williams, 1976
Chatangiella granulifera (Manum, 1963) Lentin & Williams, 1976
Chatangiella hexacalpis Harker & Sarjeant in Harker et al., 1990
Chatangiella madura Lentin & Williams, 1976
Chatangiella spp.
Chatangiella? *robusta* (Benson, 1976) Stover & Evitt, 1978
Circulodinium brevispinatum (Millioud, 1969) Fauconnier in Fauconnier & Masure, 2004
Circulodinium distinctum (Deflandre & Cookson, 1955) Jansonius, 1986
Circulodinium spp.
Cladopyxidium velatum Below, 1987
Cleistosphaeridium diversispinosum Davey et al., 1966; emend. Eaton et al., 2001
Cleistosphaeridium placacanthum (Deflandre & Cookson, 1955) Eaton et al., 2001; emend. May, 1980
Cleistosphaeridium spp.
Codoniella campanulata (Cookson & Eisenack, 1960) Downie & Sarjeant, 1965; emend. Davey, 1979
Conosphaeridium striatoconum (Deflandre & Cookson, 1955) Cookson & Eisenack, 1969
Cordosphaeridium cantharellus (Brosius, 1963) Gocht, 1969
Cordosphaeridium fibrospinosum Davey & Williams, 1966
Cordosphaeridium spp.
Coronifera cf. *striolata* (Deflandre, 1937) Stover & Evitt, 1978
Coronifera oceanica subsp. *hebospina* Yun Hyesu, 1981
Coronifera spp.
Corradinisphaeridium horridum (Deflandre, 1937) Masure, 1986; emend. Masure, 1986
Cribroperdinium? *edwardsii* (Cookson & Eisenack, 1958) Davey, 1969
Cribroperidinium cooksoniae Norvick, 1976
Cribroperidinium orthoceras (Eisenack, 1958) Davey, 1969; emend. Sarjeant, 1985
Cribroperidinium spp.
Cyclonephelium filoreticulatum (Slimani, 1994) Prince et al., 1999
Cyclonephelium spp.
Cymososphaeridium validum Davey, 1982
Damassadinium californicum (Drugg, 1967) Fensome et al., 1993
Dapsilidinium laminaspinosum (Davey & Williams, 1966) Lentin & Williams, 1981
Deflandrea antarctica Wilson, 1967
Deflandrea cygniformis Pöthe de Baldis, 1966
Deflandrea delineata Cookson & Eisenack, 1965
Deflandrea galeata (Lejeune-Carpentier, 1942) Lentin & Williams, 1973; emend. Lejeune-Carpentier & Sarjeant, 1981
Deflandrea phosphoritica Eisenack, 1938
Deflandrea spp.
Dinocyst sp. 1
Dinocyst sp. 2
Dinocyst sp. 3
Dinogymnium acuminatum Evitt et al., 1967
Dinogymnium denticulatum (Alberti, 1961) Evitt et al., 1967

Dinogymnium spp.
Diphyes colligerum (Deflandre & Cookson, 1955) Cookson, 1965; emend. Cookson, 1965
Diphyes ficusoides Islam, 1983
Disphaerogena carposphaeropsis Wetzel, 1933; emend. Sarjeant, 1985
Disphaerogena irregularis (Wilson, 1988) Lentin & Williams, 1993
Dissiliodinium spp.
Downiesphaeridium? *aciculare* (Davey, 1969) Islam, 1993
Eisenackia circumtabulata Drugg, 1967
Eisenackia margarita (Harland, 1979) Quattrocchio & Sarjeant, 2003
Eisenackia reticulata (Damassa, 1979) Quattrocchio & Sarjeant, 2003
Elytrocysta druggii Stover & Evitt, 1978
Endoscrinium asymmetricum Riding, 1987
Eocladopyxis peniculata Morgenroth, 1966; emend. McLean, 1976
Exochosphaeridium bifidum (Clarke & Verdier, 1967) Clarke et al., 1968; emend. Davey, 1969
Exochosphaeridium phragmites Davey et al., 1966
Fibrocysta bipolaris (Cookson & Eisenack, 1965) Stover & Evitt, 1978
Florentinia aculeata Kirsch, 1991
Florentinia deanei (Davey & Williams, 1966) Davey & Verdier, 1973
Florentinia ferox (Deflandre, 1937) Duxbury, 1980
Florentinia hypomagna Yun Hyesu, 1981
Florentinia mayi Kirsch, 1991
Florentinia spp.
Florentinia laciniata Davey & Verdier, 1973
Glaphyrocysta cf. *expansa* (Corradini, 1973) Roncaglia & Corradini, 1997, p. 187; emend. Roncaglia & Corradini, 1997
Glaphyrocysta exuberans (Deflandre & Cookson, 1955 ex Eaton, 1976) Stover & Evitt, 1978; emend. Sarjeant, 1986
Glaphyrocysta ordinata (Williams & Downie, 1966) Stover & Evitt, 1978
Glaphyrocysta perforata Hultberg & Malmgren, 1985
Glaphyrocysta semiticta (Bujak in Bujak et al., 1980) Lentin & Williams, 1981
Glaphyrocysta spp.
Glaphyrocysta wilsonii Kirsch, 1991
Gonyaulacysta dualis (Brideaux & Fisher, 1976) Stover & Evitt, 1978
Gonyaulacysta spp.
Gonyaulacysta? *kleithria* Duxbury, 1983
Hafniasphaera delicata Fensome et al., 2009
Hapsocysta dictyota Davey, 1979
Hapsocysta peridictya (Eisenack & Cookson, 1960) Davey, 1979; emend. Davey, 1979
Hapsocysta? *benteae* Nøhr-Hansen, 1993
Heterosphaeridium cordiforme Yun Hyesu, 1981
Heterosphaeridium spinaconjunctum Yun Hyesu, 1981
Homotryblium spp.
Homotryblium tenuispinosum Davey & Williams, 1966
Hystrichodinium pulchrum Deflandre, 1935
Hystrichodinium pulchrum subsp. *areatum* Marheinecke, 1992
Hystrichokolpoma cinctum Klumpp, 1953
Hystrichokolpoma bulbosum (Ehrenberg, 1838) Morgenroth, 1968; emend. Morgenroth, 1968
Hystrichokolpoma cf. *rigaudiae* Deflandre & Cookson, 1955
Hystrichokolpoma reductum Zevenboom & Santarelli in Zevenboom, 1995
Hystrichokolpoma spp.
Hystrichokolpoma truncatum Biffi & Manum, 1988
Hystrichokolpoma unispinum Williams & Downie, 1966
Hystrichosphaeridium bowerbankii Davey & Williams, 1966
Hystrichosphaeridium conispiniferum Yun Hyesu, 1981
Hystrichosphaeridium recurvatum (White, 1842) Lejeune-Carpentier, 1940
Hystrichosphaeridium salpingophorum Deflandre, 1935 ex Deflandre, 1937; emend. Davey & Williams, 1966
Hystrichosphaeridium spp.
Hystrichosphaeridium tenuitubatum Marheinecke, 1992
Hystrichosphaeridium tubiferum (Ehrenberg, 1838) Deflandre, 1937; emend. Davey & Williams, 1966
Hystrichosphaeridium tubiferum subsp. *brevispinum* (Davey & Williams, 1966) Lentin & Williams, 1973; emend. Marheinecke, 1992
Hystrichosphaerina schindewolfii Alberti, 1961
Hystrichosphaeropsis obscura Habib, 1972
Hystrichosphaeropsis ovum Deflandre, 1935
Hystrichostrogylon membraniphorum Agelopoulos, 1964; emend. Eaton, 1976
Impagidinium maculatum (Cookson & Eisenack, 1961) Stover & Evitt, 1978
Impagidinium spp.
Impagidinium? *ovum* (Sah et al., 1970) Stover & Evitt, 1978
Isabelidinium cooksoniae (Alberti, 1959) Lentin & Williams, 1977
Isabelidinium spp.
Kallosphaeridium brevibarbatum de Coninck, 1969; emend. Jan du Chęne et al., 1985
Kenleyia lophophora Cookson & Eisenack, 1965
Kenleyia spp.
Kleithriasphaeridium loffrense Davey & Verdier, 1976
Leberidocysta chlamydata (Cookson & Eisenack, 1962) Stover & Evitt, 1978; emend. Fechner, 1985 and Marheinecke, 1992
Leberidocysta spinosa Pestchevitskaya, 2009
Leberidocysta? *laticaudata* (Vozzhennikova, 1967) Stover & Evitt, 1978
Lejeunecysta communis Biffi & Grignani, 1983
Lejeunecysta hyalina (Gerlach, 1961) Artzner & Dörhöfer, 1978; emend. Sarjeant, 1984
Lejeunecysta spp.
Magallanesium densispinatum (Stanley, 1965) Quattrocchio & Sarjeant, 2003
Magallanesium macmurdoense Wilson, 1967
Manumiella druggii (Stover, 1974) Bujak & Davies, 1983
Manumiella seelandica (Lange, 1969) Bujak & Davies 1983; emend. Firth, 1987
Manumiella seymourensis Askin, 1999
Manumiella spp.
Manumiella? cf. *cretacea* (Cookson, 1956) Bujak & Davies, 1983
Manumiella? *hemmoorensis* Marheinecke, 1992
Membranilarnacia polycladiata Cookson & Eisenack in Eisenack, 1963
Membranilarnacia spp.
Membranilarnacia? *tenella* Morgenroth, 1968
Membranophoridium aspinatum Gerlach, 1961
Muderongia australis Helby, 1987; emend. Monteil, 1991
Muderongia extensiva Duxbury, 1977
Muderongia spp.
Nematosphaeropsis downiei Brown, 1986
Odontochitina operculata (Wetzel, 1933) Deflandre & Cookson, 1955
Odontochitina porifera Cookson, 1956
Odontochitina spp.
Oligosphaeridium albertense (Pocock, 1962) Davey & Williams, 1969
Oligosphaeridium complex (White, 1842) Davey & Williams, 1966
Oligosphaeridium pulcherrimum (Deflandre & Cookson, 1955) Davey & Williams, 1966
Oligosphaeridium? *asterigerum* (Gocht, 1959) Davey & Williams, 1969
Operculodinium centrocarpum (Deflandre & Cookson, 1955) Wall, 1967

Operculodinium severinii (Cookson & Cranwell, 1967) Islam, 1983
Palaeocystodinium australinum (Cookson, 1965) Lentin & Williams, 1976; emend. Malloy, 1972
Palaeocystodinium golzowense Alberti, 1961
Palaeocystodinium lidiae (Górka, 1963) Davey, 1969; emend. Davey, 1969
Palaeocystodinium spp.
Palaeohystrichophora infusorioides Deflandre, 1935
Palaeoperidinium cretaceum (Pocock, 1962) Lentin & Williams, 1976; emend. Harding, 1990 and Evitt et al., 1998
Palaeoperidinium pyrophorum (Ehrenberg, 1838 ex Wetzel, 1933) Sarjeant, 1967; emend. Sarjeant, 1967
Palaeotetradinium silicorum Deflandre, 1936; emend. Deflandre & Sarjeant, 1970
Palynodinium biculleus Kirsch, 1991
Palynodinium grallator Gocht, 1970
Paralecaniella indentata (Deflandre & Cookson, 1955) Cookson & Eisenack, 1970; emend. Elsik, 1977
Pareodinia ceratophora Deflandre, 1947; emend. Gocht, 1970
Pentadinium laticinctum Gerlach, 1961; emend. Benedek et al., 1982
Pentadinium sabulum Mao Shaozhi & Norris, 1988
Pervosphaeridium granaciculare Fensome et al., 2009
Pervosphaeridium pseudhystrichodinium (Deflandre, 1937) Yun Hyesu, 1981; emend. Davey, 1969
Pervosphaeridium spp.
Pervosphaeridium truncatum (Davey, 1969) Below, 1982; emend. Masure, 1988
Phelodinium magnificum (Stanley, 1965) Stover & Evitt, 1978
Phelodinium tricuspe (Wetzel, 1933) Stover & Evitt, 1978; emend. Lejeune-Carpentier & Sarjeant, 1981
Prolixosphaeridium conulum Davey, 1969
Prolixosphaeridium parvispinum (Deflandre, 1937) Davey et al., 1969
Protoellipsodinium spinosum Davey & Verdier, 1971
Pseudoceratium anaphrissum (Sarjeant, 1966) Bint, 1986; emend. Harding, 1990
Pseudoceratium pelliferum Gocht, 1957; emend. Dörhöfer & Davies, 1980
Pterodinium agadirense Below, 1981
Pterodinium aliferum Eisenack, 1958; emend. Sarjeant, 1985
Pterodinium cingulatum subsp. *cingulatum* (Wetzel, 1933) Below, 1981
Pterodinium cingulatum subsp. *polygonale* (Clarke & Verdier, 1967) Paul et al., 1994
Pterodinium cingulatum subsp. *reticulatum* (Davey & Williams, 1966) Lentin & Williams, 1981
Pterodinium? *cornutum* Cookson & Eisenack, 1962
Pterodinium? *pterotum* (Cookson & Eisenack, 1958) Pavlishina, 1990; emend. Pavlishina, 1990
Pyxidinopsis spp.
Pyxidinopsis waipawaensis Wilson, 1988
Raetiadinium evittigratia Kirsch, 1991
Raetiaedinium truncigerum (Deflandre, 1937) Kirsch, 1991
Rhiptocorys veligera (Deflandre, 1937) Lejeune-Carpentier & Sarjeant, 1983; emend. Lejeune-Carpentier & Sarjeant, 1983
Rhombodella paucispina (Alberti, 1961) Duxbury, 1980
Riculacysta amplexa Kirsch, 1991
Riculacysta spp.
Riculacysta? *pala* Kirsch, 1991
Rigaudella aemula (Deflandre, 1939) Below, 1982; emend. Below, 1982
Rigaudella apenninica (Corradini, 1973) Below, 1982
Rottnestia borussica (Eisenack, 1954) Cookson & Eisenack, 1961
Rottnestia wetzelii (Deflandre, 1937) Slimani, 1994
Scriniodinium crystallinum (Deflandre, 1939) Klement, 1960; emend. Riding & Fensome, 2003
Scriniodinium spp.
Senoniasphaera inornata (Drugg, 1970) Stover & Evitt, 1978
Senoniasphaera protrusa Clarke & Verdier, 1967; emend. Prince et al., 1999
Spinidinium echinoideum (Cookson & Eisenack, 1960) Lentin & Williams, 1976; emend. Sverdlove & Habib, 1974
Spinidinium echinoideum subsp. *rhombicum* (Cookson & Eisenack, 1974) Lentin & Williams, 1976
Spinidinium spp.
Spiniferella cornuta (Gerlach, 1961) Stover & Hardenbol, 1994; emend. Stover & Hardenbol, 1994
Spiniferites cf. *bulloideus* (Deflandre & Cookson, 1955) Sarjeant, 1970
Spiniferites dentatus (Gocht, 1959) Lentin & Williams, 1973; emend. Duxbury, 1977
Spiniferites membranaceus (Rossignol, 1964) Sarjeant, 1970
Spiniferites multibrevis (Davey & Williams, 1966) Below, 1982
Spiniferites pseudofurcatus (Klumpp, 1953) Sarjeant, 1970; emend. Sarjeant, 1981
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854
Spiniferites ramosus subsp. *brevifurcatus* (Cookson & Eisenack, 1974) Lentin & Williams, 1977
Spiniferites ramosus subsp. *cavispinosus* Hansen, 1977
Spiniferites ramosus subsp. *gracile* (Davey & Williams, 1966) Lentin & Williams, 1973
Spiniferites ramosus subsp. *granosus* (Davey & Williams, 1966) Lentin & Williams, 1973
Spiniferites scabrosus (Clarke & Verdier, 1967) Lentin & Williams, 1975
Spiniferites spp.
Spiniferites? *spongiosus* Duxbury, 2001
Spongodinium delitiense (Ehrenberg, 1838) Deflandre, 1936; emend. Lucas-Clark, 1987
Stanfordella fastigiata (Duxbury, 1977) Helenes & Lucas-Clark, 1997; emend. Helenes & Lucas-Clark, 1997
Subtilisphaera perlucida (Alberti, 1959) Jain & Millepied, 1973
Subtilisphaera terrula (Davey, 1974) Lentin & Williams, 1976; emend. Harding, 1986
Surculosphaeridium belowii Yun Hyesu, 1981
Surculosphaeridium longifurcatum (Firtion, 1952) Davey et al., 1966
Surculosphaeridium trunculum Davey, 1979
Surculosphaeridium? *basifurcatum* Yun Hyesu, 1981
Systematophora cretacea Davey, 1979
Systematophora? *septata* Wilson, 1988
Tanyosphaeridium boletus Davey, 1974
Tanyosphaeridium xanthiopyxides (Wetzel, 1933 ex Deflandre, 1937) Stover & Evitt, 1978; emend. Sarjeant, 1985
Tenua hystrix Eisenack, 1958; emend. Sarjeant, 1985
Thalassiphora delicata Williams & Downie, 1966; emend. Eaton, 1976
Thalassiphora inflata Heilmann-Clausen in Thomsen & Heilmann-Clausen, 1985
Thalassiphora pelagica (Eisenack, 1954) Eisenack & Gocht, 1960; emend. Benedek & Gocht, 1981
Thalassiphora reticulata Morgenroth, 1966
Trabeculidium pusulosum (Morgenroth, 1966) Duxbury, 1980
Trabeculidium quinquetrum Duxbury, 1980
Trichodinium ciliatum (Gocht, 1959) Eisenack & Klement, 1964
Trigonopyxidia ginella (Cookson & Eisenack, 1960) Downie & Sarjeant, 1965
Trithyrodinium cf. *evittii* Drugg, 1967
Trithyrodinium evittii Drugg, 1967
Trithyrodinium robustum Benson, 1976
Trithyrodinium suspectum (Manum & Cookson, 1964) Davey, 1969

Turbiosphaera filosa (Wilson, 1967) Archangelsky, 1969
Turnhosphaera hypoflata (Yun Hyesu, 1981) Slimani, 1994; emend. Slimani, 1994
Wetzeliella symmetrica Weiler, 1956
Xenascus cf. *asperatus* Stover & Helby, 1987
Xenascus gochtii (Corradini, 1973) Stover & Evitt, 1978
Xenascus sarjeantii (Corradini, 1973) Stover & Evitt, 1978
Xenascus spp.
Xiphophoridium alatum (Cookson & Eisenack, 1962) Sarjeant, 1966; emend. Sarjeant, 1966
Ynezidinium brevisulcatum (Michoux, 1985) Lucas-Clark & Helenes, 2000

Succession	Sample numbers	Lithostratigraphy	Age	*Achilleodinium biformoides*	*Achomosphaera* cf. *Alcicornu*	*Achomosphaera neptuni*	*Achomosphaera ramosasimilis*	*Achomosphaera ramulifera*	*Achomosphaera ramulifera* subsp. *ramulifera*	*Achomosphaera regiensis*	*Achomosphaera* spp.	*Actinotheca aphroditae*	*Adnatosphaeridium filiferum*	*Adnatosphaeridium multispinium*	*Adnatosphaeridium tutulosum*	*Alisogymnium euclaense*	*Alterbidinium acutulum*	*Alterbidinium longicornutum*	*Alterbidinium* spp.	*Andalusiella polymorpha*	*Apectodinium homomorphum*	*Apectodinium* spp.	*Apteodinium deflandrei*	*Areoligera coronata*	*Areoligera gippingensis*	*Areoligera guembelii*	*Areoligera medusettiformis*	*Areoligera senonensis*	*Areoligera* spp.	*Areoligera volata*	*Batiacasphaera grandis*	*Batiacasphaera micropapillata*	*Batiacasphaera* spp.	*Biconidinium reductum*	*Canningia reticulata*	*Canningia senonica*	*Cannosphaeropsis hughesii*	*Cannosphaeropsis utinensis*	*Carpatella cornuta*	*Cassidium fragile*	*Cerodinium diebelii*	*Cerodinium speciosum*	*Cerodinium speciosum* subsp. *glabrum*	*Cerodinium* spp.
Upper Succession (A)	20	Greifenstein Formation	Eocene					1				2			3								2		1			6				2		1			1			1	1			21
	50				1						2														9		2		22															
	100																								2																			
	110																								3		1		2															
	150																								1					14	5													
	200																								7	1				14	3													
	210						1																		10					4	1			2									
	250	1	1				5								1										43		7		21	25	5			1					1R		1	1		
	300		1				3				1											2			2	1			5	8			3				1	1R		2	1		
	320						3																	3	3				4	2			8							1			
	330	Altlengbach Formation	Paleocene																						2				3	4		3											
	380																							1	8				6	9		6											
	430						1																		5				7	7		1	1								1			
	480						1																		5				4	4		1	1				1						
	530						4						1		1										3			1	17	9	2	2	3							1			
	580						3																		2		1		11	5	5	1						2					
	630						1																			1		1	5	1			1			1				1			
	680																				1										1	2		1			1		6			
	730		Maastrichtian					1																	1				5	3	2				2					1		2		
	780						2																					2	1	1													
	790	Oberste Bunte						5			1						1							7				1		1		1		5	1		2			3		3	1
	840						1				1																		1			1	1				1						
	890					1	7						1				1							3	2				1	6		1			3			1		1			
	940						7				2														1				1	1													
	990						12									1	1											1		2		1		2			1			1			
	1010						10							1					1					1	1		1		4			3			2			1				1	
	1020	Kahlenberg				1		8										1		1					2					2		1	1		3			5			2			
	1070		Campan.					6			3							2											2	2	1							1			1			1
	1120					1		3		1	1									1				8					1	1		2		1			1						1
	1170							6	2										1										3	3		4	2	1			2			1			
	1210							8												1				1					3			3								3			1

Appendix B (*continued*)

Succession	Sample numbers	Lithostratigraphy	Age	*Chatangiella ditissima*	*Chatangiella granulifera*	*Chatangiella madura*	*Chatangiella* spp.	*Chatangiella? robusta*	*Circulodinium distinctum*	*Cladopyxidium velatum*	*Cleistosphaeridium diversispinosum*	*Cleistosphaeridium placacanthum*	*Cleistosphaeridium* spp.	*Codoniella campanulata*	*Conosphaeridium striatoconum*	*Cordosphaeridium cantharellus*	*Cordosphaeridium fibrospinosum*	*Cordosphaeridium* spp.	*Coronifera* cf. *striolata*	*Coronifera oceanica* subsp. *hebospina*	*Corradinisphaeridium horridum*	*Cribroperdinium? edwardsii*	*Cribroperidinium cooksoniae*	*Cribroperidinium* spp.	*Cyclonephelium* spp.	*Damassadinium californicum*	*Deflandrea antarctica*	*Deflandrea cygniformis*	*Deflandrea galeata*	*Deflandrea phosphoritica*	*Deflandrea* spp.	*Dinocyst* sp. 1	*Dinocyst* sp. 3	*Dinogymnium acuminatum*	*Dinogymnium denticulatum*	*Diphyes colligerum*	*Diphyes ficusoides*	*Disphaerogena carposphaeropsis*	*Disphaerogena irregularis*	*Eisenackia circumtabulata*	*Eisenackia margarita*	*Eisenackia reticulata*	*Elytrocysta druggii*	*Endoscrinium asymmetricum*	*Eocladopyxis peniculata*	*Exochosphaeridium bifidum*
Upper Succession (A)	20	Greifenstein Formation	Eocene				1		3								2	2		1												1							1							11
	50								2									1									1															1				1
	100																	1																												
	110																																													
	150																																													1
	200						1																																							
	210						1																																							2
	250			1			1		1								4	1								1		1															1				1	1
	300					1	1		1								1			1		1				3		2		1							1			1								1
	320		Paleocene														1			1						2										3				4								2
	330	Altlengbach Formation																								1										2												1
	380																3	2																												1
	430										1						1	1								1																				1
	480								1		2	1					4									2								1		1												3
	530						1				2						2	1							1	1										1						1						1
	580										2						2	2					1			4												1										4
	630						1				1						1									1																						3
	680																																							2								1
	730		Maastrichtian				1										1			1			2													1												3
	780																																							1								
	790	Oberste Bunte														1		2																							1					1
	840						1		1											2																										
	890						2		1	1		1								1				1											1											1
	940								1				3	1					1															1												2
	990													1			2	1		1													1			1		1										1
	1010								1								1			3			1																							
	1020	Kahlenberg							3		1							1		1		1										1													1			1
	1070		Campan.					1										1			1										1					2												1
	1120			1	1									1						2		1		1																								1
	1170				1								1		1		2			1																								1				2
	1210								2				7																		1																	2

Succession	Sample numbers	Lithostratigraphy	Age	*Exochosphaeridium phragmites*	*Fibrocysta bipolaris*	*Florentinia aculeata*	*Florentinia deanei*	*Florentinia ferox*	*Florentinia hypomagna*	*Florentinia mayi*	*Florentinia* spp.	*Florintina laciniata*	*Glaphyrocysta* cf. *expansa*	*Glaphyrocysta exuberans*	*Glaphyrocysta ordinata*	*Glaphyrocysta semiticta*	*Glaphyrocysta* spp.	*Glaphyrocysta wilsonii*	*Gonyaulacysta dualis*	*Gonyaulacysta* spp.	*Hafniasphaera delicata*	*Hapsocysta dictyota*	*Hapsocysta peridictya*	*Hapsocysta? benteae*	*Heterosphaeridium cordiliforme*	*Heterosphaeridium spinaconjunctum*	*Homotryblium* spp.	*Homotryblium tenuispinosum*	*Hystrichodinium pulchrum*	*Hystrichodinium pulchrum* subsp. *areatum*	*Hystrichokolpoma* cf. *rigaudiae*	*Hystrichokolpoma cinctum*	*Hystrichokolpoma reductum*	*Hystrichokolpoma* spp.	*Hystrichokolpoma truncatum*	*Hystrichokolpoma unispinum*	*Hystrichosphaeridium bowerbankii*	*Hystrichosphaeridium conispiniferum*	*Hystrichosphaeridium recurvatum*	*Hystrichosphaeridium salpingophorum*	*Hystrichosphaeridium* spp.	*Hystrichosphaeridium tenuitubatum*	*Hystrichosphaeridium tubiferum*	*Hystrichosphaeridium tubiferum* subsp. *brevispinum*	*Hystrichosphaerina schindewolfii*	*Hystrichosphaeropsis obscura*
Upper Succession (A)	20	Greifenstein Formation	Eocene											20	7	2						2	2	1																2				36
	50													15	5	1																									1				
	100													2		1																										1				
	110															1																													
	150													2	3	1									2																1			1			
	200													60	16	5									1																		1			
	210													2	10	3								1																					
	250		1											10	15	9		1							12		2	1			1										10			6			
	300	Greifenstein Formation				1										3									7		1					1			1				1	31			2			1
	320		Eocene									1			1	2						4			7					1										9			2			
	330	Altlengbach Formation												2		4									3																				
	380					1									3	9									5															1	7			1			
	430					1					2			2	8	48									2																14			5			
	480														4	5									1																9			2			
	530		Paleocene			1					1				2	1								4	4																13			4			
	580														2	6									2																15			1			
	630					2										3									5																9			2			
	680															3				1					2																5						
	730														3	2		1							3				1					1							11			2			
	780														1										1																1			1			
	790	Oberste Bunte	Maastrichtian	1				1				1				1									3				5												6		1	2	1		
	840											1									1				2	1														1	1			1			
	890					1				1						1					1				9				2					1						2	2			3	1		
	940					1																			7				5						1				4	3						
	990					4	2		1					3							2				2				1											1	7			1			
	1010			1							1					1									7	1			5						1				1	7			3	1		
	1020	Kahlenberg					2								1	2					1				6				3						1	1			4	2			2			
	1070		Campan.												1		1												3	1				1					2	3			9			
	1120						2	1							1	3	1				1			1	2	1			5				1						1			10	1		1
	1170						1						1	1		1									11			1	2										2			4		1	
	1210																	2				1	1		6														1	2			6			

Appendix B (*continued*)

Succession	Sample numbers	Lithostratigraphy	Age	*Hystrichosphaeropsis ovum*	*Hystrichostrogylon membraniphorum*	*Impagidinium maculatum*	*Impagidinium* spp.	*Impagidinium? ovum*	*Isabelidinium cooksoniae*	*Isabelidinium* spp.	*Kenleyia lophophora*	*Kenleyia* spp.	*Leberidocysta chlamydata*	*Lejeunecysta hyalina*	*Lejeunecysta* spp.	*Magallanesium densispinatum*	*Magallanesium macmurdoense*	*Manumiella druggii*	*Manumiella seelandica*	*Manumiella* spp.	*Manumiella? cf. cretacea*	*Membranilarnacia polycladiata*	*Membranilarnacia* spp.	*Membranilarnacia? tenella*	*Membranophoridium aspinatum*	*Muderongia* spp.	*Odontochitina operculata*	*Odontochitina porifera*	*Odontochitina* spp.	*Oligosphaeridium albertense*	*Oligosphaeridium complex*	*Oligosphaeridium pulcherrimum*	*Oligosphaeridium? Asterigerum*	*Operculodinium centrocarpum*	*Operculodinium severinii*	*Palaeocystodinium australinum*	*Palaeocystodinium golzowense*	*Palaeocystodinium lidiae*	*Palaeocystodinium* spp.	*Palaeoperidinium cretaceum*	*Palaeoperidinium pyrophorum*	*Palaeotetradinium silicorum*	*Palynodinium grallator*	*Paralecaniella indentata*	*Pareodinia ceratophora*	*Pentadinium sabulum*
Upper Succession (A)	20	Greifenstein Formation	Eocene													2									2									8					1		2			3		18
	50					2																												2										3		
	100																																											50		
	110						1						1																							1					1					
	150																								1																		2		
	200														1																				1	1			1	1			1		
	210																								1																2			3		
	250																								1						1			1						1	1					
	300	Greifenstein Formation	Eocene		1			1	1		1	2		2	4		1	1	2	1	2			1	1	1					3			1		1	3			2	4			1		
	320		Paleocene		3	1									1										3									2	1		1			1	3	3		4		2
	330	Altlengbach Formation					1										1																	2							1					
	380				2	1								1																				4		1	1	1			5	1		1		
	430				1	1								2			1																	10			1		2		1					
	480						1								1																										2	1				
	530									1				1												1								2						1	2			1		
	580				1																										1			1									1		
	630						1		1					1										1											1							1					
	680								3				1																											1	1					
	730		Maastrichtian										3	1	2				1			1									1					1		1		2	2					
	780																																							1	2					
	790	Oberste Bunte											1	1					1				1									1								4	3					
	840				1		1		1				2		1					1																					3					
	890			1	1				1	1			3	1								1		1			1	1R			1										3					1
	940				1																	1		1			1																		
	990				2				1				1						1			1					1							2							3					
	1010				2										1										1				1					2							4		1			
	1020	Kahlenberg	Campan.		1					1			3	1	1							1		1								1								1	1					
	1070				1			2	5	1			1								1					1				3						2		1	7	22					
	1120				1				4												2			1		1	1	1		3	1		1				1		3	1					
	1170												1															1		1	2	1		1						1		1			
	1210				1								2																	1	1									1			1		

Appendix B (*continued*)

Succession	Sample numbers	Lithostratigraphy	Age	*Pervosphaeridium granaciculare*	*Pervosphaeridium pseudhystrichodinium*	*Pervosphaeridium* spp.	*Pervosphaeridium truncatum*	*Phelodinium magnificum*	*Prolixosphaeridium conulum*	*Protoellipsodinium spinosum*	*Pterodinium aliferum*	*Pterodinium cingulatum* subsp. *polygonale*	*Pterodinium cingulatum* subsp. *cingulatum*	*Pterodinium cingulatum* subsp. *reticulatum*	*Pterodinium? cornutum*	*Pterodinium? pterotum*	*Pyxidinopsis* spp.	*Pyxidinopsis waipawaensis*	*Raetiadinium evittigratia*	*Raetiaedinium truncigerum*	*Rhiptocorys veligera*	*Rhombodella paucispina*	*Riculacysta amplexa*	*Riculacysta* spp.	*Riculacysta? pala*	*Rigaudella aemula*	*Rigaudella apenninica*	*Rottnestia borussica*	*Rottnestia wetzelii*	*Scriniodinium crystallinum*	*Senoniasphaera inornata*	*Spinidinium echinoideum*	*Spiniferella cornuta*	*Spiniferites* cf. *bulloideus*	*Spiniferites dentatus*	*Spiniferites membranaceus*	*Spiniferites multibrevis*	*Spiniferites pseudofurcatus*	*Spiniferites ramosus*	*Spiniferites ramosus* subsp. *brevifurcatus*	*Spiniferites ramosus* subsp. *cavispinosus*	*Spiniferites ramosus* subsp. *gracile*	*Spiniferites ramosus* subsp. *granosus*	*Spiniferites scabrosus*	*Spiniferites* spp.	*Spiniferites? spongiosus*
Upper Succession (A)	20	Greifenstein Formation	Eocene	5	1												22				2		1							1						1	1	1	28				1			64
	50			2													4						4																7							
	100																																													
	110			1																			1																2							
	150			1	1																		4																2				1	1		
	200																																1					5				1			
	210			1																1											1						4				2			
	250			9	2												1			2						1	1								1	1	1	58				13	3		
	300			4	3	1		1					1				4	2		1			4					1			1	1		3		7	3	2	80	1			18		6	
	320		Paleocene	3									1				2	3					3	1				1			1			4		2	2		55				23	1	1	
	330	Altlengbach Formation			1												2	4														1				1	2		22				12			
	380			2													4	6					2												3			66				10		1	
	430			1				1									1	1					45												5			85				14	2		
	480			4									1				3	1					3				1					1			3	1	1	29				4			
	530			5				1									2	1					3								3		1		4		1	40				6	1		
	580			2																						3							2				1	16				7			
	630			1									1					1					1								1				3	1	1	21				2			
	680			1				1					1																	1			1				14				4			
	730		Maastrichtian	2	1								1		1								1												2	1		24				7	1		
	780			1				1																										1			5				1			
	790	Oberste Bunte		1	8	2		2									1	1					2					1	1			2		3		1		3	52				11	1		
	840			1	1								1				1																		1		3	7							
	890				4		1					1	1			1	2					1											1	2	1	2		3	18				8		1	
	940					1													1																	3	2	9				4		2	1
	990			2	1			2					1														1	1							1	1	1	37		1		8	1		
	1010				3			1			1		2				1								1						1				4	4	3	30				9		1	
	1020	Kahlenberg			7				1				3	1	1		1												1				1		5	3	2	27			1	9	1		
	1070		Campan.		1	1		1					1		1					1								1			2		3		1	1	1	35				3		4	
	1120			1	13	3				1			2				1									1	1				1		2		1	4	3	51	1			5		2	
	1170				3					1					1		10								1						1			1	1		3	26		1		4			
	1210									2							1																			1	1	18				2			

Upper Succession (A)																																						Succession
1210	1170	1120	1070	1020	1010	990	940	890	840	790	780	730	680	630	580	530	480	430	380	330	320	300	250	210	200	150	110	100	50	20								Sample numbers
Kahlenberg					Oberste Bunte						Altlengbach Formation										Greifenstein Formation																	Lithostratigraphy
Campan.				Maastrichtian									Paleocene									Eocene																	Age
2		1		1				1					2																1									*Spongodinium delitiense*
		1						1																					1									*Stanfordella fastigiata*
																						1																*Subtilisphaera perlucida*
		1																																				*Subtilisphaera terrula*
								1																														*Surculosphaeridium belowii*
	2			2	1	3	4	4	3	1			1						2		1		1															*Surculosphaeridium longifurcatum*
1				2	1			2	1																													*Surculosphaeridium? basifurcatum*
								1																														*Systematophora cretacea*
					1																																	*Tanyosphaeridium boletus*
	2	1		2		1	3	2	1				1			3			1																			*Tanyosphaeridium xanthiopyxides*
				1																																		*Tenua hystrix*
2		1		1	1	1						2				1			3				1			1											*Thalassiphora delicata*
		1			1								1			2		2				1	1							1							*Thalassiphora pelagica*
		1																																				*Thalassiphora reticulata*
	1									1																												*Trabeculidium pusulosum*
			1	1				1																														*Trabeculidium quinquetrum*
							1							2			1				7	1																*Trigonopyxidia ginella*
		1		1		1	1			1		1										1																*Trithyrodinium* cf. *evittii*
1	2	1	7			2						1	1	3	3	7	3	2	4		10	10	1		1					1							*Trithyrodinium evittii*
1	2	3	12	2	1	3	4			3			2	1		1		1				3			1	1		1										*Trithyrodinium suspectum*
1				1		1									1																							*Turbiosphaera filosa*
1	3		3	1		1		2							1																							*Turnhosphaera hypoflata*
			1		1																																	*Xenascus gochtii*
				1			1			1																													*Xenascus sarjeantii*

Succession	Sample numbers	Lithostratigraphy	Age	*Chatangiella ditissima*	*Chatangiella granulifera*	*Chatangiella madura*	*Chatangiella* spp.	*Chatangiella? robusta*	*Circulodinium distinctum*	*Cladopyxidium velatum*	*Cleistosphaeridium diversispinosum*	*Cleistosphaeridium placacanthum*	*Cleistosphaeridium* spp.	*Codoniella campanulata*	*Conosphaeridium striatoconum*	*Cordosphaeridium cantharellus*	*Cordosphaeridium fibrospinosum*	*Cordosphaeridium* spp.	*Coronifera* cf. *striolata*	*Coronifera oceanica* subsp. *hebospina*	*Corradinisphaeridium horridum*	*Cribroperdinium? edwardsii*	*Cribroperidinium cooksoniae*	*Cribroperidinium* spp.	*Cyclonephelium* spp.	*Damassadinium californicum*	*Deflandrea antarctica*	*Deflandrea cygniformis*	*Deflandrea galeata*	*Deflandrea phosphoritica*	*Deflandrea* spp.	*Dinocyst* sp. 1	*Dinocyst* sp. 3	*Dinogymnium acuminatum*	*Dinogymnium denticulatum*	*Diphyes colligerum*	*Diphyes ficusoides*	*Disphaerogena carposphaeropsis*	*Disphaerogena irregularis*	*Eisenackia circumtabulata*	*Eisenackia margarita*	*Eisenackia reticulata*	*Elytrocysta druggii*	*Endoscrinium asymmetricum*	*Eocladopyxis peniculata*	*Exochosphaeridium bifidum*
Upper Succession (A)	20	Greifenstein Formation	Eocene				1		3								2	2		1											1						1						11
	50								2									1								1													1				1
	100																	1																									
	110																																											
	150																																											1
	200				1																																						
	210				1																																						2
	250	1			1		1										4	1							1		1														1		1
	300			1	1		1										1			1		1			3		2		1						1				1			1
	320																1			1					2									3					4				2
	330		Altlengbach Formation	Paleocene																							1									2								1
	380																3	2																									1
	430										1						1	1							1																		1
	480							1			2	1					4								2								1		1								3
	530				1						2						2	1						1	1									1					1				1
	580										2						2	2					1		4										1								4
	630				1						1						1								1																		3
	680																																								2				1
	730				1												1			1			2											1									3
	780																																							1				
	790		Oberste Bunte	Maastrichtian												1		2																							1				1
	840				1		1													2																							
	890				2		1	1		1										1				1										1									1
	940						1				3	1							1														1										2
	990											1				2	1			1											1				1		1						1
	1010						1									1				3			1																				
	1020						3		1									1		1		1								1											1			1
	1070		Kahlenberg	Campan.		1												1			1							1				2											1
	1120	1	1										1							2		1		1																			1
	1170		1										1		1		2			1																					1			2
	1210						2						7															1															2

Appendix C (continued)

Succession	Sample numbers	Lithostratigraphy	Age	*Chatangiella ditissima*	*Chatangiella granulifera*	*Chatangiella hexacalpis*	*Chatangiella madura*	*Chatangiella* spp.	*Circulodinium brevispinatum*	*Circulodinium distinctum*	*Circulodinium* spp.	*Cleistosphaeridium diversispinosum*	*Cleistosphaeridium placacanthum*	*Cleistosphaeridium* spp.	*Codoniella campanulata*	*Cordosphaeridium fibrospinosum*	*Cordosphaeridium* spp.	*Coronifera oceanica* subsp. *hebospina*	*Coronifera* spp.	*Corradinisphaeridium horridum*	*Cribroperdinium? edwardsii*	*Cribroperidinium cooksoniae*	*Cribroperidinium orthoceras*	*Cribroperidinium* spp.	*Cyclonephelium floreticulatum*	*Cyclonephelium* spp.	*Cymososphaeridium validum*	*Damassadinium californicum*	*Dapsilidinium laminaspinosum*	*Deflandrea antarctica*	*Deflandrea ygniformis*	*Deflandrea delineata*	*Dinocyst* sp. 2	*Dinogymnium acuminatum*	*Dinogymnium denticulatum*	*Dinogymnium* spp.	*Diphyes colligerum*	*Disphaerogena carposphaeropsis*	*Dissiliodinium* spp.	*Downiesphaeridium? aciculare*	*Eisenackia margarita*	*Eisenackia reticulata*	*Exochosphaeridium bifidum*	*Exochosphaeridium phragmites*
Lower Succession (B)	1220	Greifenstein Fm	Eocene						1												1				1					1					1				1				2	
	1270									1						1	2				1																1						1	
	1320									1																							1										1	
	1370							R		2							1													1														
	1420															1		1													1						6						2	
	1470							1		1						1			1									1			1	1					1	1					1	
	1520		Paleoc.									6	6			3	1	1													1												3	
	1530	Altlengbach Formation						1				8		9		3		1													1						1						1	
	1580									1		1		1		1	1														1										1		4	
	1630									3		1		1				1						1				1										1				1		
	1680		Maast.										1			2								2							1													
	1730				1																	1									1												1	
	1780																																				1						1	
	1830												1			1																												
	1880									1																								1			1						1	
	1930		Campanian			1	1			1				6	1	1		2			1			1			1																	
	1980									1				1			1							1																			1	1
	2030																			1																				1				
	2080												1	2		1				1																								
	2130							2						2				1								1																	1	
	2180											1																																
	2230																				1																							
	2280																																										1	
	2330							1						1				1																		1							1	
	2380																																											
	2430													1		1																												
	2470							1																																				1
	2480	Wolfpas.		1							1	1		1																														
	2530		Sant.						3	9				6			1	1			1	2	1	6		4			1															
	2560									1														1		1																		
	2565									1																																		

Succession	Sample numbers	Lithostratigraphy	Age	*Fibrocysta bipolaris*	*Florentinia aculeata*	*Florentinia deanei*	*Florentinia ferox*	*Florentinia hypomagna*	*Florentinia* spp.	*Glaphyrocysta* cf. *expansa*	*Glaphyrocysta exuberans*	*Glaphyrocysta ordinata*	*Glaphyrocysta perforata*	*Glaphyrocysta semiticta*	*Glaphyrocysta* spp.	*Glaphyrocysta wilsonii*	*Gonyaulacysta* spp.	*Gonyaulacysta? kleithria*	*Hafniasphaera delicata*	*Hapsocysta peridictya*	*Hapsocysta? benteae*	*Heterosphaeridium cordiformis*	*Heterosphaeridium spinaconjunctum*	*Homotryblium* spp.	*Homotryblium tenuispinosum*	*Hystrichodinium pulchrum*	*Hystrichodinium pulchrum* subsp. *areatum*	*Hystrichokolpoma bulbosum*	*Hystrichokolpoma* cf. *rigaudiae*	*Hystrichokolpoma truncatum*	*Hystrichosphaeridium recurvatum*	*Hystrichosphaeridium salpingophorum*	*Hystrichosphaeridium* spp.	*Hystrichosphaeridium tubiferum*	*Hystrichosphaerina schindewolfii*	*Hystrichosphaeropsis obscura*	*Hystrichostrogylon membraniphorum*	*Impagidinium* spp.	*Isabelidinium cooksoniae*	*Isabelidinium* spp.	*Kallosphaeridium brevibarbatum*	*Kleithriasphaeridium loffrense*	*Leberidocysta chlamydata*	*Leberidocysta spinosa*
Lower Succession (B)	1220	Greifenstein Fm	Eocene								2										4				1							1					2	1		1	2
	1270										16	2									4											1									
	1320										8	1		1																										
	1370										14	2							1		1									1	2									
	1420	1									120	23		5							1							1			3					1				
	1470	1	1								35	17		7						1								1			1	1						1	
	1520	1									23	6		4							1	4							1	12		5			1		1				
	1530		1	1					1		3	4		1	5							6			3					1	6		10			2						
	1580										4			5								4									1		3				1					
	1630										3			3								6								1	2		8				2					
	1680											1			1																7		8		1	1		1				
	1730										1			1								6					1			2	2		14		1	1		15				
	1780													2																1							2				
	1830																															2									
	1880													2	1							1									1		1					1				
	1930													2	1	1						7		1		13				1	1		2			1		1			1	
	1980																												1				1			1				1	1	
	2030			1								1		1								2											1			1		3	1			1	
	2080																					1	1			1							4	1								
	2130		2	1	1								1			1						5								1	5		9					1	1			
	2180																					1				1						2	3									
	2230		1	2	1	1																2										1	1							1	
	2280																																			1						
	2330		1																			4				3				1	2		1				1			1	
	2380			1										1																			4		1							
	2430																																1				1					
	2470														1							1				1							1						2				
	2480	Wolfpas.												1			1																3							1			
	2530		Sant.						1						1		1	1					4	2			3		1					1	1							1	
	2560																																									
	2565																																									

Appendix C (continued)

Succession	Sample numbers	Lithostratigraphy	Age	*Leberidocysta? Laticaudata*	*Lejeunecysta communis*	*Lejeunecysta hyalina*	*Lejeunecysta* spp.	*Magallanesium densispinatum*	*Magallanesium macmurdoense*	*Manumiella druggii*	*Manumiella seelandica*	*Manumiella seymourensis*	*Manumiella* spp.	*Manumiella?* cf. *cretacea*	*Manumiella? hemmoorensis*	*Membranilarnacia polycladiata*	*Membranilarnacia? tenella*	*Membranophoridium aspinatum*	*Muderongia australis*	*Muderongia extensiva*	*Muderongia* spp.	*Nematosphaeropsis downiei*	*Odontochitina operculata*	*Odontochitina porifera*	*Oligosphaeridium albertense*	*Oligosphaeridium complex*	*Oligosphaeridium pulcherrimum*	*Operculodinium centrocarpum*	*Palaeocystodinium australinum*	*Palaeocystodinium golzowense*	*Palaeocystodinium lidiae*	*Palaeocystodinium* spp.	*Palaeohystrichophora infusorioides*	*Palaeoperidinium cretaceum*	*Palaeoperidinium pyrophorum*	*Palaeotetradinium silicorum*	*Palynodinium biculleus*	*Paralecaniella indentata*	*Pentadinium laticinctum*	*Pentadinium sabulum*	*Pervosphaeridium granaciculare*	*Pervosphaeridium pseudhystrichodinium*	*Pervosphaeridium* spp.	*Phelodinium magnificum*
Lower Succession (B)	1220	Greifenstein Fm	Eocene		1				1		1															1		1							1		3			2			1
	1270																											1							1		25			1			
	1320																	2										2									37			1	1		
	1370																1	1								1		5									20			5			
	1420																	2									1			9				2	3			4			5	4		
	1470				1	4	1											1										1			2			2	38			1		1	3	1		
	1520		Paleoc.		1		1			1						1					2	1						5	1					1	7	1				1	3			1
	1530	Altlengbach Formation			1												1										9	1	2						3						1	1		1
	1580				1	2																					1		6		1			20			1			3	2		2
	1630					1	1											1									1		4		1		1	1	1			1			1			
	1680		Maast.								1				1														2					3	1			1			1		1	
	1730									1				3													1				1				2		1			4		1	
	1780									1	1			1															1		1						1			3			
	1830																										3										1	1				1		
	1880												1				1										1							1						1			1
	1930		Campanian										1												2			4		2			2				1		1		3	2		
	1980																																	2									1	1
	2030													1												1						1												
	2080																									1	1								1									
	2130				1	1										1							1							1					1		1					1		
	2180						1																							1						1					1		
	2230																									2									1									
	2280																																											
	2330																													1					1						1		
	2380																																				1						
	2430																																										
	2470																																										
	2480	Wolfpas.				1						1		1												1	1						1	3									2
	2530		Sant.	1															1	2					1	15								1	1							1		
	2560																									2																	
	2565																									1																	

Succession	Sample numbers	Lithostratigraphy	Age	*Phelodinium tricuspe*	*Prolixosphaeridium conulum*	*Prolixosphaeridium parvispinum*	*Pseudoceratium anaphrissum*	*Pseudoceratium pelliferum*	*Pterodinium agadirense*	*Pterodinium cingulatum* subsp. *cingulatum*	*Pterodinium? cornutum*	*Pyxidinopsis* spp.	*Pyxidinopsis waipawaensis*	*Raetiaedinium truncigerum*	*Riculacysta amplexa*	*Riculacysta? pala*	*Rigaudella aemula*	*Rigaudella apenninica*	*Rottnestia borussica*	*Scriniodinium* spp.	*Senoniasphaera inornata*	*Senoniasphaera protrusa*	*Spinidinium echinoideum*	*Spinidinium echinoideum* subsp. *rhombicum*	*Spinidinium* spp.	*Spiniferella cornuta*	*Spiniferites* cf. *bulloideus*	*Spiniferites dentatus*	*Spiniferites membranaceus*	*Spiniferites multibrevis*	*Spiniferites pseudofurcatus*	*Spiniferites ramosus*	*Spiniferites ramosus* subsp. *brevifurcatus*	*Spiniferites ramosus* subsp. *cavispinosus*	*Spiniferites ramosus* subsp. *granosus*	*Spiniferites scabrosus*	*Spiniferites* spp.	*Spongodinium delitiense*	*Stanfordella fastigiata*	*Subtilisphaera perlucida*	*Surculosphaeridium longifurcatum*	*Surculosphaeridium truncullum*	*Surculosphaeridium? basifurcatum*	*Systematophora cretacea*
Lower Succession (B)	1220	Greifenstein Fm	Eocene									4	1		1						1										14			4				1					
	1270											4																			9			3									
	1320																			1	1							1			8											
	1370											1																	1		4			2			R					
	1420									1				1	1													3	4		12				1								
	1470											1			5		1	1			3	1	1					3	3	1	11			2	1							
	1520		Paleoc.									2		1	2						2										42			15								
	1530	Altlengbach Formation								1				2	1	1	1	1					1					2	5		38	1		4		2				1		
	1580														3			1			1						2		1	1	47			5								
	1630									1					1													1	2	1		20			3								
	1680		Maast.									2																		1	26			4								
	1730									1					2				1										1	1	36			11			1			1		
	1780																													1	1			1			1					
	1830																										1				7			1		1						
	1880									4		1														1					5											
	1930		Campanian						1	2		2											5		1		1		3		3	72			4				4			1
	1980									1		1																			3										1
	2030			1						2					1		1										1				6						1		1			
	2080																							1	1						3										
	2130									1	1							1									1		1			14			1							
	2180												1		1	2													1	1		9			2					1		
	2230																										1				4			2		2			1		1	
	2280																									1			1	2		1				2						
	2330									3		1																	1		1	30			1							
	2380														1																4										
	2430																																									
	2470																														1										
	2480	Wolfpas.								2							1							2							17		1					1				
	2530		Sant.		1	1	1	1																							8				1				20		1	
	2560																																						2			1
	2565																														1											1

Appendix C (continued)

Succession	Sample numbers	Lithostratigraphy	Age	*Systematophora? septata*	*Tanyosphaeridium xanthiopyxides*	*Tenua hystrix*	*Thalassiphora delicata*	*Thalassiphora inflata*	*Thalassiphora pelagica*	*Thalassiphora reticulata*	*Trichodinium ciliatum*	*Trigonopyxidia ginella*	*Trithyrodinium* cf. *evittii*	*Trithyrodinium evittii*	*Trithyrodinium robustum*	*Trithyrodinium suspectum*	*Turbiosphaera filosa*	*Turnhosphaera hypoflata*	*wetzeliella symmetrica*	*Xenascus* cf. *asperatus*	*Xenascus sarjeantii*	*Xenascus* spp.	*Xiphophoridium alatum*	*Ynezidinium brevisulcatum*	**Deformed dinocyst**	**Spores**	**Pollen grains**	**Fungal spores**	**SUM**	**Species number**
Lower Succession (B)	**1220**	Greifenstein Fm	Eocene		1				1					2											47	5	5	1	**141**	**46**
	1270				1		2																		58	2	3	3	**160**	**27**
	1320						1																		23		12	2	**117**	**19**
	1370						3																1		27		8		**124**	**29**
	1420						1							R		1									60		2	1	**306**	**39**
	1470			1			1					1		1											37	1	1		**308**	**61**
	1520		Paleoc.											8		2		2			1			1	32		1		**296**	**55**
	1530	Altlengbach Formation			1		2							2		2									53		1		**241**	**61**
	1580				1		1		2					4											25	2	4	2	**198**	**43**
	1630				1				1					10		1									27	1	5		**150**	**47**
	1680		Maast.		2		5			1			8	11		2									20	4	10		**163**	**38**
	1730						2		1					12		1									38	6	12		**218**	**46**
	1780						1							7											10	2	3		**54**	**26**
	1830															1			1						20	2	8		**61**	**19**
	1880																								9	2	3		**49**	**25**
	1930		Campanian		2	1										3		1		1	1	1	1		45	1	3		**246**	**60**
	1980																					1			9	7	6		**53**	**27**
	2030					1				1		1	1	1		1	1								6	5	9		**70**	**37**
	2080				2	1										1									10	4	7		**53**	**23**
	2130								1					27		4					1				12	3	3		**263**	**44**
	2180						1							4		1									13	3	6		**69**	**26**
	2230																								10		8		**51**	**21**
	2280					1																			8	14	2		**38**	**10**
	2330															1									20	7	12		**114**	**31**
	2380													1											3		1		**24**	**11**
	2430																								4	1	4		**13**	**4**
	2470																								3	5	2		**21**	**10**
	2480	Wolfpas.													1										17	16	27		**125**	**34**
	2530		Sant.			8		1			1		4			4		1							35	13	16		**204**	**54**
	2560				1								1												5	3	9		**28**	**9**
	2565																								5	1	1		**11**	**4**