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Abstract

Revision of the lithostratigraphy of Ordovician deposits in southern and southeastern Turkey led to a re-evaluation of the age assignments of formations identified in the subsurface and at outcrop. Previous datings were based on macrofauna (mainly trilobites and graptolites). The present paper focuses exclusively on organic-walled microfossils (chitinozoans and acritarchs), which provide numerous chronostratigraphical improvements, especially in successions barren or poor in macrofossils. Close to 200 samples were collected in the Taurus chain (i.e. from Kemer, Seydisehir, Ovacik, Kozan, to Sariz regions in southern Turkey) and in the Border Folds (Mardin and Hakkari regions), usually regarded as part of the Arabian Plate in palaeogeographical reconstructions. Many samples are productive and yield chitinozoans and/or acritarchs of extremely variable preservation, depending on their geographical and geological location. In the Taurus chain, the material is "coalified" and frequently fragmented whereas, in the Border Folds, maturation of the organic matter is much lower and preservation of the microfossils is good to excellent. Several Ordovician chitinozoan biozones (northern Gondwana zonation) as well as diagnostic acritarch assemblages are identified in southern and southeastern Turkey. These Ordovician formations are assigned here to the new global stages of the Ordovician chronostratigraphical scale. The Seydisehir (upper part), Sobova, and Kilgen Lake (lower part) formations are referred to the Darriwilian. The Kilgen Lake (upper part), Sort Tepe, and Bedinan formations are attributed to the Sandbian and to the Katian, and the Halevikdere Formation (glacio-marine part) is assigned to the Hirnantian. Reworking of Early Ordovician acritarchs is documented in pre-glacial and in glacial Late Ordovician deposits. They indicate that active erosive processes occurred during the Middle and Late Ordovician sedimentation. The organic-walled microfossils recorded in the Ordovician of south and southeastern Turkey belong to the northern Gondwana realm. Interestingly however, some Baltoscandian influences are noted in the Border Folds during Early Late Ordovician.

Résumé

Une révision de la lithostratigraphie des dépôts ordoviciens du sud et du sud-est de la Turquie a conduit à une réévaluation des attributions stratigraphiques des diverses formations reconnues, à la fois à l'affleurement et en forage. Des datations étaient déjà fournies par la macrofaune (trilobites et graptolites notamment). Le présent article est consacré exclusivement aux microfossiles organiques (chitinozoaires, acritarches) qui apportent de nombreuses précisions d'ordre chronostratigraphique, notamment dans des séquences pauvres ou dépourvues en macrofossiles. Près de 200 échantillons ont été prélevés dans la chaîne du Taurus (régions de Kemer, Seydisehir, Ovacik, Kozan, Sariz, dans la Turquie méridionale) et aux confins sud-est de la Turquie, dans les régions de Mardin et de Hakkari (« Border Folds »), généralement intégrées à la Plaque Arabe dans les reconstitutions paléogéographiques. Beaucoup de ces échantillons se sont révélés fertiles. Ils ont livré des chitinozoaires et/ou des acritarches de conservation très variable en fonction des régions. Le matériel est carbonifié et souvent fragmentaire dans le Taurus. Par contre, la maturation de la matière organique est bien plus faible dans la région de Mardin où la conservation est le plus souvent bonne à excellente. Plusieurs biozones de la zonation des chitinozoaires ordoviciens nord gondwaniens, ainsi que des assemblages d'acritarches significatifs au plan stratigraphique, sont identifiés dans les formations du sud et du sud-est de la Turquie. Celles-ci sont replacées dans la nouvelle échelle globale des étages de la chronostratigraphie ordovicienne. Les formations de Seydisehir (partie supérieure), de Sobova, et de Kilgen Lake (partie inférieure) sont attribuées au Darriwilien. Les formations de Kilgen Lake (partie supérieure), de Sort Tepe et de Bedinan sont rapportées au Sandbien et au Katien. Quant à la Formation de Halevikdere (partie glacio-marine), elle est datée de l'Hirnantien. Des remaniements d'acritarches de l'Ordovicien Inférieur sont notés dans les sédiments pré- et syn-glaciaires à l'Ordovicien Moyen et Supérieur. Ils témoignent d'épisodes d'érosion active durant cette période. Au plan paléobiogéographique, les assemblages de microfossiles organiques observés dans l'Ordovicien de Turquie appartiennent à la Province nord-gondwanienne. Quelques influences balto-scandinaves sont toutefois relevées dans les « Border Folds », notamment au début de l'Ordovicien Supérieur.

Keywords: Chitinozoans; Acritarchs; Ordovician; Turkey (S and SE); Stratigraphy; Palaeogeography
Mots clés: Chitinozoaires; Acritarches; Ordovicien; Turquie (S et SE); Stratigraphie; Paléogéographie

1. Introduction

Lower Palaeozoic sedimentary rocks are fairly widely represented in Turkey (Fig. 1). Many of the formations crop in the central and eastern parts of the Taurus Range belonging to the Anatolian microplate (e.g., Seydisehir, Akyaka, Ovacik, Kozan or Degirmentas areas). Other outcrops are situated in southeastern Turkey, in the Border Folds (e.g., Derik, Mardin, Sort Tepe, and Zab areas) where Lower Palaeozoic strata are also known in the subsurface. The Border Folds region is regarded as the northern part of the Arabian plate (Monod et al., 2003). Macrofaunas (trilobites, brachiopods, graptolites) have been described from the outcrops (Dean, 1967, Dean and Monod, 1990 and Dean et al., 1999, and references therein). Early Darriwilian conodonts are also reported (Sarmiento et al., 1999). However, these fauna are frequently concentrated in restricted horizons, and thus large intervals remained poorly dated.

Palynological investigations on Lower Palaeozoic deposits from Turkey are fairly rare. They deal principally with the less mature organic-walled microfossils recorded in the Border Folds area where rich and well preserved Late Ordovician acritarchs, sporomorphs, and chitinozoans have been reported from the "Bedinan Group" s.l. (Erkmen, 1979, Miller and Bozdogan, 1989 and Steemans et al., 1996). Other palynomorph assemblages are known from the Late Silurian-Early Devonian Dadas and Hazro formations (Fontaine et al., 1980, Steemans et al., 1996 and Brocke et al., 2004). Preliminary data on the more mature and less well-preserved palynological material are also available from the central and eastern Taurus Range (Dean and Martin, 1992, Dean et al., 1993, Monod et al., 2003 and Paris et al., 2004).

2. Samples and localities

In recent years, a reappraisal of the regional lithological and biostratigraphical data has been made through extensive field investigations carried out by some of us (O.M, H.K., W.T.D, J.-F. G), with particular emphasis being devoted to the Hirnantian glacial related deposits (Ghienne et al., 2001 and Monod et al., 2003). All these new data provide a more robust framework for the palynological investigations being developed to complete, and/or to improve the chronostratigraphical information available on the recorded formations.

The sampling for palynological studies was made during several fieldwork seasons. A total of 122 samples from outcrops (82 samples from eastern Taurus and Border Folds) and subsurface (41 cutting samples from the Border Folds) have been investigated for chitinozoans (Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9 and Fig. 10a,b); 96 are productive when poor fragmentary material recovered from some of the Taurus samples is taken into account. Concerning the acritarchs, 52 outcrop samples and 41 cutting samples (the same as for the chitinozoans) have been investigated. In addition, previous data from 11 core samples from four boreholes in the Diyabakir region (Border Folds, Fig. 1) are updated and included in the biostratigraphic discussion (Fig. 5 and Fig. 10a,b).

The present investigations focus on chitinozoans (Plate 1, Plate 2, Plate 3 and Plate 4) and acritarches (Plate 5) from the Seydisehir (upper part), Sobova, Kilgen Lake, Bedinan, Sort Tepe, and Halevikdere formations. The Seydisehir Formation is composed of alternating quartzites, siltstones and shales ranging from the Upper Cambrian to Lower Ordovician (Dean and Monod, 1990 and Dean et al., 1999). In the Beysehir-Seydisehir area the Seydisehir

Formation is overlain by the Sobova Formation, which consists of a basal limestone member containing cystoids and a rich trilobitic fauna (Upper Arenig, Dean, 1973), followed by reddish to dark siltstones of Darriwilian age (see below) (Fig. 3 and Fig. 4). North of Adana (Kozan area), the Kilgen Lake Formation (informal name) corresponds to dark-grey mudstones and siltstones resting also on cystoid-bearing limestones (Fig. 3). The Kilgen Lake Formation ranges from the Late Darriwilian to Early Late Ordovician (see below). In the Border Folds, although cropping out separately, the Bedinan Formation (Caradoc, Dean, 1967 and Dean, 1983) and the younger Sort Tepe Formation (early Ashgill, Dean and Zhou, 1988) composed of dark green silty shales and siltstones may be regarded as part of a more comprehensive detrital unit (Dean et al., 1981), which is referred to a "Bedinan Group", a term used here for the subsurface cutting samples as no detailed lithostratigraphical information is available. The uppermost Ordovician Halevikdere Formation corresponds to Hirnantian glacially related sediments. It extends widely over southern and southeastern Turkey and overlies the Upper Ordovician Bedinan and Sort Tepe formations (Fig. 4 and Fig. 6), or rests unconformably on various older strata, e.g. Kilgen Lake, or even Seydisehir formations (Ghienne et al., 2001 and Monod et al., 2003).

Global Ordovician chronostratigraphy used here includes the Floian, Sandbian, and Katian stages corresponding respectively to Ordovician Stage 2, Stage 5 and Stage 6 is used here (Fig. 11). Additional references are made also to the British regional scale (series and stages) as redefined by Fortey et al., 1995 and Fortey et al., 2000.

3. Organic-walled microfossils from the Taurus Range

Preservation of the organic-walled microfossils is highly variable in southern Turkey. It ranges from brownish to black and frequently fragmented chitinozoan specimens in the Taurus Range (e.g., Seydisehir, Akyaka, Kozan, Degirmentas regions) where accurate identifications at specific level are scarce. The acritarchs and cryptospores are also usually poorly preserved (dark yellow-brown to black coloured vesicles; Plate 5). This contrasts with the well-preserved (low thermal alteration) acritarch and chitinozoan material from the Border Folds (see below).

3.1. Biostratigraphic data from the Seydisehir Formation

3.1.1. Chitinozoans from the Seydisehir Formation

A few poorly preserved chitinozoans (*Conochitina* sp. and fragments of Conochitinidae) have been recovered from the uppermost part of the Seydisehir Formation in the Akyaka section (samples BAK 53 and BAK 54; Fig. 2). In the Kozan area, another sample (KZ 171) at the top of the Seydisehir Formation yielded numerous chitinozoans; most of them are fragmented, but *Belonechitina* sp. is clearly identified among Conochitinidae species. These chitinozoan assemblages do not provide a firm age assignment, but they indicate that the Seydisehir Formation in these two localities extends at least into the Early Middle Ordovician, and most likely into the early Darriwilian (Late Arenig) as no classical components of early or middle Arenig chitinozoan assemblages have been observed. This is consistent with the age of the trilobites, conodonts (Sarmiento et al., 1999 and Sarmiento et al., 2003), and acritarchs (Fig. 5) recovered in the upper part of the formation in several sections.

3.1.2. Acritarchs from the Seydisehir Formation

Only a few samples have been studied. Productive samples are located in the upper part of the Seydisehir Formation in the Kozan section (SS 77, KZ 171) (Fig. 2), where the assemblages include *Coryphidium bohemicum*, *Ericanthea pollicipes*, *Polygonium acuminosum*, *Striatotheca rarirugulata*, which indicate the early Darriwilian (late Arenig to early Llanvirn). These taxa are accompanied by *Arbusculidium filamentosum*, *Aureotesta clathrata*, *Dactylofusa velifera* (Fig. 5), which appeared earlier, in the latest Tremadocian or early Floian (early Arenig), but range into the late Arenig. These results partially confirm and complement the age assignment based on acritarch assemblages proposed by F. Martin (in Dean and Martin, 1992) for the Seydisehir Formation in southern Turkey, and fits well with conodont determinations by G.N. Sarmiento extracted from the Tekmen limestone lens situated in the upper part of the Seydisehir Formation in the Akyaka section (Sarmiento et al., 1999, Sarmiento et al., 2003 and Kozlu et al., 2003; see Fig. 11).

The early Darriwilian age (late Arenig/early Llanvirn) also proposed here for the uppermost part of the Seydisehir Formation in the Kozan area is based on comparison with assemblages from Bohemia (Vavrdová, 1965, Vavrdová, 1966, Vavrdová, 1972 and Vavrdová, 1973), South Wales (Molyneux, 1987), England (Molyneux and Dorning, 1989), France (Rauscher, 1974), Morocco (Elaouad-Debbaj, 1984, Cramer et al., 1974a, Cramer et al., 1974b, Cramer and Diez, 1977 and Deunff, 1977), Algeria and Libya (Jardiné et al., 1974 and Vecoli, 2000), and from Sardinia (Albani, 1989). The closest affinities are with assemblages reported from coeval localities in North Gondwana and peri-Gondwanan areas, for instance, in Algeria, Bohemia or Morocco.

3.2. Biostratigraphic data from the Sobova Formation (Fig. 2)

Dark shaly samples (SS 29a and b; JFK 104 - JFK 111) from detrital deposits in the upper part of the Sobova Formation (Monod, 1977 and Dean, 1973) yield fairly poorly preserved dark coloured chitinozoans and acritarchs. Most of the recorded chitinozoans belong to the Conochitininae (e.g., *Conochitina* and *Euconochitina*), but are too fragmented for specific identifications. *Belonechitina* sp., *Cyathochitina campanulaeformis*, *Cyathochitina* sp. are also present in the lower part of the formation (JFK 104 and 105). Stratigraphically more interesting are the few damaged large individuals recorded in samples JFK 106 and 107. Some of them are tentatively referred to *Laufeldochitina striata* because of their large vesicle and the densely distributed small ridges (more or less parallel to the longitudinal axis) running on the vesicle. Others resemble *Laufeldochitina clavata*, but cannot be identified firmly as their carina is broken. *L. striata* is a species ranging through the Aseri, Lasnamägi, and Uhaku Baltoscandian regional stages (Nõlvak and Grahn, 1993 and Nõlvak, 1999) that is, in the late Darriwilian. A few taxa with a very peculiar morphology are recorded in samples SS 29A, SS 29B, and JFK 106. The first species is provisionally identified as ?*Lagenochitina spinatostoma*. It has a short vesicle (around 100 microns length) with a smooth conical chamber and a cylindrical neck with lips ended by long spines. The conical chamber of the Turkish specimens represents the main difference with regard to the species described by Soufiane and Achab (1993) in the Llanvirn of Morocco. The second taxon resembles *Salopochitina* (i.e., piriform chamber, long sheathing processes). The neck, however, is better developed than in typical *Salopochitina* a genus normally restricted to the Middle-Late Silurian (Swire, 1990 and Verniers et al., 1995) and thus the possibility of reworking of Ordovician forms within Silurian deposits was for a time envisaged, despite the absence of miospores and other Silurian palynomorphs. Recently, however, a similar chitinozoan form has been observed in Llanvirn strata of Belgium (J. Vanmeirhaeghe, oral. comm., 2005), and therefore a middle late Darriwilian age (Abereiddian) is most likely for detrital deposits of the upper part of the Sobova Formation in the Seydisehir area. The acritarchs (numerous galeate forms, *Peteinosphaeridium*, *Aremoricanium rigaudae*) recorded in samples SS 29A and B (A.L.H.) are in agreement with this chronostratigraphical assignment.

3.3. Biostratigraphic data from the "Kilgen Lake Formation" (informal name)

Late Darriwilian faunas were unknown in Turkey until the recent discovery of graptolites and chitinozoans in the lower part of the siltstones of the "Kilgen Lake Formation", defined close to Kozan (TPAO unpublished report) (Fig. 1, Fig. 2 and Fig. 3).

3.3.1. Chitinozoans from the "Kilgen Lake Formation" (Fig. 2 and Plate 1)

In the type section of the formation, 10 km north of Kozan, 16 samples have been collected (Fig. 3). Most of them, although fairly mature (dark opaque vesicles), provided workable chitinozoan assemblages (Plate 1, Figs. 1–7, 9–12). The lower part of the formation (BAK 117-BAK 119) contains *Cyathochitina campanulaeformis*, *Desmochitina minor*, *D. cocca*, and/or various *Conochitina* and *Belonechitina* species. The most interesting species, however, are *L. clavata* and *Linochitina pissotensis*, which are index species of the upper Darriwilian (upper Llanvirn) chitinozoan biozones in northern Gondwana regions (Paris, 1981 and Paris et al., 1999). The coexistence of rare *L. clavata* with abundant *L. pissotensis* in BAK 118 indicates that these samples belong to the *pissotensis* biozone of latest Darriwilian age (late Llanvirn, i.e., Llandeilian). This age assignment is consistent with the presence of graptolites representative of the *teretiusculus* Zone in neighbouring samples (Rickards et al., in preparation).

Higher in the section (i.e., BAK 119 to BAK 127) *Cyathochitina* species (including a small thickset form, and *C. kuckersiana*) dominate the recorded chitinozoan assemblages (Plate 1, Figs. 6, 7, 9–12), which contain *Tanuchitina* sp. aff. *ontariensis* (carina probably eroded) and various fragmentary vesicles belonging to *Belonechitina*, *Conochitina*, and *Euconochitina*. A small bulbous chitinozoan recovered in sample BAK 125 is tentatively referred to *Eisenackitina* sp. aff. *rhenan*a. These chitinozoans are assigned to the Early Late Ordovician (Sandbian), despite no stratigraphically diagnostic chitinozoan species having been identified. It is worth noting that *E. rhenana* is a chitinozoan index species in the GSSP of the Sandbian at Fålgesång, in Sweden (Vandenbroucke, 2004 and Vandenbroucke, 2005). This is consistent with the occurrence of *N. gracilis* (lowest Caradoc) close to BAK 119 (Rickards et al., in preparation).

In the upper part of the section (BAK 130 to BAK 132), *Euconochitina* communis is the most abundant species. It coexists with a few *Calpichitina* sp. indet., and with *Cyathochitina* ssp. (some individuals have a silhouette resembling *C. latipatagium* but their carina is broken). No Late Katian chitinozoans (i.e., latest Caradoc or Ashgill species) have been recorded in the upper part of the Kilgen Lake Formation where graptolite remains are recorded in the organic residue (e.g., BAK 130).

In the upper part of the Akyaka section (Fig. 2), an azoic succession of sandstones followed by black shales has been equated with the Bedinan Formation by Kozlu et al. (2003). In the black shale member, a few samples (BAK 57 from the lower part of the member and BAK 64 from its middle/upper part) yielded poor chitinozoan assemblages (rare fragmented and opaque individuals). Most of the recovered specimens belong to *Belonechitina* sp. indet. (eroded spines). They do not provide any precise improvement for the age assignment of the shale member, but may be compatible with ?Abereiddian to ?lower Caradoc (see Fig. 11).

3.4. Biostratigraphic data from the Sort Tepe Formation

3.4.1. Chitinozoans from the Sort Tepe Formation

The formation has been studied in sections close to Sariz (Degirmentas section, Fig. 1, Fig. 2 and Fig. 4). Investigated samples from the lowest part of the formation yield a few poorly preserved chitinozoan assemblages (e.g., BAK 149 to BAK 155a and b) and contain only Conochitinidae fragments, which lack any significance in detailed biostratigraphy. In the lower part, however, a few samples (BAK 151 and 154) yield Late Ordovician forms e.g., *Cyathochitina* individuals recalling *C. latipatagium* (their damaged carina does not allow a firm identification), *D. minor*, *Euconochitin*a sp. aff. *communis*, and a small *Lagenochitina* sp. indet. in BAK 154. In the middle part of the formation, lower Ashgill trilobite assemblages have been described in Dean and Monod (1990).

South of Antalya, a fairly similar chitinozoan assemblage dominated by *Euconochitina* and *Cyathochitina* species has been recovered from strata previously referred (Dean et al., 1999) to the Sort Tepe Formation in a tectonic slice in the Kemer Gorge section (BDK 120).

3.4.2. Acritarchs from the Sort Tepe Formation (Fig. 5)

The samples from the lower part of the Sort Tepe Formation in the Degirmentas section (BAK 152, BAK 153, BAK 154), eastern central Taurus, yielded poorly preserved acritarch assemblages (e.g., BAK 149) including *Actinotodissus crassus*, some *Baltisphaeridium* spp., *Multiplicisphaeridium* cf. *irregulare*, some *Orthosphaeridium*, rare *Villosacapsula irrorata*, but fairly abundant triapsidate *Veryhachium*. These assemblages suggest at least a Late Ordovician age (Caradoc to early Ashgill) for this formation. These Late Ordovician acritarchs coexist with some obviously reworked early Darriwilian forms (e.g., *Acanthodiacrodium* spp., *Arkonia virgata*, *Baltisphaeridium ternatum*, *Dicrodiacrodium ancorifome*, *Pirea* sp., ?*Stelliferidium* cf. *philippotii*, *Vogtlandia* sp.) (Fig. 5). Dean and Martin (1992) have already noted this reworking. Some of the reworked acritarchs have their L.A.D. in the basal Caradoc (e.g., *Baltisphaeridium ternatum*; see Vecoli and Le Hérissé, 2004). The recycling of *Arkonia virgata*, and to a lesser extent of *Baltisphaeridium ternatum* are good arguments in favour of the development of marine sedimentation in the Taurus area during the late Darriwilian (Llanvirn). These sediments were locally eroded prior to/or during deposition of the Sort Tepe Formation, which has been regarded as corresponding to the Ashgill transgression (Dean and Monod, 1990).

In the same section two samples from the top of the Sort Tepe Formation (SS 89-SS 90) contain abundant cryptospores, some leiospheres, triapsidate veryhachiids, *Baltisphaeridium* and large fusiform acritarchs such as *Dactylofusa platynetrella*. These palynomorphs are not stratigraphically diagnostic. However, the peculiar composition of these assemblages, particularly the abundance of veryhachiids and cryptospores, recalls stressed conditions such as those recorded during the Late Ordovician glaciation and the associated sea-level fall (Le Hérissé et al., 2003 and Paris et al., 2000a). In the highest beds of the Sort Tepe Fm., these peculiar conditions are also reflected by thin layers of Mn oxides immediately beneath the onset of the glacial sedimentation, as already noted in Sardinia in the same position (Ghienne et al., 2000).

In the Kozan section, two samples close to the boundary between the Kilgen Lake and Halevikdere formations (PK 62 and PK 63) yield fairly rich acritarch assemblages with *Baltisphaeridium* cf. *hirsutoides*, *Baltisphaeridium* spp., *Multiplicisphaeridium bifurcatum*, *Ordovicidium heteromorphicum*, *Peteinosphaeridium* cf. *bergstroemi*, *Peteinosphaeridium trifurcatum intermedium*, *Polyancistrodorus intricatus*, *Solisphaeridium nanum*, *Veryhachium trispinosum*, *Villosacapsula irroratum*. These species are regarded as characteristic of the Caradoc and the Ashgill (ranging up to the latest Ordovician for some of them). They are mixed with reworked Cambro/Tremadocian to Arenig/Llanvirn taxa such as *Acanthodiacrodium* spp., *Arbusculiferum filamentosum*, *Aremoricanium rigaudae*, *Aureotesta clathrata*, *Cymatiogalea* spp., ?*Retisphaeridium* sp., *Rhopaliophora membrana*, *Stelliferidium stelligerum*, *Stelliferidium* cf. *philippotii*, *Striatotheca principalis parva*, *Vulcanisphaera frequens*. Erosion processes, possibly related to early glacial phases (sea level fall) were active during deposition of the upper part of the Kilgen Lake Formation. The Late Ordovician glacial period is regarded as a time of active acritarch reworking (Vavrdová, 1982 and Vecoli and Le Hérissé, 2004).

Rhopaliophora membrana is characterised by dispersed fairly large processes, and by a smooth vesicle wall. This species is recorded in uppermost Tremadocian to lower Arenig in China (Martin and Yin, 1988, Lu, 1987 and Tongiorgi et al., 2003). It is also recorded in late Arenig strata in the Kopet-Dagh region, northeastern Iran (Ghavidel-Syooki, 2000 and Ghavidel-Syooki, 2001). From a palaeogeographical point of view, the occurrence of this species reworked in SE Turkey among classical elements of the “Peri-Gondwana province” (Tongiorgi et al., 1994), suggests that Turkey, and probably Iran, were located along the northeastern margin of Gondwana, in an intermediate position between South China and the Mediterranean regions.

In the Kemer Gorge section, sample BDK 120 yields abundant and relatively well-preserved acritarchs from a tectonic shaly slice. The corresponding strata were previously referred to the Sort Tepe Formation in Dean et al. (1999). The assemblage is dominated by large *Baltisphaeridium*, in association with some *Ordovicidium, Goniosphaeridium, Orthosphaeridium* but also with *Multiplicisphaeridium* spp., some veryhachiids, netromorphs (*Leiofusa, Navifusa* spp.), and a few *Pirea*. One species of *Baltisphaeridium* here called *B.* aff. *latiradiatum*, is well represented and demonstrates a high polymorphism in the number of processes (three to eight). The spherical vesicle is smooth. The processes are long and large, slightly constricted at their base, and smooth. By its general aspect this form recalls *B. macroceros*, but the processes are not as large. It recalls also *B. bramkaense* or *B. constrictum* but these two species have ornamented vesicle and processes. Moreover, their processes are shorter. Another species, assigned to *Pirea* sp., is also well represented. It has a smooth, rounded vesicle and a short cylindrical apical horn. By the form of the vesicle, not pear-shaped or ovate, but clearly rounded, it differs from *P. capitata, P. capitulifera, P. colliformis* or *P. inflata* (described in the upper Llanvirn of Germany), from *P. dubia* (described in the Arenig of Bohemia), or *P. laevigata* (described in China). The following species of acritarchs have been identified too: *Baltisphaeridium annelieae, Baltisphaeridium calicispinae, Baltisphaeridium* cf. *hirsutoides, Baltisphaeridium multipilosum, Goniosphaeridium splendens, Goniosphaeridium* aff. *Goniosphaeridium* sp. A in Turner, 1984, *Leiofusa fusiformis, Multiplicisphaeridium irregulare, Multiplicisphaeridium raspa, Multiplicisphaeridium* aff. *cladum, Navifusa similis, Pirea* sp., *Ordovicidium elegantulum,* *Ordovicidium nudum, Orthosphaeridium chondrododora, Tunispaheridium pactile, Veryhachium lairdii, Veryhachium minutum* among others. Several of these species occur in the Upper Ordovician e.g., in the type Caradoc series (now Sandbian-basal Katian) in England (Turner, 1984), or in the Middle Ordovician of Poland, Sweden, or in North America. A few species, such as *Petaloferidium florigerum* could be reworked from the Arenig-Llanvirn.

3.5. Organic-walled microfossils from the glacial deposits (Halevikdere Formation, Hirnantian)

3.5.1. Chitinozoans from the Halevikdere Formation (Fig. 2 and Fig. 4)

Several sections exposing the Halevikdere Formation have been investigated in the Taurus Range. The preservation of the chitinozoans is usually fairly poor. However, some of the classical components of the Hirnantian chitinozoan assemblages in northern Gondwana regions (Paris, 1988 and Paris, 1990; Oulebsir, 1992, Oulebsir and Paris, 1995, Bourahrouh, 2002 and Bourahrouh et al., 2004) are identified, i.e. *Armoricochitina nigerica*, *Tanuchitina elongata*, *Calpichitina lenticularis*, *Euconochitina* gr. *lepta*, *Desmochitina minor*, *Lagenochitina prussica*, *Belonechitina* sp. 1 (with blunt spines), *Cyathochitina* cf. k*uckersiana*. All, or several of these occur in the upper part of the Halevikdere Formation in the Ovacik section (SS 72, Ovacik 8 and 4), Kozan (SS 103, KZ 165A, and KZ 166A, with an abundant and diversified assemblage dominated by *A. nigerica*) and Degirmentas (T 91-DEG 12) sections. The *oulebsiri* biozone, which is the uppermost Ordovician chitinozoan biozone in northern Gondwana regions (Paris et al., 2000a), has not been identified yet in the Taurus samples, possibly due to poor preservation of the material.

3.5.2. Acritarchs from the Halevikdere Formation (Fig. 5 and Plate 5)

Upper Ordovician glacial deposits of the Halevikdere Formation in the eastern Taurus (Ghienne et al., 2001) have yielded only poorly preserved and oxidised phytoplanktonic and continental organic remains. The composition of the recorded assemblages is variable depending on the position of the samples in the formation. In the Degirmentas section, the base and the top of the glacial deposits have been studied (SS 91, SS 92, SS 95, SS 96) whereas in the Kozan (KZ 165A, KZ 166A) and the Ovacik (PK 91A, PK 91B, PK 92) sections, the samples are only from the finer upper part of the formation. The richness of acritarch associations is classically limited during glaciation and deglaciation periods. The same characteristics are found herein, with over-representation of veryhachiids with three processes (i.e., *Veryhachium* and *Villosacapsula*), the occurrence of *Neoveryhachium carminae*, of some netromorphs (e.g., *Eupoikilofusa striatifera*), and of *Evittia denticulata denticulata*, a widespread and tolerant form, which announces the Silurian taxa. Some reworking is suspected in KZ 165A, which contains Caradoc or lower Ashgill taxa such as *Baltisphaeridium* spp., *Orthosphaeridium* spp. with broken processes, or *Veryhachium hamii* (?); above, in the Ovacik section, important reworking is present in the basal Silurian black shales, which contain Arenig forms (sample PK 93).

4. Organic-walled-microfossils from the Border Folds

The Border Folds of SE Turkey are regarded as representing the northern part of the Arabian Plate in the Palaeozoic palaeogeography. Both outcrop and subsurface samples from this area (e.g., Derik, Mardin, Diyarbakir, Zap valley regions) have been processed.

Palynological investigations have been carried out on 17 surface samples from the Derik-Mardin composite section (Fig. 6) and from the Sort Tepe section (GBS 16 to GBS 30), and on 41 cutting samples from three deep wells CEYLANPINAR 1 (Fig. 7), DARA 2 (Fig. 8) and GIRMELLI 1 (Fig. 9). In addition, the data available from 21 core samples from four other wells located close to Diyarbakir (Steemans et al., 1996) have been integrated into the proposed biostratigraphic scheme.

The lithostratigraphy of the Ordovician strata in the Border Folds is not yet definitively established. When originally defined, based on the outcrops of the Mardin region, the comprehensive Bedinan Formation was restricted to the Caradoc (Dean, 1967 and Dean, 1983). Recently, glacially related sediments (diamictites and siltstones) have been identified on top of the Bedinan Formation in the type-locality (Fig. 6), and assigned to the Halevikdere Formation (Ghienne et al., 2001 and Monod et al., 2003). In all likelihood, the youngest Ordovician samples in the wells studied by Steemans et al. (1996) also belong to this formation.

On the other hand, other deposits (mainly siltstones and silty-shales) cropping out in south-easternmost Turkey (Zap valley, south of Hakkari, samples GBS 16 to GBS 30) are referred to the Sort Tepe Formation (Dean et al., 1981). Consequently, the Bedinan Formation is here restricted to the pre-glacial deposits represented by siltstone, shale, and subordinate sandstone beds (Fig. 6) cropping out 25 km west of Mardin (Fig. 1).

In subsurface, due to the poor lithological data available (cutting samples), the strata penetrated by the three investigated wells are provisionally referred to a comprehensive "Bedinan Group" (i.e., without separate recognition for specific formations). The deepest cutting samples from these wells are tentatively referred to the Seydisehir Formation *s.l.* because of their early Darriwilian age (Fig. 7, Fig. 8, Fig. 9 and Fig. 10).

4.1. Chitinozoans from the Border Folds

4.1.1. Chitinozoans from the Halevikdere Formation (Plate 2)

In the Derik-Mardin region as well as in the youngest Ordovician core samples studied by Steemans et al. (1996), Hirnantian chitinozoan assemblages corresponding to the *elongata* biozone are recorded in the upper part of the Halevikdere Formation. These chitinozoan assemblages include the classical components of the *elongata* biozone i.e., *Armoricochitina nigerica*, *Calpichitina lenticularis*, *Rhabdochitina magna*, *Tanuchitina elongata*, and some subordinates taxa (e.g., *Ancyrochitina* ssp., *Desmochitina minor*, *Cyathochitina* gr. *kuckersiana*, *Euconochitina* gr. *lepta*). Other taxa are also present such as *Acanthochitina* cf. *barbata* (with pillars supporting a membranous sleeve shorter than that of typical specimens of *A. barbata*; see Plate 2, Fig. 4a,b), and *Belonechitina* nov. sp. 1 (peculiar ornamentation with densely distributed blunt spines; see Plate 2, Figs. 1a,b, 6a,b). It is worth noting the occurrence of *Spinachitina* sp. A sensu Steemans et al., 1996 (Pl. VII, Fig. 5) in the youngest Ordovician core samples (B2, B1, and H1) from the Diyarbakir area. Although no biometric studies were published for these individuals, they suggest the presence of the *oulebsiri* chitinozoan biozone of late Hirnantian age (Paris et al., 2000a) in the uppermost part of the Halevikdere Formation in the Border Folds.

4.1.2. Chitinozoans from the Bedinan Formation (Plate 3)

In the Mardin region, well-preserved and diversified chitinozoan assemblages have been recovered from the type locality of the Bedinan Formation corresponding to the siltstones and shales, with subordinate sandy beds, as defined by Dean, 1967 and Dean, 1983.

The productive samples are respectively from the upper part and from the lower part of the formation (Fig. 6). *Euconochitina* e.g. *communis* dominates the chitinozoan assemblages in the youngest samples (GBS 82 and 83). It is associated with a few *Calpichitina lenticularis* and *D. minor*. A striking mix of well preserved transparent vesicles and of opaque and fragmentary individuals is noted. The oldest part yields *Conochitina dolosa*, *Conochitina* ssp., *Cyathochitina kuckersian*a, *Cyathochitina* sp., *Desmochitina minor*, *Hercochitina* sp. aff. *spinetum* (Plate 3, Figs. 4, 5, 7, 9), *Kalochitina* nov. sp. aff. *multispinata* (Plate 3, Fig. 2b), and *Spinachitina* sp. aff. *tvarenensis*. Another chitinozoan, *Armoricochitina granulifera* (Plate 3, Fig. 1) is a well-known species from the early Idavere regional stage in Baltoscandia (Nõlvak and Grahn, 1993 and Nõlvak et al., 1999). This species indicates a Sandbian age for the lowest part of the Bedinan Formation (i.e., early part of the Caradoc, Aurelucian in the British regional chronostratigraphy), in good agreement with the trilobite assemblages situated in the middle part of the formation (Dean, 1983).

4.1.3. Chitinozoans from the Sort Tepe Formation

Ten samples from the lower part (GBS 16–18, GBS 24–26, and GBS 35) and the upper part (GBS 28–30) of the Sort Tepe Formation in its type area (Zap region in south-eastern Turkey, Fig. 1) have been studied. Most of the samples from the base of the formation are barren. However, sample GBS 24 yields *Cyathochitina campanulaeformis*, *Cyathochitina* sp., *D. minor*, *Belonechitina* sp. aff. *robardeti* (with long spines), *Euconochitin*a sp. and *Tanuchitina* sp. None of these chitinozoans are stratigraphically diagnostic, but a few damaged *Lagenochitina* sp. resembling *L. spinastostoma* (neck provided with well-developed spiny denticules extending from the lips) might indicate a Darriwilian age for the lower part of the Sort Tepe Formation in the Zap area. In Turkey, *L. spinastostoma* is recorded in the lower part of well CEYLANPINAR 1 (see below) and other individuals, tentatively referred to this species, are present in the upper part of the Sobova Formation (see above).

In the upper part of the Sort Tepe Formation (samples GBS 28 and 29) the composition of the chitinozoan assemblages is different: *Cyathochitina* is no longer present, whereas *Euconochitina* specimens recalling *E. communis*, and a few *Desmochitina* gr. *minor* are recorded among numerous acritarchs and a few scolecodont and graptolite remains. No classical Ashgill species are recorded in these assemblages, which are similar to those observed in Algeria in samples of early late Caradoc age (i.e., pre-*fistulosa* strata). Consequently the upper part of the Sort Tepe Formation is referred to the early Katian (late Caradoc). However, trilobites from the same beds are referred to lower Ashgill in Dean and Zhou (1988) and additional sampling is needed to complete the microfaunal assemblages.

4.1.4. Chitinozoans from the "Bedinan Group" (Fig. 7, Fig. 8 and Fig. 9)

The investigated cutting samples from the subsurface of the Border Folds are referred to a comprehensive "Bedinan Group" because the lithological information available is not accurate enough for allowing a firm attribution of the penetrated deposits to one of the formations defined in the outcrops (i.e., Halevikdere, Sort Tepe, and Bedinan formations). The available cutting samples are too sparsely distributed and, moreover, there are no precise indications on the actual thickness of the strata as the dips are unknown. Important caving processes are proved in the three wells by the presence of Permo-Triassic spores and pollen among the recovered Ordovician palynomorphs assemblages. Caving processes affected also the chitinozoans, within the 1000 to 1500 metres thick Ordovician successions penetrated by the boreholes. Consequently, in order to prevent erroneous age assignment due to caved individuals, identification of the chitinozoan biozones is based here exclusively on the youngest record of index species. However, the accurate position of the limits of the identified biozones is not very well constrained because of the widely spaced samples and of possible barren intervals. Consequently, the deduced chronostratigraphical assignment should be regarded as a minimum age (i.e., possibly older if the index species are caved).

In well CEYLANPINAR 1 (CEY-1), from 1858 to 1698 m (Fig. 7), the chitinozoans recovered from cutting samples are classical components of Late Ordovician assemblages of northern Gondwana regions. They include *Acanthochitina barbata*, *Armoricochitina nigerica*, *Calpichitina lenticularis*, *Desmochitina minor*, *Lagenochitina baltica*, and *L. prussica*, which have their LAD in the Hirnantian but range through the Ashgill, or even below for some of them (Paris, 1990 and Paris et al., 2000a). However, at 1698 m (i.e., close below the Permo-Triassic unconformity) a few broken specimens of *T. elongata* coexisting with the species listed above indicate the early Hirnantian *elongata* biozone (Paris et al., 2000a). An early Hirnantian age is therefore proposed for this sample whereas the two underlying samples (1788 and 1858 m) without *T. elongata* firmly identified are assigned to the late Katian (i.e., pre-Hirnantian Ashgill). The youngest graptolite remains observed in the investigated wells occur at 1858 m in CEY-1.

At 1928 m, in CEY-1, and at 2590 m in GIRMELLI 1 (GIR-1), chitinozoan species representative of the *fistulosa* biozone are present, e.g. *Conochitina elegans*, *Cyathochitina latipatagium*, *Fungochitina fungiformis*, *Hyalochitina fistulosa*, *T. ontariensis* (Fig. 7 and Fig. 8). They coexist with the Ashgill species listed above, which, in all likelihood, are caved as their range biozones normally do not overlap with those from the *fistulosa* biozone. From 1928 to 2118 m in CEY-1, the composition of the recovered chitinozoan assemblages remains fairly similar. The three samples are therefore referred to the *fistulosa* biozone, even if a small change corresponding to the LAD of *Angochitina* nov. sp. A (with a large piriform chamber) and the LAD of *Spinachitina* sp. (not pointed on Fig. 7) is noted at 2018 m. In CEY-1 and GIR-1 the upper limit of the *fistulosa* biozone is probably located slightly higher than the documented LAD of the index species, respectively in the 70 and 50 m intervals without available samples (Fig. 7 and Fig. 8). The lower limit is poorly constrained with an interval of dubiousness of 380 m in CEY-1, and of 170 m in GIR-1 (Fig. 7 and Fig. 8). The *fistulosa* biozone, which is well documented in Saudi Arabia in the Ra'an Member of the Qasim Formation (Paris et al., 2000b), is regarded as representative of the late Caradoc (Paris in Webby et al., 2004). According to the recent Ordovician chronostratigraphical scale, the *fistulosa* biozone belongs to the middle part of the Katian (i.e., the sixth Ordovician Stage defined by the FAD of *Ensigratus caudatus* in the GSSP of Black Knob Ridge; see Goldman et al., 2005). It is worth noting that *Fungochitina fungiformis* (= *F. spinifera* in

Vandenbroucke, 2005) ranges in Pusgillian strata of pre-*linearis* age (Rickards, 2002) in the Cautley District (UK). Then, this species, which is common in the *fistulosa* biozone, extends beyond the Caradoc-Ashgill in the British local chronostratigraphy. *A. barbata* is usually regarded as an early Ashgill species (Nõlvak and Grahn, 1993 and Vandenbroucke, 2005). Its occurrence at 2590 m in GIR-1 (Fig. 8 and Plate 4, Figs. 2, 3) suggests that this species is probably caved from strata immediately above or, alternatively, that the *fistulosa* biozone may extend into the earliest Ashgill. The assemblages recovered at 2198 m in CEY-1 and at 2810 m in GIR-1 are less diagnostic for accurate biostratigraphy. However, the abundance of *C. latipatagium* and the LAD of *Acanthochitina latebrosa* nomen nudum (in Vandenbroucke, 2005) suggest an early Katian age (late Caradoc, i.e. Streffordian; see Vandenbroucke, 2005).

The *robusta* biozone is documented in the three investigated wells. The index species is associated with *Euconochitina tanvillensis* at 2308 and 2578 m in CEY-1. The two species coexist usually in the lower part of the *robusta* biozone (Paris, 1981) but in the present case (cutting samples) *B. robusta* may be caved. Consequently, the two corresponding samples are tentatively referred to the *tanvillensis* biozone of early Katian age (Achab and Paris, 2007). *B. robusta* is recorded in GIR-1, and in DARA 2, respectively at 2980 and 2420 m (and ?2730 m). The deepest records of *B. robusta* in these wells, in all likelihood, correspond to caved individuals as they are mixed with older taxa (Fig. 7, Fig. 8 and Fig. 9). The associated species are *Desmochitina cocca*, and species recorded higher in the well (e.g., *E. communis*, *Angochitina* n. sp. 1) or caved from younger strata (e.g., *C. latipatagium*, *C. elegans*, *Acanthochitina latebrosa* nomen nudum). A mid to early late Caradoc age was assigned to the *robusta* biozone (Paris, 1990 and Webby et al., 2004). This time interval is now regarded as the lower part of the Katian (sixth Ordovician Stage) in the new International Ordovician chronostratigraphy.

The *dalbyensis* biozone is usually a well-represented chitinozoan biozone in Baltoscandia and in northern Gondwana regions (Nõlvak and Grahn, 1993 and Paris et al., 1999). Surprisingly, it has not been recovered in the investigated wells. However, there is enough space for this biozone in the interval without samples or without diagnostic taxa in the three investigated wells, i.e. 120 m in CEY-1, 100 m in GIR-1, and 130 m in DARA-2 (Fig. 7, Fig. 8 and Fig. 9). Interestingly, on palaeogeographical and biostratigraphical grounds, *Angochitina curvata* and *Armoricochitina granulifera*, two index species of the Baltoscandian chitinozoan zonation, have been identified in the three wells. *A. curvata* and *A. granulifera* are two short-ranging species of early Idavere age (Baltoscandian regional terminology) preceding the FAD of *L. dalbyensis* (Nõlvak and Grahn, 1993, Nõlvak, 1999 and Nõlvak et al., 1999). In CEY-1, *A. curvata* has its LAD at 2578 m, above the LAD of *A. granulifera* (at 2718 m). Therefore, the *curvata* biozone is used in CEY-1 (Fig. 7). However, because of the sparse sampling in DAR-2 and GIR-1, the two species have their LAD in the same cutting samples (respectively at 2730 and 3080 m). Consequently, the oldest biozone, i.e. the *granulifera* biozone, is preferred here (Fig. 8 and Fig. 9). Both biozones provide a robust mid-Sandbian age for the corresponding samples (Fig. 7, Fig. 8 and Fig. 9). *Lagenochitina deunffi*, index species of the eponymous biozone of mid-Sandbian age, is identified at 2870 m in DARA-2 and at 2718 m in CEY-1. The individuals recorded at 3158 m in this well and at 3350 m in GIR-1 are obviously caved as they occur clearly below older species.

The *ponceti* biozone is identified in wells CEY-1 (2718 m), and DAR-2 (2870 m). It is possibly present in GIR-1 at 3200 m, but the characteristic taxa have not been observed. The *ponceti* biozone seems restricted to a short time interval close to the Middle-Upper Ordovician boundary (Paris in Webby et al., 2004). It is regarded as indicative of the lower part of the Sandbian, that is, just above the FAD of *Nemagraptus gracilis*, the index graptolite of the base of the Sandbian (Bergström et al., 2000, and references therein). *Lagenochitina ponceti* has not been firmly identified yet in the GSSP of the Sandbyan at Fålgesång (Vandenbroucke, 2005), but the accompanying species (e.g., *P. capitata*, *Eisenackitina* forms closely related to *E. rhenana*) support the age assignment adopted here.

The *pissotensis* biozone is usually well represented in northern Gondwana regions (Paris, 1981 and Paris, 1990). It corresponds to the upper part of the Darriwilian (see Webby et al., 2004), that is it ranges through the Llandeilian in the British regional chronostratigraphy elaborated by Fortey et al., 1995 and Fortey et al., 2000. However, *L. pissotensis* may have its FAD in the latest Abereiddian (Albani in Gutiérrez-Marco et al., 1996). In the investigated subsurface material from the Border Folds, the index species is recorded at 2878 m in CEY-1 (Fig. 7). In this well, due to the widely spaced cutting samples and of caving processes, large intervals of incertainty still occur for the upper limit (160 m) and for the lower limit (496 m) of this biozone. The occurrence of *Pogonochitina spinifera* at 3158 m in CEY-1 suggests that the *pissotensis* biozone ranges close to this depth. In this cutting sample, *P. spinifera*, which usually coexists with *L. pissotensis* (Oulebsir and Paris, 1995), is probably caved and mixed with older chitinozoans (e.g., *Cyathochitina varennensis*, *Belonechitina micracantha*, *B. punctata*) of early middle Darriwilian age (mid-early Abereiddian) (Paris, 1981 and Paris, 1990).

In CEY-1, the deepest cutting sample (3374 m) yields chitinozoan species which normally do not coexist (Fig. 7). The youngest species (i.e., *Belonechitina robardeti*, *Cyathochitina varennensis*, *Lagenochitina spinatostoma*) are interpreted as caved individuals from Early middle Darriwilian levels (early Llanvirn) within older assemblages of Early Darriwilian age (i.e., late Arenig) because the association of *Belonechitina henryi*, *Eremochitina brevis* (short forms), *Lagenochitina obeligis*, *Laufeldochitin*a cf. *baculata*, and *V. veligera* is representative of the *henryi* biozone (Paris, 1981 and Paris, 1990). Consequently, an early Darriwilian age is favoured for this deepest sample from this well. The Arenig-Llanvirn boundary is therefore located within the 216 m thick interval without available sample.

The deepest cutting samples from GIR-1 (3350 and 3490 m) and DARA-2 (3170 to 3390 m) yield confusing chitinozoan assemblages as Arenig species are mixed with a few early Llanvirn forms (Fig. 8 and Fig. 9). Moreover, the oldest recorded taxa are represented by darker and less well preserved individuals (e.g., *L. obeligis* in GIR-1). This may be related either to the reworking of Arenig taxa in early Llanvirn strata, or, alternatively, caving of early Llanvirn individuals within older and deeper assemblages, which were more affected by diagenesis. Chitinozoan reworking is rather an uncommon process; it may occur during syn-sedimentary tectonic events, e.g. block tilting as reported by Paris and Elaouad-Debbaj (1989) in the Upper Devonian of Morocco. However, despite the reworking of Early Ordovician acritarchs (see below), and local stratigraphical gaps and unconformities (Dean et al., 1993, and references therein) which have been documented in southeastern Turkey, this hypothesis is not favoured here, and the corresponding samples are tentatively referred to the early Darriwilian (late Arenig).

4.2. Acritarchs and cryptospores from the Halevikdere Formation and "Bedinan Group" of the Border Folds (Plate 5 and Fig. 10b)

All the processed samples from the Border Folds region have yielded abundant and well-preserved acritarch assemblages. This deeply contrasts with the situation in the Taurus area. Different local assemblage biozones are here informally designated: TAR1 and TAR2 in the Arenig (T for Turkey), TLL1 in the Llanvirn, TCA1 and TCA2 in the Caradoc and TAS1, TAS2, and TAS3 in the Ashgill (Fig. 10a,b). The age assignment of these local biozones is based on independent control provided by the chitinozoans recorded in the same samples, and by the graptolites coexisting with the same acritarchs taxa elsewhere. This local zonation is informal because the available samples are sparsely distributed and because numerous individuals from the cuttings are caved. The apparent homogenisation of oceanic conditions and/or easier marine communications during the Late Ordovician, particularly the Ashgill, allow fairly good correlations with assemblages described in North America as well as in the Prague Basin or on the North African border.

An important reworking event of acritarch species related to the erosion processes resulting from local tectonic readjustments and/or to sea-level changes from the basal Caradoc to the basal Ashgill, and during the sea level fall occurring during the Hirnantian glaciation is noticed in the investigated samples. Consequently, and in spite of additional complications due to caved individuals, the recorded acritarch assemblages are discussed from oldest to youngest. This allows a better appraisal of the reworking of Early Ordovician palynomorphs.

4.2.1. Assemblage TAR1

It is only present in well DARA-2 at 3390 m. It is characterised by the abundance of *Pirea* spp., the presence of *Dactylofusa velifera brevis* (which seems to be in its correct position), *Ferromia pellita*, *Striatotheca rarirugulata*, and by the good representation of the diacrodians. This association is characteristic of the Floian and of Early Ordovician Stage 3 (early Arenig to base of the late Arenig, i.e. *D. extensus* graptolite Zone) in Great Britain (Molyneux and Dorning, 1989), Prague Basin (Vavrdová, 1990), and Sardinia (Albani, 1989). It should be noted that the caved individuals present at this depth are not listed in Fig. 10a.

4.2.2. Assemblage TAR2

It is defined in the deepest samples from CEY-1 (3374 m), where the acritarchs are diverse in composition, DARA-2 (3170 m) and GIR-1 (between 3350 and 3490 m). The most important species are: *Acanthodiacrodium* spp., *Aurotesta clathrata* var. *simplex*, *Baltisphaeridium klabavense*, abundant *Coryphidium* spp., *Dicrodiacrodium ancoriforme*, *Kladothecidium eligmosum*, *Multiplicisphaeridium* cf. *maroquense*, *Petaloferidium florigerum*, some *Pirea* spp. This assemblage is equivalent to that described elsewhere in the early Darriwilian (around the Arenig/Llanvirn boundary). This corresponds to a period of high morphological diversification of the acritarchs.

Remarks: *Dicrodiacrodium ancoriforme* has long been considered as a typical indicator of the Llanvirn. However, the FAD of this species is now documented in the upper Arenig in Morocco (Soufiane and Achab, 1993) and in Bohemia (revision of graptolites dating the base of the Sarka Formation; see Kraft and Kraft, 1999). *Frankea sartbernardensis* observed at 3170 m in DARA-2 may be caved.

Assemblage TAR 2 is very close to those described in the upper part of the Klabava Formation and in the lower Sarka Formation in Bohemia (Vavrdová, 1972 and Vavrdová, 1977), and around the Arenig/Llanvirn boundary in Morocco, (Cramer and Diez, 1977, Cramer et al., 1974a, Cramer et al., 1974b, Deunff, 1977, Marhoumi et al., 1982 and Fournier-Vinas, 1985). Several species encountered here are also reported in the Middle Ordovician of southern Iran (northeastern Alborz Range or Zagros Basin; Ghavidel-Syooki, 1996 and Ghavidel-Syooki, 2000).

4.2.3. Assemblage TLL1

It concerns the interval 2878–3028 m in CEY-1 and one cutting sample at 3020 m in DARA-2. The assignment of the assemblage to the late Darriwilian (Llanvirn) is based on the increased representation of the *Veryhachium trispinosum* group (see Servais, 1991) and on the occurrence of *Arkonia* spp. or *Striatotheca quieta*, which are unknown from pre-Llanvirn strata (Vecoli et al., 1999). A recurrence of *Virgatosporites* (3020 m in DARA-2) is also mentioned in the Llanvirn in Morocco (Cramer and Diez, 1977). Several groups of taxa, well developed in the Arenig, have disappeared e.g., *Coryphidium* spp., *Cymatiogalea* spp., *Multiplicisphaeridium maroquense*.

4.2.4. Assemblage TCA1

The oldest Caradoc interval is located between 2730–2870 m in DARA 2, and at 3290 m depth in GIR-1. The base of the assemblage shows recycling of Arenig and Llanvirn acritarchs (e.g., *Aureotesta clathrata*, *Arkonia tenuata* or *Petaloferidium florigerum*, the youngest record of which is in the *D. artus* graptolite Zone in Germany; see Maletz and Servais, 1993).

Very few data are available on the Caradoc sections of the Mediterranean Province (Jardiné et al., 1974, Deunff and Massa, 1975 and Molyneux and Paris, 1988). The Caradoc type sections in Britain (Turner, 1982 and Turner, 1984), and the Edenian of Indiana, U.S.A (Colbath, 1979) provide better-documented comparisons with similarly a good representation of some genera (e.g., *Aremoricanium*, *Baltisphaeridium*, *Goniosphaeridium*, *Stellechinatum*) and of *Leiofusa fusiformis*. Reworked Darriwilian acritarchs are observed in this assemblage, which is referred to the basal Late Ordovician (early Caradoc). Reworking, which is also noted in the Taurus area (Fig. 5), persisted during the middle Caradoc to the early Ashgill.

4.2.5. Assemblage TCA2

This interval is proposed for a group of samples from CEY-1 (2308 to 2408 m), DARA-2 (2420 to 2600 m), GIR-1 (2810 and 3200 m), and for core samples of the Diyarbakir area (after revision of the former data: H5 to H7 in well No. 2, and GS6 to GS8 in well No. 3). It is characterised by the abundance of *Baltisphaeridium* and *Orthosphaeridium*, *Ordovicidium*, *Polygonium*, *Stellechinatum* species. *Aremoricanium syryngosagis* and *Fractoricoronula* are relatively frequent. *Enneadikosocheia*, *Nexosarium* sp. and *Pheoclosterium fuscinulaagerum* are less abundant. This assemblage is assigned to the mid-late Caradoc, based on its affinities with Caradoc assemblages from Baltoscandia or North America (Colbath, 1979 and Turner, 1984).

In this interval, reworking of Darriwilian species (e.g., *Barakella fortunata*, *Eponula saccata*, ?*Priscotheca siempreplicata*, ?*Sylvanidium operculatum*) is still important, particularly in

GIR-1, and in core samples from the Diyarbakir area. Among the recycled elements, *Eponula saccata*, and possibly ?*Sylvanidium operculatum*, were reported previously only from the Arenig-early Llanvirn in Bohemia (Vavrdová, 1972 and Vavrdová, 1986).

4.2.6. Assemblage TAS1

This assemblage is characterised in CEY-1 (1928 and 2198 m) and in GIR-1 (2590 to 2680 m) by the influx of new forms among the abundant *Baltisphaeridium*, *Orthosphaeridium* and *Ordovicidium* species already present in assemblage TCA2 (Caradoc). The new taxa, such as *Cheleutochroa gymnobrachiata* or *Poikilofusa spinata*, have their FAD in the Ashgill of North America, in the Sylvan Shale of Oklahoma (Loeblich and Tappan, 1978) and in the Vauréal Formation of Anticosti, Canada (Jacobson and Achab, 1985 and Jacobson, 1987). *Evittia denticulata denticulata* is also not known in the Caradoc. However, some of these species could be caved from younger strata. Jardiné et al. (1974) described *Veryhachium longispinosum* in the uppermost Ordovician of the Algerian Sahara (Gd-1bis, 3912–3919 m; *T. elongata* Zone, Oulebsir and Paris, 1995), but it is also reported from the type Caradoc of Britain (Turner, 1984). *Neoveryhachium carminae*, which is not recorded in older Turkish assemblages (Fig. 10b), extends elsewhere into the upper Caradoc. However, it is more characteristic of the Ashgill. Similar assemblages occur in Morocco (Elaouad-Debbaj, 1988), in Jordan (Keegan et al., 1990), and in Iran (Ghavidel-Syooki, 1990). Strong affinities are also noted with the assemblages of NE Kansas, USA (Wright and Meyers, 1981), and from the Bohdalec shales (upper Berounian) in Bohemia (Vavrdová, 1986). These various data suggest an early Ashgill age for assemblage TAS1.

4.2.7. Assemblage TAS2

It is represented between 1788 and 1858 m in CEY-1, and is characterised by a moderate diversity, with a dominance of the ubiquitous forms such as *Multiplicisphaeridium irregulare*, triapsidate or quadratic veryhachiids, *Villosacapsula irrorata*, abundant netromorphs, cryptospores and possibly freshwater algae with *Moyeria cabottii* (if they are not the result of caving?). This assemblage may indicate a near-shore environment related to a regressive period. It is referred to the middle or late Ashgill.

4.2.8. Assemblage TAS3

It is defined in core samples of the Diyarbakir area (well No. 2, samples H1 and H2; well No. 3, samples GS1 to GS4, and well No.4, samples B1 and B2). In addition, it is identified in CEY-1 at 1698 m. Assemblage TAS3 is characterised (Fig. 10) by abundant netromorphs (*Dactylofusa cucurbita*, *Dactylofusa platynetrella*, *Eupoikilofusa striatifera*, *Poikilofusa spinata*), frequent triapsidate veryhachiids and mature and thick-walled cysts. The well represented *Villosacapsula irrorata/setosapellicula* group coexists with *Veryhachium subglobosum*, some *Multiplicisphaeridium* and *Evittia* species and other acritarchs with Silurian affinity e.g., *Oppilatala* spp., *Tunisphaeridium tentaculiferum* and *Tylotopalla caelamenicutis*. *Striatotheca* sp. A of Molyneux (1988) is here regarded as indicative of the late Ashgill. In agreement with the chitinozoans data (see Fig. 7 and discussion above), assemblage TAS3 is referred to the latest Ordovician. A Hirnantian age is the most likely for this assemblage.

At present, phytoplanktonic assemblages controlled by glacial-interglacial cycles, as have been documented in Algeria (Le Hérissé et al., 2003), are not recognised in the samples available from Turkey. Assemblage TAS3 documents the glacial history of the Hirnantian, including periods of incision of glacial valleys and finally the main melting of the Gondwanan ice cap during the late Hirnantian (Ghienne, 2003, Monod et al., 2003 and Paris et al., 2000a). On northern Gondwana, the glacial erosion of older strata (see Paris et al., 1995) is responsible of the recycling of Early, Middle and Late Ordovician acritarchs, including abundant diacrodians, *Vulcanisphaera* sp., some *Cymatiogalea* spp., *Lusatia dendroidea, Frankea longiuscula*, some *Baltisphaeridium* and *Orthosphaeridium* spp.

5. Conclusions

All the investigated Ordovician formations in southern and southeastern Turkey yield chitinozoans and acritarchs providing useful chronostratigraphic information. The precision of the datings depends greatly on the preservation of the microfossils. However, even in the Taurus Range, where the organic matter is more mature, fairly accurate age assignments in terms of Ordovician Global Stages can be proposed for most of the formations, that is in ascending order, the Seydisehir, Sobova, Kilgen Lake, Bedinan, Sort Tepe and Halevikdere formations (Fig. 11). Many Ordovician chitinozoan biozones from the northern Gondwana zonation have been identified in southern Turkey. Some biozones are very well constrained (e.g., *elongata*, *nigerica*, *fistulosa*, *robusta*, *tanvillensis*, *ponceti*, and *pissotensis* biozones) whereas the characterization of a few others is more tentative (e.g., *deunffi*, and *henryi* biozones). Index species of the Ordovician chitinozoan biozones for Baltica are also identified (e.g., *fungiformis*, *curvata*, and *granulifera* biozones). They provide excellent ties with the Baltoscandian regional chronostratigraphy and, in addition, indicate the existence of efficient marine seaways between Baltica and northern Gondwana from the Middle Ordovician onward.

In some cases, the chronostratigraphic assignment simply confirms or slightly improves previous datings based on macrofossils. In other cases (e.g., Sobova, Kilgen Lake, Halevikdere formations, and the so-called "Bedinan Group") the chitinozoans and/or the acritarchs provide new ages modifying significantly the regional stratigraphical scheme. For instance, middle and Late Darriwilian marine deposits were previously unknown in southern Turkey. The microfossils from the glacio-marine Halevikdere Formation clearly indicate a Hirnantian age for these deposits, which are perfectly synchronous with the other glacially related uppermost Ordovician sediments recorded in northern Gondwana (Ghienne, 2003).

Evidence of acritarch reworking is quite common in the recovered assemblages and concerns Early Ordovician individuals re-deposited during the Middle and the Late Ordovician. They probably originate from neighbouring areas (brief transport as their preservation is generally good) resulting from erosion processes related to tectonics (e.g., block tilting), and/or alternatively with marine transgressive events. The reworking of acritarchs and chitinozoans observed in the Hirnantian glacio-marine sediments has another origin as it is driven by the fall of sea-level and results from subsequent aerial and/or glacial erosion. This glacial reworking affects Early Ordovician taxa as well as Middle and Late Ordovician forms from more remote southern sources (e.g., Arabian Plate, Egypt and Libya; see Fig. 7 in Monod et al., 2003).

In a palaeobiogeographical context, southern Turkey (both the Taurus Range, and the Border Folds) clearly belongs to the northern Gondwana realm, at least as far as the chitinozoans are concerned. The northern Gondwana chitinozoan biozones are documented by their classical components represented from the Maghreb (i.e., Morocco, Algeria, Libya) in the west to Iran in the east, and from the Arabian Plate (i.e., Saudi Arabia, Oman, Emirates) and Niger in the south, to the Iberian Peninsula, Armorican Massif and Bohemia in the north. However, in the Border Folds, the occurrence of chitinozoan species so far exclusively reported in Baltica or Avalonia must be noted since they confirm the existence of counter clockwise marine currents bringing planktonic organisms from lower latitude (Baltica) to higher latitude (northern Gondwana) areas. Such currents, already postulated (see Paris, 1991 and Achab and Paris, 2007), seem more active from the late Darriwilian onward. These changes probably resulted from deep modifications of the oceanic southern gyre generated by the rapid northward drift of Avalonia during the Ordovician (Fortey and Cocks, 2003 and references therein), and its docking to Baltica by Late Ordovician times (Vecoli and Samuelsson, 2001, and references therein). Even if the Gondwanan ice-sheet extended onto southern Turkey during the Hirnantian, the area was probably located at a slightly lower latitudite position than the North-African regions during Late Ordovician times. This is suggested by the occurrence of macrofaunas (e.g. trilobites) showing affinities with Bohemia, and with areas of lower palaeolatitude location such as Baltoscandia, Kazakhstan, Uzbekhistan (Dean et al., 1999, and references).

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Figures

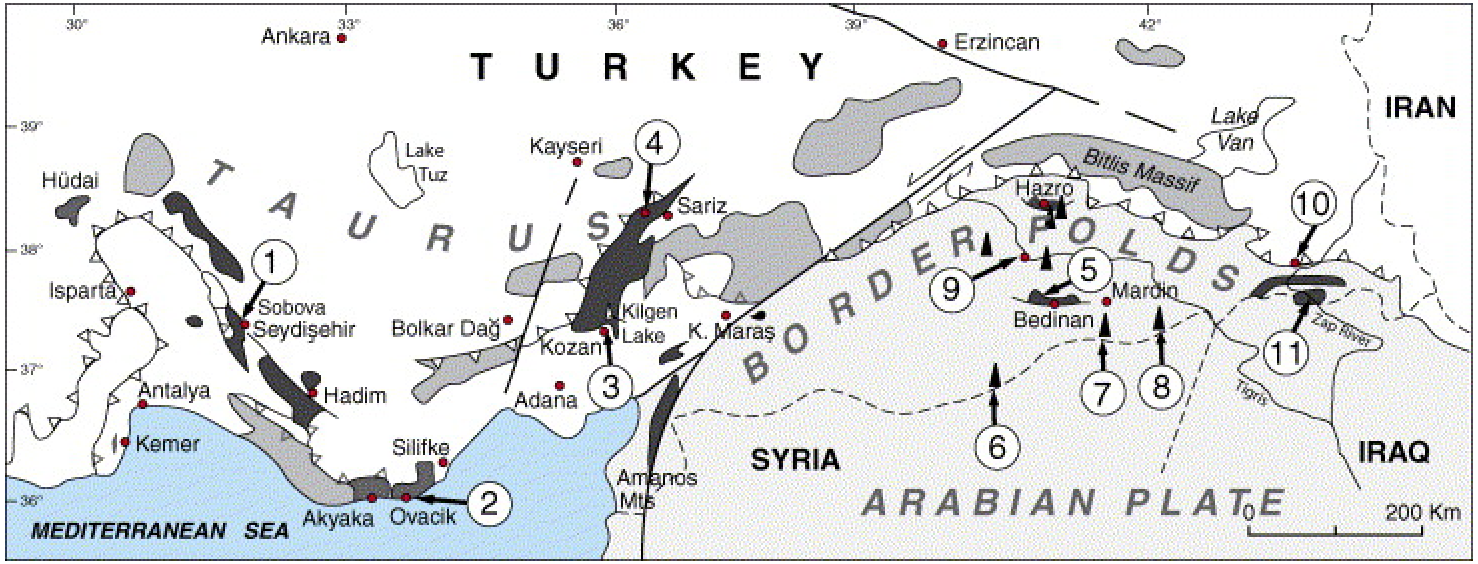


Fig. 1. Schematic map showing the geographical location of the main investigated areas in southeastern Turkey. Grey: metamorphosed Palaeozoic rocks; black: unmetamorphosed Palaeozoic sediments. **1**: Seydisehir, **2**: Ovacik, **3**: Kozan, **4**: Degirmentas, **5**: Derik-Mardin, **6**: Ceylanpinar, **7**: Dara, **8**: Girmelli, **9**: Diyarbakir, **10**: Hakkari, **11**: Sort Tepe.

Fig. 1. Carte simplifiée montrant la position géographique des principales régions étudiées dans le sud-est de la Turquie. Gris : roches métamorphiques paléozoïques ; noir : sediments paléozoïques non affectés par un métamorphisme. **1** : Seydisehir, **2** : Ovacik, **3** : Kozan, **4** : Degirmentas, **5** : Derik-Mardin, **6** : Ceylanpinar, **7** : Dara, **8** : Girmelli, **9** : Diyarbakir, **10** : Hakkari, **11** : Sort Tepe.

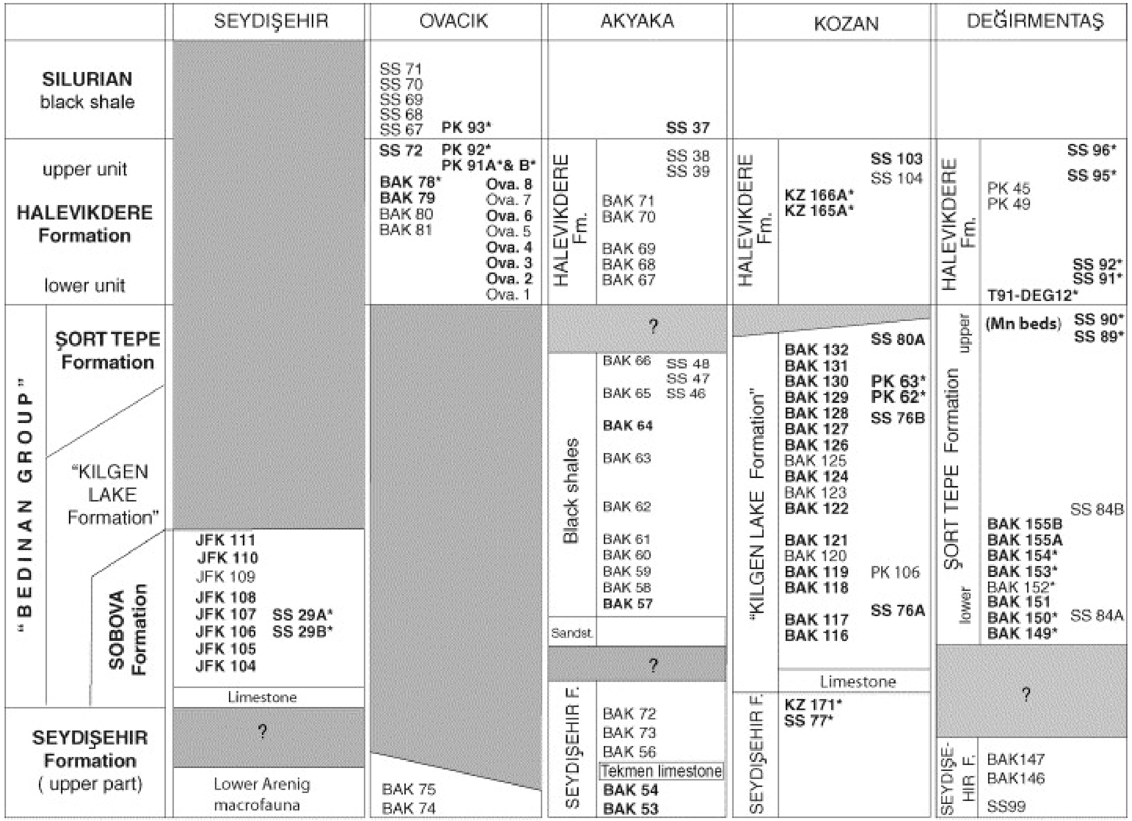


Fig. 2. List of the outcrop samples investigated for their Ordovician organic-walled microfossil content in five regions of the Taurus Range (southern Turkey). The productive samples are in bold, and the asterisk indicates acritarch-bearing samples.

Fig. 2. Liste des échantillons analysés pour leurs microfossiles organiques ordoviciens et provenant d'affleurements de cinq régions du Taurus (sud de la Turquie). Les échantillons fertiles sont en gras ; l'astérisque indique la présence d'acritarches.

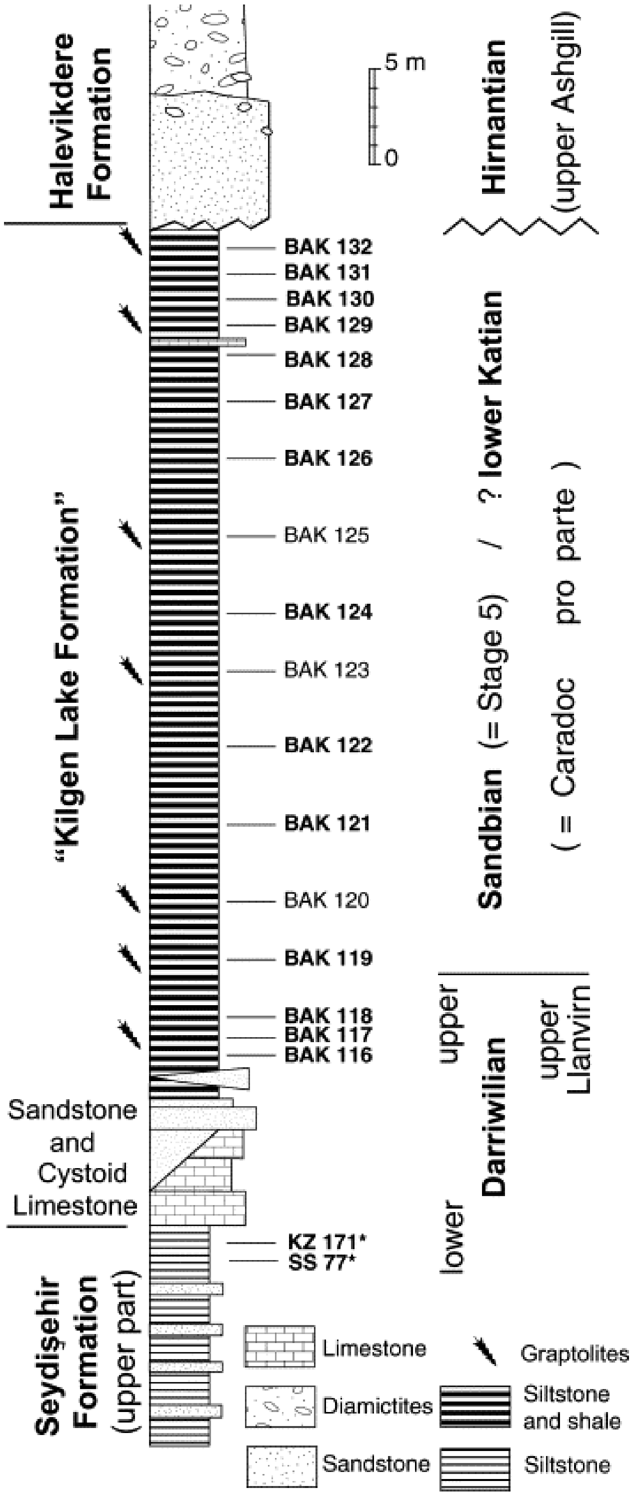


Fig. 3. Lithostratigraphy of the Kilgen Lake section (Kozan area) and location of the studied samples (productive samples are in bold).

Fig. 3. Lithostratigraphie de la coupe de Kilgen Lake (région de Kozan) et position des échantillons analysés (en gras : échantillons fertiles).

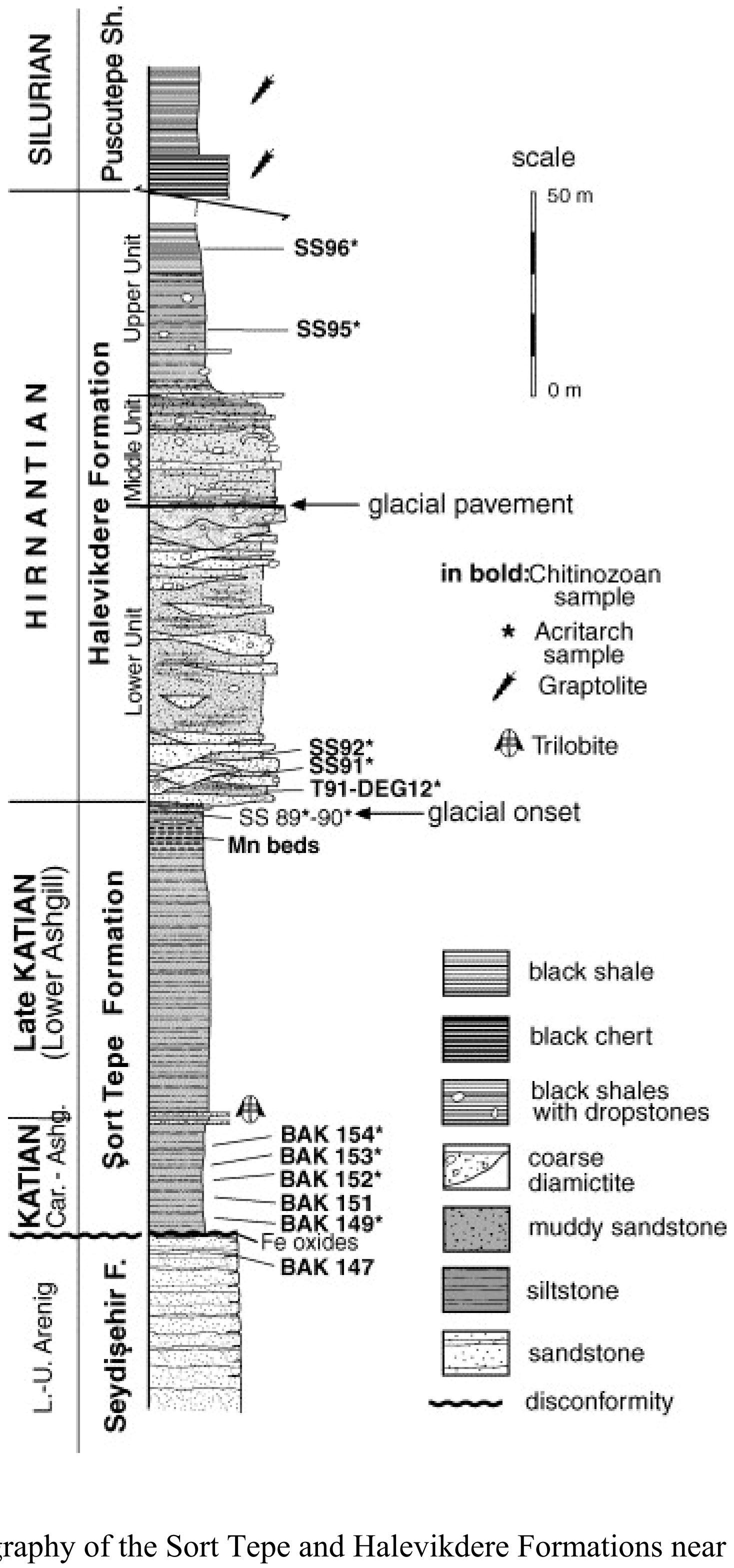


Fig. 4. Lithostratigraphy of the Sort Tepe and Halevikdere Formations near Sariz (Degirmentas section), and location of the studied samples (productive samples are in bold).

Fig. 4. Lithostratigraphie des formations de Sort Tepe et de Halevikdere près de Sariz (régions de Degirmentas) et position des échantillons analysés (en gras : échantillons fertiles).

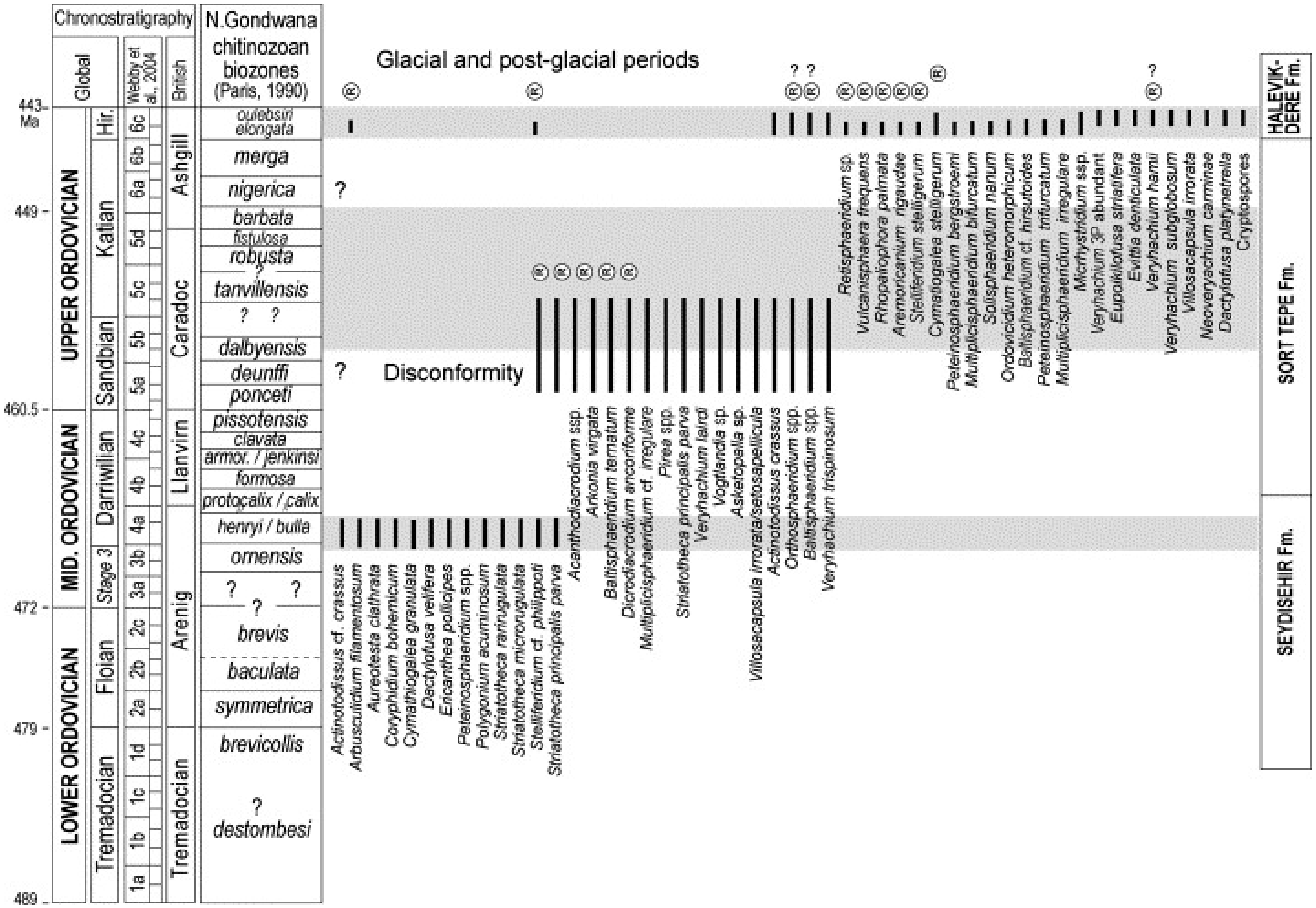


Fig. 5. Distribution and age assignment of selected acritarch species from various localities of the Taurus Range. R: reworked taxa.

Fig. 5. Répartition et âge d'une sélection d'acritarches provenant de diverses localités du Taurus. R : taxon remanié.

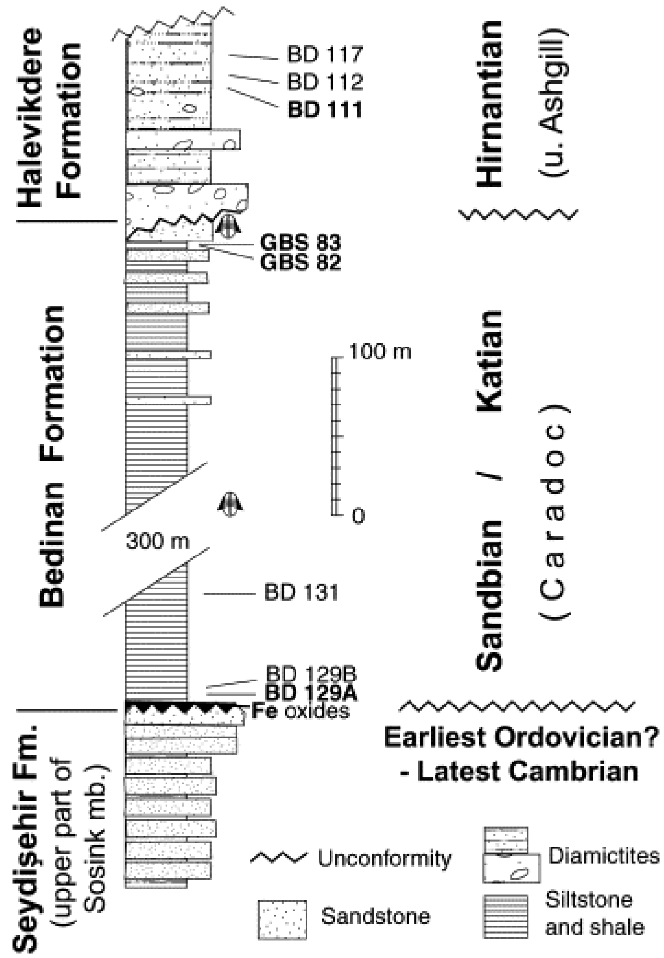


Fig. 6. Schematic composite section of the Derik-Mardin area with the location of the investigated samples (productive samples are in bold).

Fig. 6. Coupe composite simplifiée de la région de Derik-Mardin et position des échantillons analysés (en gras : échantillons fertiles).

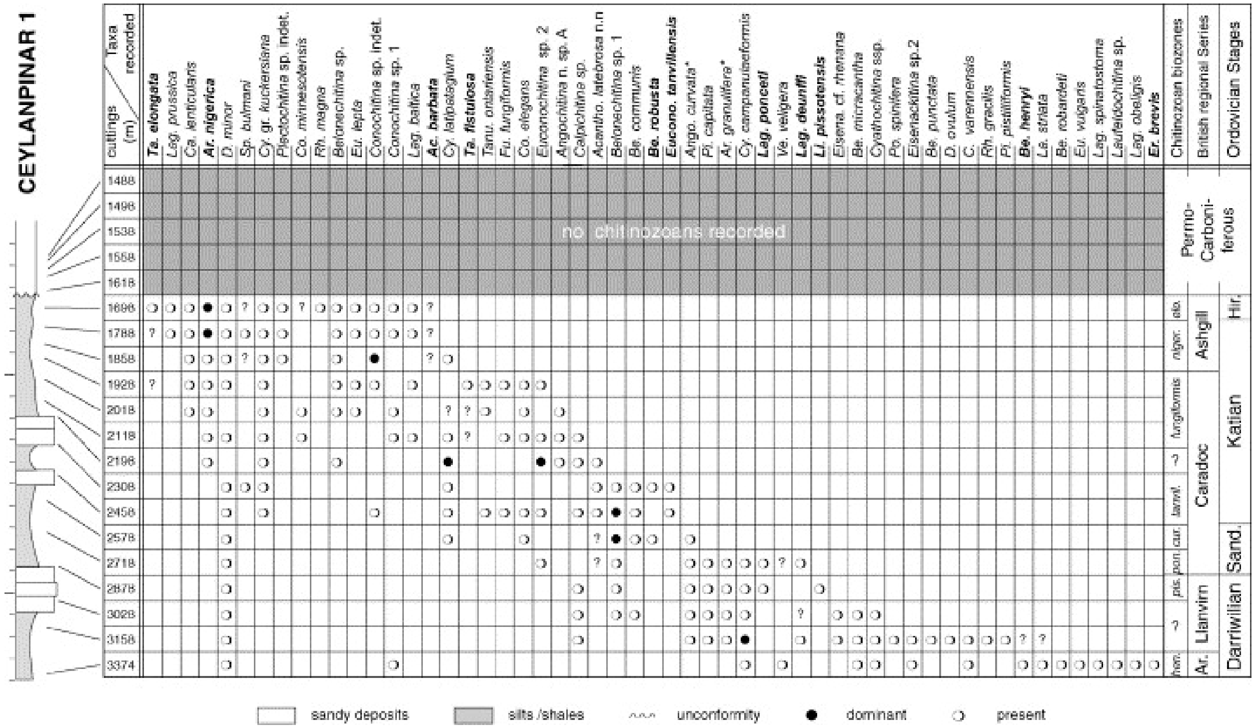


Fig. 7. Range and age assignment of the chitinozoans recovered in well CEYLANPINAR 1. Chitinozoan biozones and chronostratigraphical assignment from **Paris (1990)**, and **Achab and Paris (2007)**. The zonal index species are in bold; the asterisk indicates a Baltoscandian biozone (abbreviations: Sand. = Sandbian; Ar. = Arenig; hen. = *henryi*; pis. = *pissotensis*; pon. = *ponceti*; cur. = *curvata*: elo. = *elongata*).

Fig. 7. Distribution et attribution stratigraphique des chitinozoaires recueillis dans le puits CEYLANPINAR 1. Biozones de chitinozoaires et chronostratigraphie d'après **Paris (1990)** et **Achab et Paris (2007)**. Les espèces index sont en gras ; l'astérisque indique une biozone baltoscandinave (abréviations : Sand. = Sandbien ; Ar. = Arenig ; hen. = *henryi* ; pis. = *pissotensis* ; pon. = *ponceti* ; cur. = *curvata* ; elo. = *elongata*).

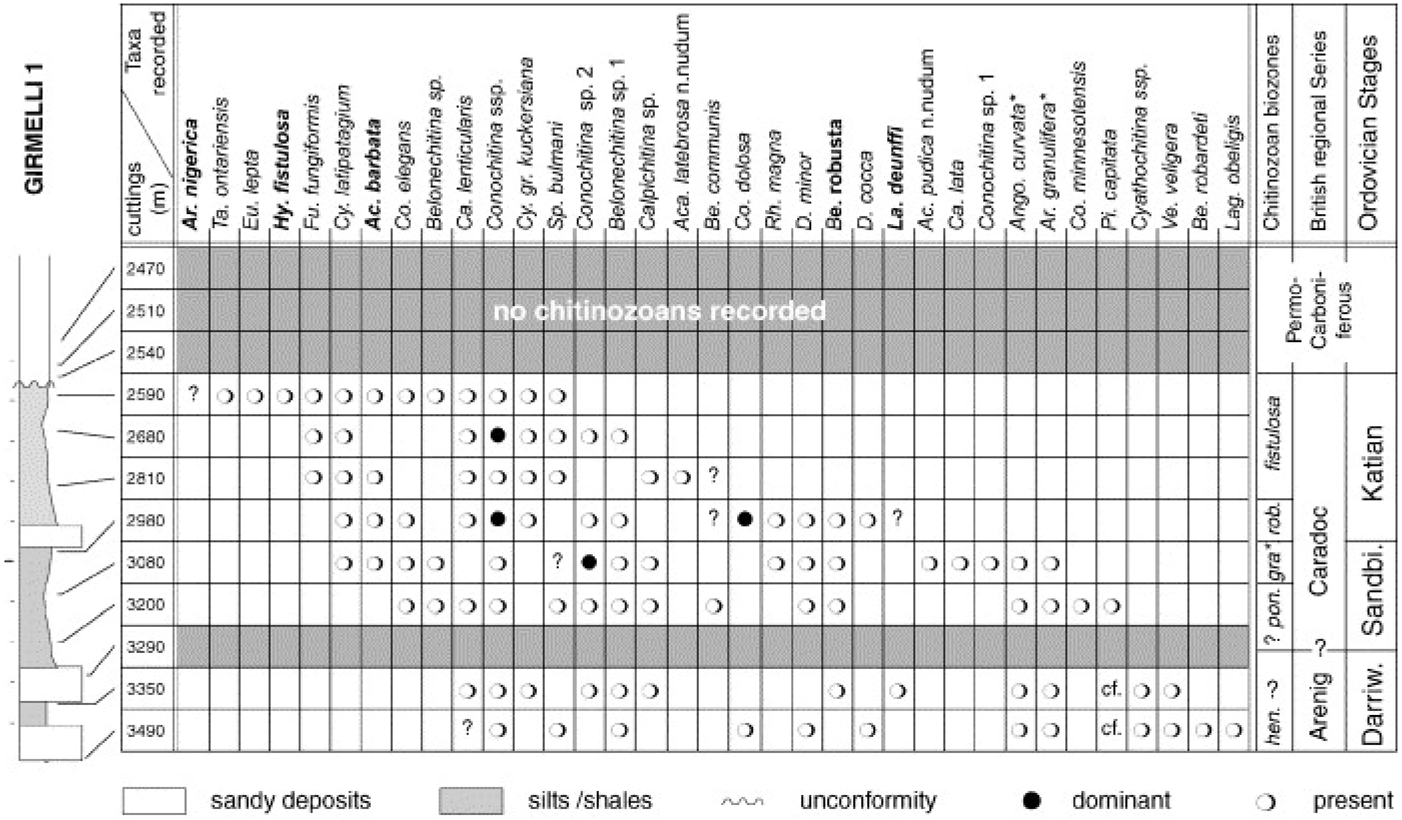


Fig. 8. Range and age assignment of the chitinozoans recovered in well DARA 2. Chitinozoan biozones and chronostratigraphical assignment from **Paris (1990)**, and **Achab and Paris (2007)**. The zonal index species are in bold; the asterisk indicates a Baltoscandian biozone (abbreviations: Sandbi. = Sandbian; pis. = *pissotensis*; pon. = *ponceti*; gra. = *granulata*).

Fig. 8. Distribution et attribution stratigraphique des chitinozoaires recueillis dans le puits DARA 2. Biozones de chitinozoaires et chronostratigraphie d'après **Paris (1990)** et **Achab et Paris (2007)**. Les espèces index sont en gras ; l'astérisque indique une biozone baltoscandinave (abréviations : Sandbi. = Sandbien ; pis. = *pissotensis* ; pon. = *ponceti* ; gra. = *granulata*).

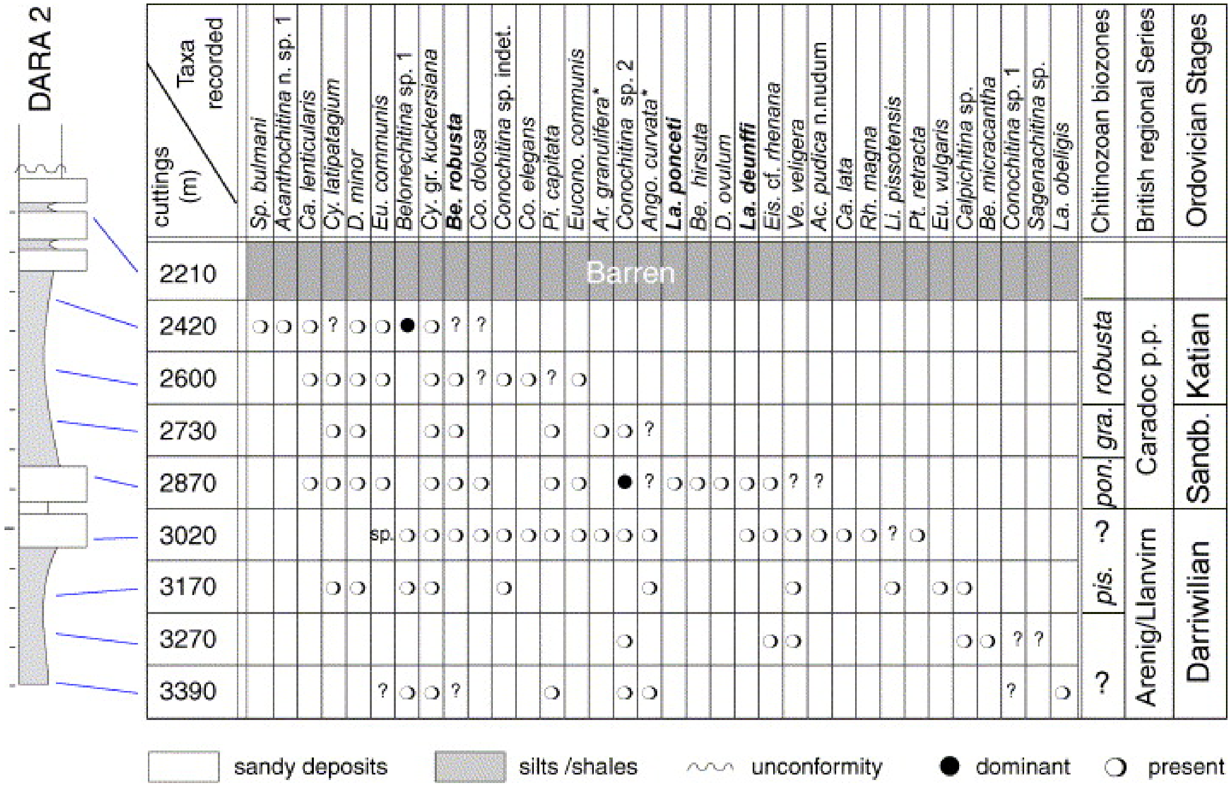
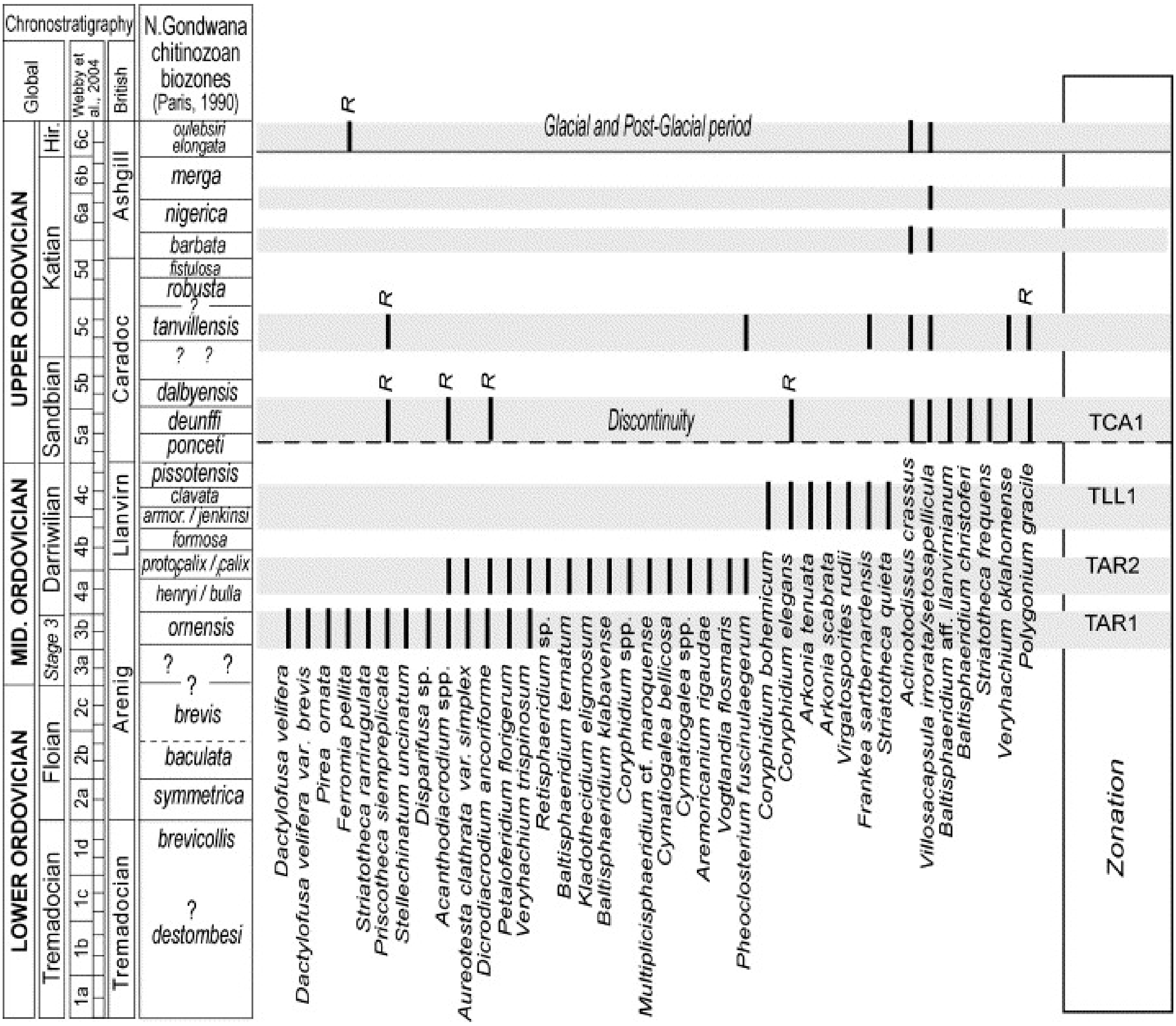


Fig. 9. Range and age assignment of the chitinozoans recovered from well GIRMELLI 1. Chitinozoan biozones and chronostratigraphical assignment from **Paris (1990)** and **Achab and Paris (2007)**. The zonal index species are in bold; the asterisk indicates a Baltoscandian biozone (abbreviations: Darriw. = Darriwilian; Sandbi. = Sandbian; hen. = *henryi*; pon. = *ponceti*; rob. = *robusta*).

Fig. 9. Distribution et attribution stratigraphique des chitinozoaires recueillis dans le puits GIRMELLI 1. Biozones de chitinozoaires et chronostratigraphie d'après **Paris (1990)**, et **Achab et Paris (2007)**. Les espèces index sont en gras ; l'astérisque indique une biozone baltoscandinave (abréviations : Darriw. = Darriwilien ; Sandbi. = Sandbien ; hen. = *henryi* ; pon. = *ponceti* ; rob. = *robusta*).


Chronostratigraphy
Global
Webby et al., 2004
British
N.Gondwana chitinozoan biozones (Paris, 1990)
UPPER ORDOVICIAN
MID. ORDOVICIAN
LOWER ORDOVICIAN
Hir.
Katian
Sandbian
Darriwilian
Stage 3
Floian
Tremadocian
6c
6b
6a
5d
5c
5b
5a
4c
4b
4a
3b
3a
2c
2b
2a
1d
1c
1b
1a
Ashgill
Caradoc
Llanvirn
Arenig
Tremadocian
oulebsiri
elongata
merga
nigerica
barbata
fistulosa
robusta
tanvillensis
dalbyensis
deunffi
ponceti
pissotensis
clavata
armor. / jenkinsi
formosa
protocalix / calix
henryi / bulla
ornensis
brevis
baculata
symmetrica
brevicollis
destombesi
Glacial and Post-Glacial period
Discontinuity
R
Dactylofusa velifera
Dactylofusa velifera var. brevis
Pirea ornata
Ferromia pellita
Striatotheca rarirrugulata
Priscotheca siempreplicata
Stellechinatum uncinatum
Disparifusa sp.
Acanthodiacrodium spp.
Aureotesta clathrata var. simplex
Dicrodiacrodium ancoriforme
Petaloferidium florigerum
Veryhachium trispinosum
Retisphaeridium sp.
Baltisphaeridium ternatum
Kladothecidium eligmosum
Baltisphaeridium klabavense
Coryphidium spp.
Multiplicisphaeridium cf. maroquense
Cymatiogalea bellicosa
Cymatiogalea spp.
Aremoricanium rigaudae
Vogtlandia flosmaris
Pheoclosterium fuscinulaegerum
Coryphidium bohemicum
Coryphidium elegans
Arkonia tenuata
Arkonia scabrata
Virgatosporites rudii
Frankea sartbernardensis
Striatotheca quieta
Actinotodissus crassus
Villosacapsula irrorata/setosapellicula
Baltisphaeridium aff. llanvirnianum
Baltisphaeridium christoferi
Striatotheca frequens
Veryhachium oklahomense
Polygonium gracile
TCA1
TLL1
TAR2
TAR1
Zonation

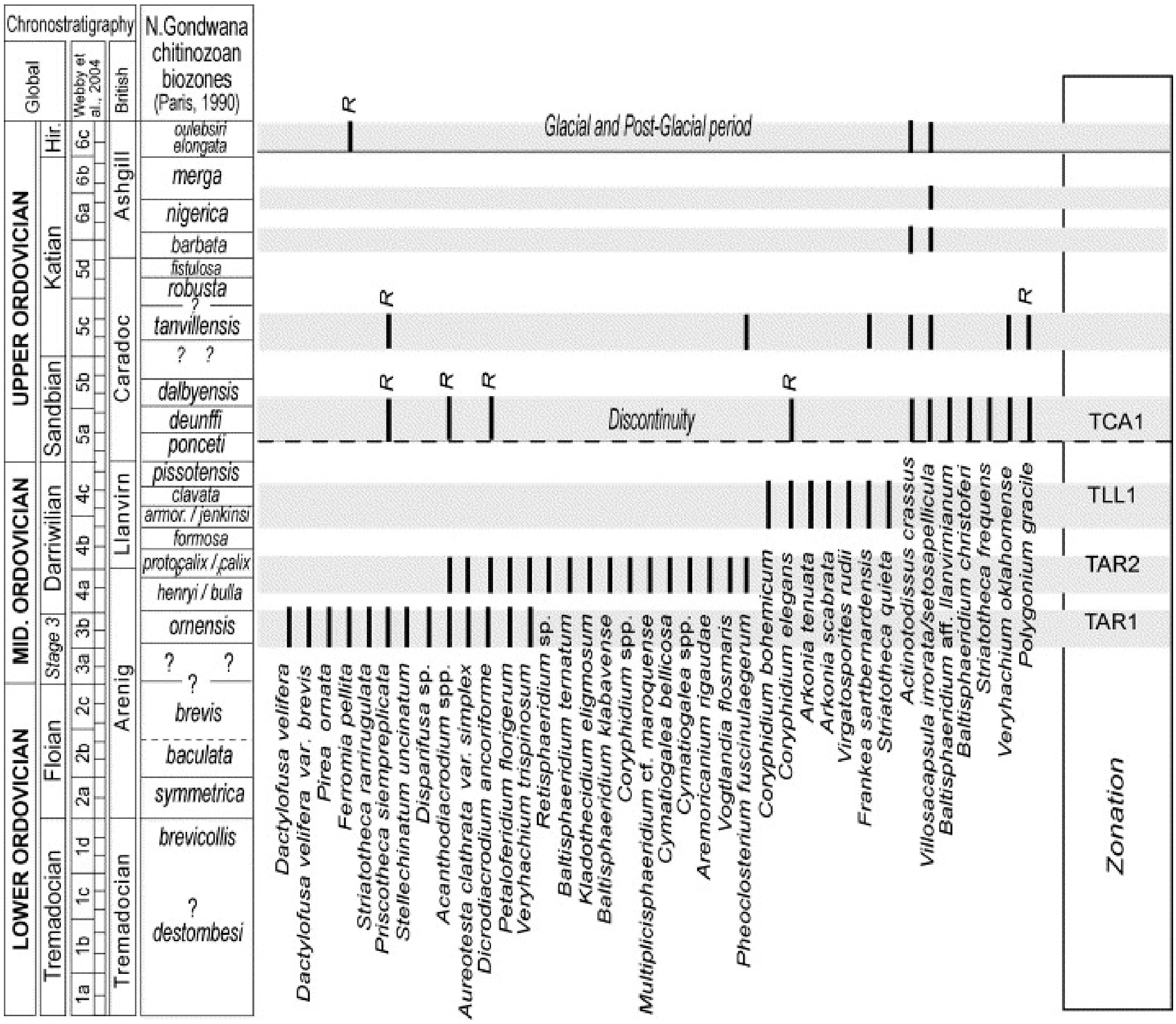


Fig. 10. (a, b) Distribution and age assignment of selected acritarch species from the subsurface of the Border Folds. R: reworked taxa; C: caved. **(a)**: Mid and Early Late Ordovician forms. **(b)**: Late Ordovician forms.

Fig. 10. (a, b) Distribution et attribution stratigraphique d'une sélection d'espèces d'acritarches des « Border Folds ». R : taxon remanié ; C : retombée. **(a)** : formes de l'Ordovicien Moyen et du début de l'Ordovicien Supérieur. **(b)** : formes de l'Ordovicien Supérieur.

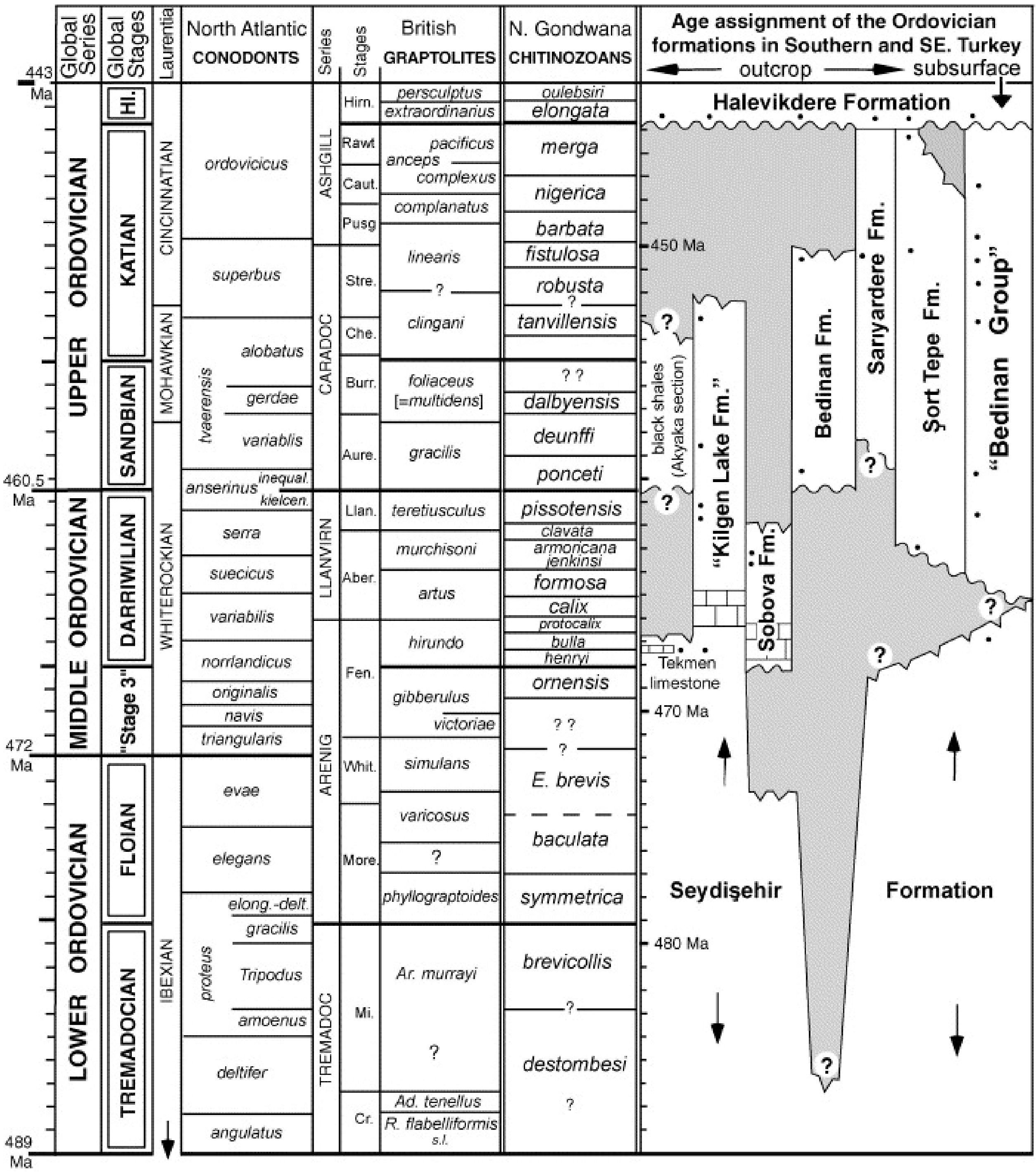


Fig. 11. Chronostratigraphy, biostratigraphic scales for conodonts, graptolites and chitinozoans (based on **Webby et al., 2004**) and tentative location of the Ordovician formations of southern and southeastern Turkey. Black dots indicate the position of the main assemblages discussed in the text. The Sariyardere Formation (**Senel, 1997**), south of Kemer, is dated as Late Ordovician (Caradoc-Ashgill) by its macrofauna (Dean personal communication) and by the organic walled microfossils from BDK 120. Broken and wavy

lines represent respectively erosion surfaces and disconformities (abbreviations: Hi.: Hirnantian; British regional stages: see **Fortey et al., 2000**).

Fig. 11. Chronostratigraphie, biozones de conodontes, de graptolites et de chitinozoaires (d'après **Webby et al., 2004**) et essai de positionnement des formations ordoviciennes du sud et du sud-est de la Turquie. Les points noirs matérialisent la position des assemblages de microfossiles discutés dans le texte. L'âge Ordovicien Supérieur (Caradoc-Ashgill) de la Formation de Sariyardere (**Senel, 1997**), au sud de Kemer, est fixé par sa macrofaune (Dean, communication personnelle) et par les microfossiles organiques de BDK 120. Les lignes brisées et ondulées symbolisent respectivement les surfaces d'érosion et les discordances. (Abréviations : Hi : Hirnantien ; pour les étages régionaux britanniques, voir **Fortey et al., 2000**

Plates

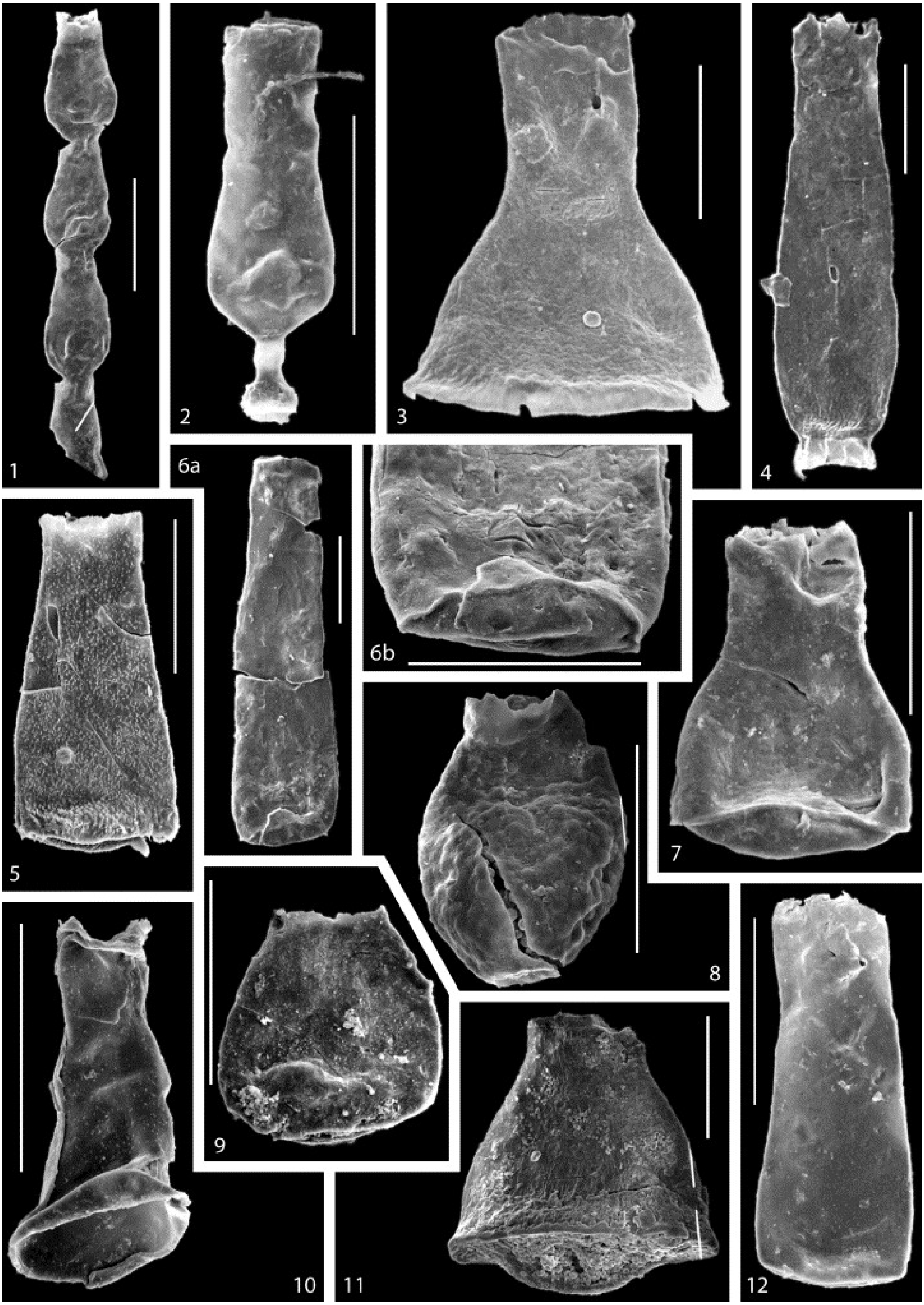


Plate 1. **Figs. 1, 2**. *Linochitina pissotensis* **<u>Paris, 1981</u>**; sample BAK 118, late Darriwilian (= Llandeilian); *pissotensis* chitinozoan biozone (lower part). **Fig. 3**. *Cyathochitina campanulaeformis* Eisenack, 1931; sample BAK 118, late Darriwilian (= Llandeilian); *pissotensis* chitinozoan biozone (lower part). **Fig. 4**. *Laufeldochitina clavata* Jenkins, 1967; sample BAK 118, late Darriwilian (= Llandeilian); *pissotensis* chitinozoan biozone (lower part). **Fig. 5**. *Belonechitina* gr. *micracantha* Eisenack, 1931; sample BAK 118, late Darriwilian (= Llandeilian); *pissotensis* chitinozoan biozone (lower part). **Fig. 6a,b**. *Tanuchitina* sp. aff. *ontariensis* Jansonius, 1964, (carina probably eroded); sample BAK 123, Early Late Ordovician, Sandbian (Caradoc p.p.). **Fig. 7**. *Cyathochitina* sp.; sample BAK 124, Early Late Ordovician, Sandbian (Caradoc p.p.). **Fig. 8**. *Desmochitina* gr. *minor* Eisenack, 1931; sample BD 111 (Late Ordovician, Hirnantian). **Fig. 9**. ?*Eisenackitina* sp.; sample BAK 125, Early Late Ordovician, Sandbian (Caradoc p.p.). **Fig. 10**. *Belonechitina* sp. indet.; sample BAK 124, Early Late Ordovician, Sandbian, Caradoc p.p. **Fig. 11**. *Cyathochitina kuckersiana* (Eisenack, 1934); sample BAK 125, Early Late Ordovician, Sandbian (Caradoc p.p.). **Fig. 12**. *Conochitina* sp.; sample BAK 131, Early Late Ordovician, early Katian (Caradoc p.p.). All the specimens are housed in the collections of the Institut de Géologie de Rennes (IGR). The chitinozoans illustrated on Figs. 1–7 and 9–12 are from the Kilgen Lake, Fire station (south) section, Kozan area, Taurus Range, SE Turkey; specimen on Fig. 8 is from the Derik-Mardin area, Border Folds, SE Turkey. The scale bar represents 100 microns.

Planche 1. **Fig. 1, 2**. *Linochitina pissotensis* **<u>Paris, 1981</u>** ; échantillon BAK 118, « station incendie » (sud), « Formation de Kilgen Lake », Darriwilien supérieur (= Llandeilien) ; partie inférieure de la biozone à *pissotensis*. **Fig. 3**. *Cyathochitina campanulaeformis* Eisenack, 1931 ; échantillon BAK 118, « station incendie » (sud), « Formation de Kilgen Lake », Darriwilien supérieur (= Llandeilien) ; partie inférieure de la biozone à *pissotensis*. **Fig. 4**. *Laufeldochitina clavata* Jenkins, 1967 ; échantillon BAK 118, « station incendie » (sud), « Formation de Kilgen Lake », Darriwilien supérieur (= Llandeilien) ; partie inférieure de la biozone à *pissotensis*. **Fig. 5**. *Belonechitina* gr. *micracantha* Eisenack, 1931 ; échantillon BAK 118, « station incendie » (sud), « Formation de Kilgen Lake », Darriwilien supérieur (= Llandeilien) ; partie inférieure de la biozone à *pissotensis*. **Fig. 6 (a,b)**. *Tanuchitina* sp. aff. *ontariensis* Jansonius, 1964 ; échantillon BAK 123, « station incendie » (sud), « Formation de Kilgen Lake ». Partie inférieure de l'Ordovicien Supérieur, Sandbien, Caradoc p.p. (carène probablement érodée). **Fig. 7**. *Cyathochitina* sp. ; échantillon BAK 124, « station incendie » (sud), « Formation de Kilgen Lake ». Partie inférieure de l'Ordovicien Supérieur, Sandbien, Caradoc p.p. **Fig. 8**. *Desmochitina* gr. *minor* Eisenack, 1931 ; échantillon BD 111 (Ordovicien Supérieur, Hirnantien). **Fig. 9**. ?*Eisenackitina* sp. ; échantillon BAK 125, (Partie inférieure de l'Ordovicien Supérieur, Sandbien, Caradoc p.p.). **Fig. 10**. *Belonechitina* sp. indet. ; échantillon BAK 124 (Partie inférieure de l'Ordovicien Supérieur, Sandbien, Caradoc p.p.). **Fig. 11**. *Cyathochitina kuckersiana* Eisenack, 1934 ; échantillon BAK 125 (Partie inférieure de l'Ordovicien Supérieur, Sandbien, Caradoc p.p.). **Fig. 12**. *Conochitina* sp. ; échantillon BAK 131 (Partie inférieure de l'Ordovicien Supérieur (Katien inférieur, Caradoc p.p.). Les spécimens figurés sont déposés dans les collections of l'Institut de Géologie de Rennes (IGR). Les chitinozoaires illustrés sur les Figs. 1–7 et 9–12 proviennent de la Formation de Kilgen Lake », coupe de la « station incendie sud » du Lac de Kilgen (région de Kozan, Taurus, SE de la Turquie) ; le spécimen de la Fig. 8 provient de la Formation de Halevikdere, coupe de Sosink-Bedinan (région de Derik-Mardin, « Border Folds », SE de la Turquie). La barre-échelle mesure 100 microns.

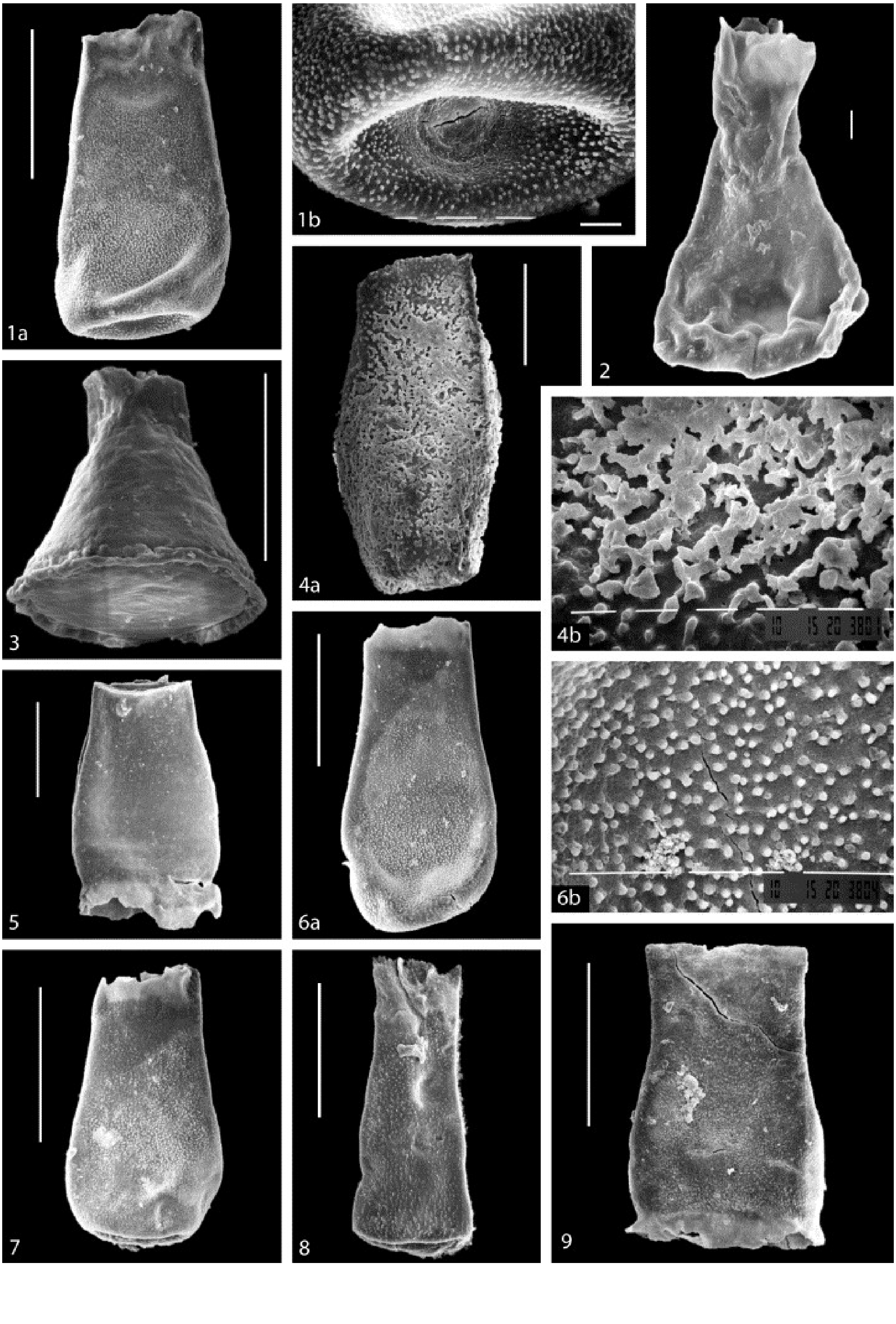

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Plate 2. **Figs. 1 (a,b), 6 (a,b), 7**. *Belonechitina* n. sp. 1. **Fig. 2**. *Euconochitina lepta* Jenkins, 1970. **Fig. 3**. *Cyathochitina* gr. *kuckersiana* Eisenack 1934. **Fig. 4 (a,b)**. *Acanthochitina* cf. *barbata* Eisenack, 1934. **Fig. 5, 9**. *Armoricochitina nigerica* Bouché, 1965. **Fig. 8**. *Hercochitina* sp. All the specimens are the Sosink-Bedinan section (Derik-Mardin area, Border Folds, SE Turkey). They are housed in the collections of the Institut de Géologie de Rennes (IGR). Specimens on Figs. 1–7, 9 are from sample BD 111, Halevikdere Formation, Late Ordovician, Hirnantian. Specimen on Fig. 8 is from sample BD 129A, Bedinan Formation, Early Late Ordovician, Sandbian, (Caradoc p.p.). The scale bar represents 100 microns, excepted for Figs. 1 (b), 2, 4 (b) and 6 (b) where it represents 10 microns.

Planche 2. **Fig. 1 (a,b), 6(a,b), 7**. *Belonechitina* n. sp. 1. **Fig. 2**. *Euconochitina lepta* Jenkins, 1970. **Fig. 3**. *Cyathochitina* gr. *kuckersiana* Eisenack, 1934. **Fig. 4 (a,b)**. *Acanthochitina* cf. *barbata* Eisenack, 1934. **Fig. 5, 9**. *Armoricochitina nigerica* Bouché, 1965. **Fig. 8**. *Hercochitina* sp. Tous ces chitinozoaires proviennent de la coupe de Sosink-Bedinan (région de Derik-Mardin, « Border Folds », SE de la Turquie). Ils sont déposés dans les collections de l'Institut de Géologie de Rennes (IGR). Les exemplaires des Figs. 1–7, 9 proviennent de l'échantillon BD 111, Formation de Halevikdere, Ordovicien Supérieur, Hirnantien. Le spécimen de la Fig. 8 provient de l'échantillon BD 129A, Formation de Bedinan, Ordovicien Supérieur précoce, Sandbian, (Caradoc p.p.). La barre-échelle mesure 100 microns sauf pour les Figs. 1 (b), 2, 4(b) et 6 (b) où elle représente 10 microns.

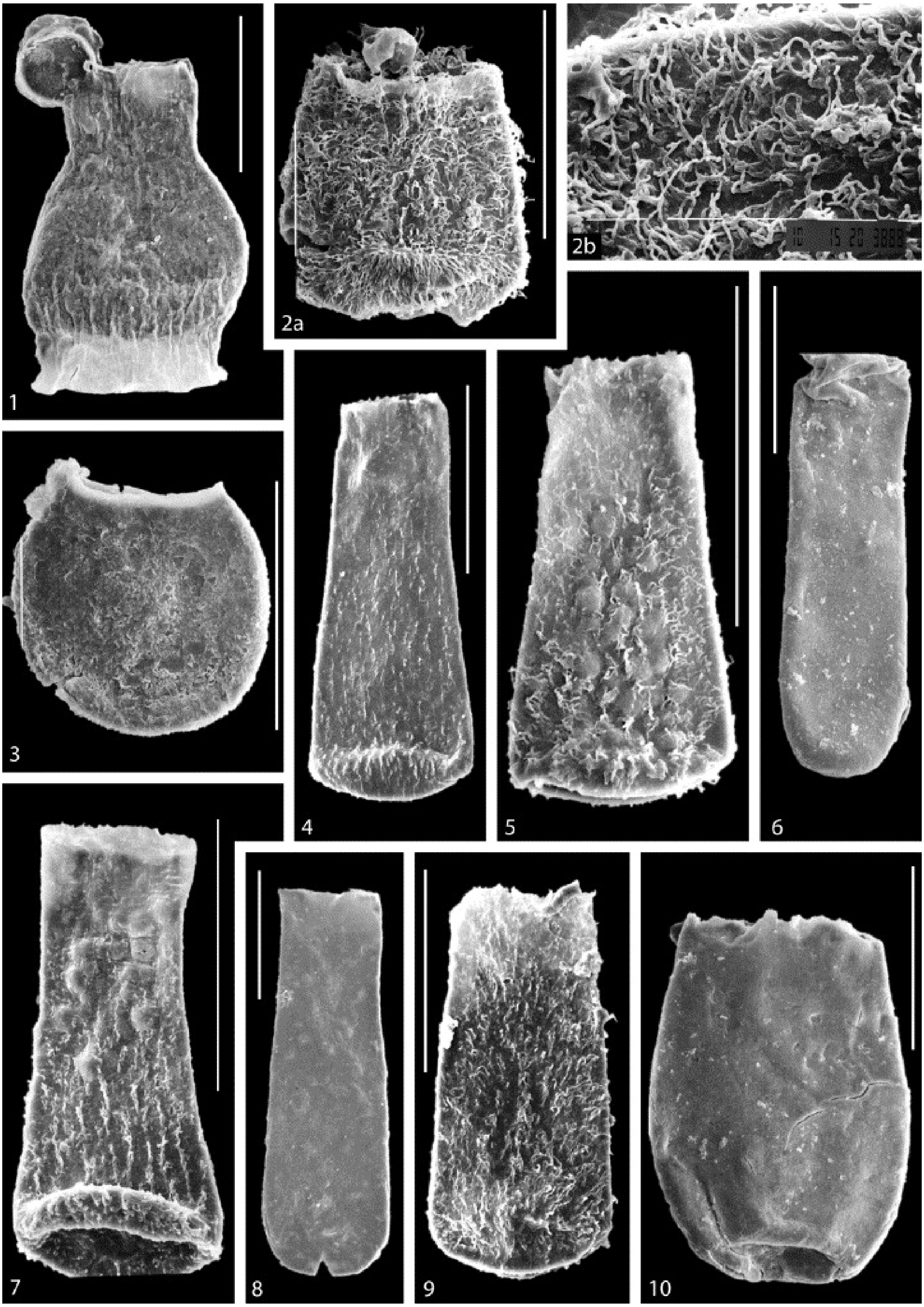
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Plate 3. **Fig. 1**. *Armoricochitina granulifera* **Nõlvak and Grahn, 1993**. **Fig. 2 (a,b)**. *Kalochitina* sp. nov. aff. *multispinata* (Jansonius, 1964). **Fig. 3**. *Desmochitina minor* Eisenack, 1931. **Figs. 4, 5, 7, 9**. *Hercochitina* sp. aff. *spinetum* Melchin and Legault, 1985. **Figs. 6, 10**. *Conochitina* sp. **Fig. 8**. *Conochitina dolosa* Laufled, 1967. All the specimens are the Sosink-Bedinan section (Derik-Mardin area, Border Folds, SE Turkey). They are housed in the collections of the Institut de Géologie de Rennes (IGR). Specimens on Figs. 1–5, 7–9 are from sample BD 129A, Bedinan Formation, Early Late Ordovician, Sandbian, (Caradoc p.p.). Specimens on Figs. 6 and 10 are from sample BD 111 Halevikdere Formation, Late Ordovician, Hirnantian. The scale bar represents 100 microns, except for Fig. 2 (b) where it represents 10 microns.

Planche 3. **Fig. 1**. *Armoricochitina granulifera* **Nõlvak et Grahn, 1993**. **Fig. 2 (a,b)**. *Kalochitina* sp. nov. aff. *multispinata* Jansonius, 1964. **Fig. 3**. *Desmochitina minor* Eisenack, 1931. **Fig. 4, 5, 7, 9**. *Hercochitina* sp. aff. *spinetum* Melchin et Legault, 1985. **Fig. 6, 10**. *Conochitina* sp. **Fig. 8**. *Conochitina dolosa* Laufled, 1967. Les chitinozoaires illustrés proviennent de la coupe de Sosink-Bedinan (région de Derik-Mardin, « Border Folds », SE de la Turquie). Ils sont déposés dans les collections de l'Institut de Géologie de Rennes (IGR). Les exemplaires des Figs. 1–5, 7–9 proviennent de l'échantillon BD 129A, Formation de Bedinan, Ordovicien Supérieur précoce, Sandbian, (Caradoc p.p.). Les spécimens des Figs. 6 et 10 proviennent de l'échantillon BD 111, Formation de Halevikdere, Ordovicien Supérieur, Hirnantien. La barre-échelle mesure 100 microns sauf pour la Fig. 2b où elle représente 10 microns.

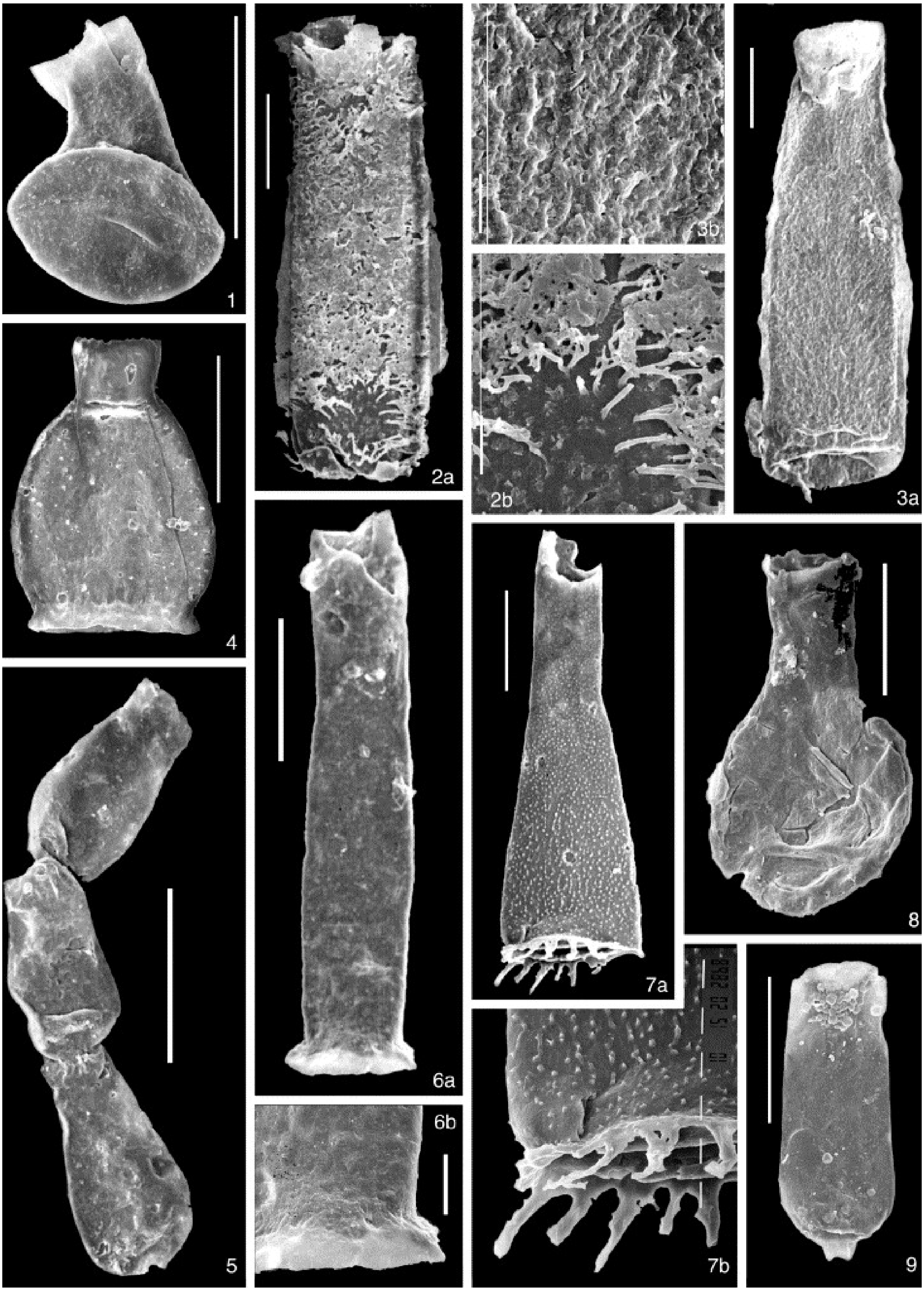
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Plate 4. **Fig. 1**. *Fungochitina fungiformis* Eisenack, 1931; well CEYLANPINAR 1, cuttings from 2018 m, “Bedinan Group”, Late Ordovician, Katian (early Ashgill). **Figs. 2 (a,b), 3 (a,b)**. *Acanthochitina barbata* Eisenack, 1931; well GIRMELLI 1, cuttings from 2590 m, “Bedinan Group”, Late Ordovician, middle part of the Katian (earliest Ashgill). **Fig. 4**. *Armoricochitina granulifera* **Nõlvak and Grahn, 1993**; well CEYLANPINAR 1, cuttings from 2878 m; “Bedinan Group”, Sandbian species (earliest Idavere Baltoscandian regional stage) in all likelihood caved from the Early Late Ordovician strata. **Fig. 5**. *Linochitina pissotensis* **Paris, 1981**; well CEYLANPINAR 1, cuttings from 2878 m, “Bedinan Group”, Late Middle Ordovician, late Darriwilian (late Llanvirn, i.e., Llandeilian). **Figs. 6 (a,b)**. *Hyalochitina fistulosa* Taugourdeau and de Jekhowsky, 1960; well CEYLANPINAR 1, cuttings from 1928 m, “Bedinan Group”, Late Ordovician, middle part of the Katian (latest Caradoc/earliest Ashgill). 6 (b): detail of the carina. **Figs. 7 (a,b)**. *Pogonochitina spinifera* Taugourdeau, 1961; well CEYLANPINAR 1, cuttings from 3158 m; specimen in all likelihood caved from the “Bedinan Group”, Late Middle Ordovician, late Darriwilian (late Llanvirn, i.e., Llandeilian). **Fig. 8**. *Lagenochitina obeligis* **Paris, 1981**; well DARA 2, cuttings from 3390 m, ?Seydisehir Formation, early Middle Ordovician, Early Darriwilian (late Arenig?). **Fig. 9**. *Eremochitina brevis* Benoît and Taugourdeau, 1961; well CEYLANPINAR 1, cuttings from 3374 m, ?Seydisehir Formation, Early Middle Ordovician, early Darriwilian (late Arenig). These specimens from the subsurface of the Border Folds (SE Turkey) are housed in the collections of the Institut de Géologie de Rennes (IGR). The scale bar represents 100 microns, excepted for Figs. 2 (b), 3 (b), 6 (b) where it represents 20 microns, and 7 (b) where it represents 10 microns.

Planche 4. **Fig. 1**. *Fungochitina fungiformis* Eisenack, 1931 ; puits CEYLANPINAR 1, déblais de forage à 2018 m, « Groupe de Bedinan » (Ordovicien Supérieur, Katian, Ashgill inférieur). **Fig. 2 (a,b), 3 (a,b)**. *Acanthochitina barbata* Eisenack, 1931 ; puits GIRMELLI 1, déblais de forage à 2590 m, « Groupe de Bedinan » (Ordovicien Supérieur, partie moyenne du Katian, Ashgill basal). **Fig. 4**. *Armoricochitina granulifera* **Nõlvak et Grahn, 1993** ; puits CEYLANPINAR 1, déblais de forage à 2878 m ; « Groupe de Bedinan », Sandbian (probablement retombé de l’Ordovicien Supérieur). **Fig. 5**. *Linochitina pissotensis* **Paris, 1981** ; puits CEYLANPINAR 1, déblais de forage à 2878 m ; « Groupe de Bedinan », Ordovicien Moyen tardif, Darriwilien supérieur (Llanvirn supérieur, i.e., Llandeilien). **Fig. 6 (a,b)**. *Hyalochitina fistulosa* Taugourdeau et de Jekhowsky, 1960 ; puits CEYLANPINAR 1, déblais de forage à 1928 m ; « Groupe de Bedinan », Ordovicien Supérieur, partie moyenne du Katien (Caradoc terminal/ Ashgill basal). 6 (b) : détail de la carène. **Fig. 7 (a,b)**. *Pogonochitina spinifera* Taugourdeau, 1961 ; puits CEYLANPINAR 1, déblais de forage à 3158 m ; « Groupe de Bedinan » ; spécimen probablement retombé du « Groupe de Bedinan », Ordovicien Moyen tardif, Darriwilien supérieur (Llanvirn supérieur, i.e., Llandeilien). **Fig. 8**. *Lagenochitina obeligis* **Paris, 1981** ; puits DARA 2, déblais de forage à 3390 m, Formation de Seydisehir ?, Ordovicien Moyen précoce, Darriwilien inférieur (Arenig supérieur ?). **Fig. 9**. *Eremochitina brevis* Benoît et Taugourdeau, 1961 ; puits CEYLANPINAR 1, déblais de forage à 3374 m, Formation de Seydisehir ?, Ordovicien Moyen précoce, Darriwilien inférieur (Arenig supérieur). Ces chitinozoaires provenant de forages des « Border Folds » (SE Turquie) sont déposés dans les collections de l'Institut de Géologie de Rennes (IGR). La barre-échelle mesure 100 microns sauf pour les Figs. 2 (b), 3 (b), 6 (b) où elle représente 20 microns et la Fig. 7 (b) où elle représente 10 microns.

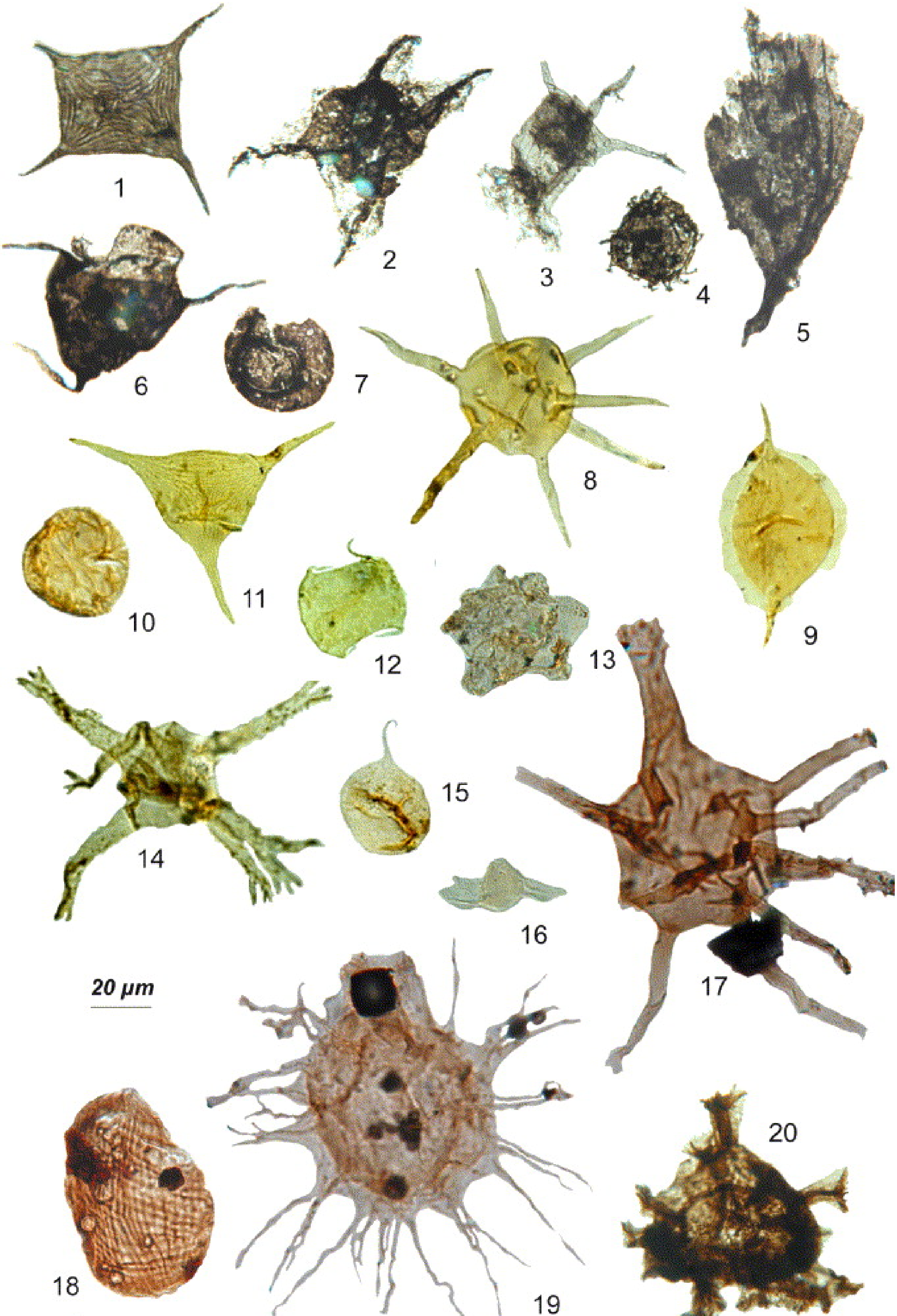
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Plate 5. **Fig. 1**. *Striatotheca principalis parva* Burmann, 1970. Taurus Range, SE Turkey, Kozan section, KZ 171.1, LPB 13047 (H46.1). **Fig. 2**. *Aureotesta clathrata* var. *simplex* **Cramer et al., 1974b** emend Brocke et al., 1998. Taurus Range, SE Turkey, Kozan section, KZ 171.1, LPB 13047 (N45). **Fig. 3**. *Arbusculidium filamentosum* (Vavrdová) **Vavrdová, 1972**. Taurus Range, SE Turkey, Kozan section, KZ 171.1, LPB 13047 (K44.3). **Fig. 4**. *Coryphidium bohemicum* **Vavrdová, 1972**. Taurus Range, SE Turkey, Kozan section, KZ 171.1, LPB 13047 (S44.1). **Fig. 5**. *Dactylofusa platynetrella* (Loeblich and Tappan) Fensome et al. (1990). Taurus Range, SE Turkey, Degirmentas section, top of the Sort Tepe Formation, SS 89, LPB 13048 (032.1). **Fig. 6**. *Veryhachium subglobosum* **Jardiné et al., 1974**. A mature specimen with the excystment released. Taurus Range, SE Turkey, Degirmentas section, base of the Halevikdere Formation SS 92, LPB 13049 (G26.4). **Fig. 7**. *Caldariola glabra* (Martin) Molyneux in Molyneux and Rushton, 1988. **Cramer and Diez (1977)**. Reworked specimen at the top of the Halevikdere Formation, Degirmentas, Taurus Range, SE Turkey, SS 95, LPB 13050 (G42.1). **Fig. 8**. *Cheleutochroa gymnobrachiata* **Loeblich and Tappan, 1978**. Border Folds, SE Turkey, well GIRMELLI 1, 2680 m, LPB 13051 (C44.4). **Fig. 9**. *Dactylofusa velifera* Cocchio, 1982. Border Folds, SE Turkey, well DARA 2, 3170 m, LPB 13052 (M39). **Fig. 10**. *Virgatosporites rudii* Combaz, 1967. Border Folds, SE Turkey, well DARA 2, 3020 m, LPB 13053(M39). **Fig. 11**. *Arkonia tenuata* Burmann, 1970. Border Folds, SE Turkey, well DARA 2, 3020 m, LPB 13053(U34). **Fig. 12**. ?*Priscotheca siempreplicata* Cramer and Diez, 1974b. Border Folds, SE Turkey, well DARA 2, 3020 m, LPB 13053(F41.1). **Fig. 13**. *Enneadikosocheia granulata* **Colbath, 1979**. Border Folds, SE Turkey, well GIRMELLI 1, 3200 m, LPB 13054 (U30.2). **Fig. 14**. *Evittia (= Diexallophasis) denticulata denticulata* (Cramer) Le Hérissé, 1989. Border Folds, SE Turkey, well W1, sample GH3, LPB 13055 (F41.1). **Fig. 15**. *Monocrodium mediterraneum* Pittau, 1985. Border Folds, SE Turkey, core W2, sample H7.2, LPB 13056 (N38.3). **Fig. 16**. *Eponula saccata* **Vavrdová, 1986**. Border Folds, SE Turkey, well GIRMELLI 1, 2980 m, LPB 13057 (E32). **Fig. 17**. *Aremoricanium syringosagis* Loeblich and McAdam, 1971. Border Folds, SE Turkey, well GIRMELLI 1, 2810 m, LPB 13058 (M27). **Fig. 18**. *Moyeria cabotii* (Cramer) emend Miller and Eames, 1982. Border Folds, SE Turkey, well CEYLANPINAR 1, 1788 m, LPB 13059 (K33). **Fig. 19**. *Aremoricanium rigaudae* Deunff, Loelblich and Mac Adam, 1971. Border Folds, SE Turkey, well GIRMELLI 1, 3200 m, LPB 13054 (P43.2). **Fig. 20**. *Peteinosphaeridium* cf. *bergstroemi*. Border Folds, SE Turkey, well CEYLANPINAR 1, 3371 m, LPB 13060 (G22.1). The illustrated acritarchs are stored in the collections of the

Laboratoire de Paléontologie de Brest (LPB) under the reference slide numbers 13047 to 13060.

Planche 5. **Fig. 1**. *Striatotheca principalis parva* Burmann, 1970. Taurus, SE de la Turquie, coupe de Kozan, KZ 171.1, LPB 13047 (H46.1). **Fig. 2**. *Aureotesta clathrata* var. *simplex* (**Cramer et al., 1974b**) emend Brocke et al., 1998. Taurus, SE de la Turquie, coupe de Kozan, KZ 171.1, LPB 13047 (N45). **Fig. 3**. *Arbusculidium filamentosum* (Vavrdová) **Vavrdová, 1972**. Taurus, SE de la Turquie, coupe de Kozan, KZ 171.1, LPB 13047 (K44.3). **Fig. 4**. *Coryphidium bohemicum* **Vavrdová, 1972**. Taurus, SE de la Turquie, coupe de Kozan, KZ 171.1, LPB 13047 (S44.1). **Fig. 5**. *Dactylofusa platynetrella* (Loeblich et Tappan) Fensome et al. (1990). Taurus, SE de la Turquie, coupe de Degirmentas, sommet de la Formation de Sort Tepe, SS 89, LPB 13048 (032.1). **Fig. 6**. *Veryhachium subglobosum* **Jardiné et al., 1974**. Spécimen mature désenkysté. Taurus, SE Turkey, coupe de Degirmentas, base de la Formation de Halevikdere, SS 92, LPB 13049 (G26.4). **Fig. 7**. *Caldariola glabra* (Martin) Molyneux in Molyneux et Rushton, 1988. **Cramer et Diez (1977)**. Spécimen remanié dans le somme de la Formation de Halevikdere, Degirmentas, Taurus, SE de la Turquie, SS 95, LPB 13050 (G42.1). **Fig. 8**. *Cheleutochroa gymnobrachiata* **Loeblich et Tappan, 1978**, « Border Folds », SE de la Turquie, puits GIRMELLI 1, 2680 m, LPB 13051 (C44.4). **Fig. 9**. *Dactylofusa velifera* Cocchio, 1982, « Border Folds », SE de la Turquie, well DARA 2, 3170 m, LPB 13052 (M39). **Fig. 10**. *Virgatosporites rudii* Combaz, 1967, « Border Folds », SE de la Turquie, puits DARA 2, 3020 m, LPB 13053(M39). **Fig. 11**. *Arkonia tenuata* Burmann, 1970, « Border Folds », SE de la Turquie, puits DARA 2, 3020 m, LPB 13053(U34). **Fig. 12**. ?*Priscotheca siempreplicata* Cramer et Diez, 1974b, « Border Folds », SE de la Turquie, puits DARA 2, 3020 m, LPB 13053(F41.1). **Fig. 13**. *Enneadikosocheia granulata* **Colbath, 1979**, « Border Folds », SE de la Turquie, puits GIRMELLI 1, 3200 m, LPB 13054 (U30.2). **Fig. 14**. *Evittia (= Diexallophasis) denticulata denticulata* (Cramer) Le Hérissé, 1989. « Border Folds », SE de la Turquie, puits W1, échantillon GH3, LPB 13055 (F41.1). **Fig. 15**. *Monocrodium mediterraneum* Pittau, 1985. « Border Folds », SE de la Turquie, puits W2, échantillon H7.2, LPB 13056 (N38.3). **Fig. 16**. *Eponula saccata* **Vavrdová, 1986**. « Border Folds », SE de la Turquie, puits GIRMELLI 1, 2980 m, LPB 13057 (E32). **Fig. 17**. *Aremoricanium syringosagis* Loeblich et McAdam, 1971. « Border Folds », SE de la Turquie, puits GIRMELLI 1, 2810 m, LPB 13058 (M27). **Fig. 18**. *Moyeria cabotii* (Cramer) emend Miller et Eames, 1982. « Border Folds », SE de la Turquie, CEYLANPINAR 1, 1788 m, LPB 13059 (K33). **Fig. 19**. *Aremoricanium rigaudae* Deunff, Loelblich et Mac Adam, 1971. « Border Folds », SE de la Turquie, puits GIRMELLI 1, 3200 m, LPB 13054 (P43.2). **Fig. 20**. *Peteinosphaeridium* cf. *bergstroemi.* « Border Folds », SE de la Turquie, puits CEYLANPINAR 1, 3371 m, LPB 13060 (G22.1). Les acritarches figurés sont conservés dans les collections du Laboratoire de Paléontologie de Brest (LPB) sous les numéros de lame 13047 à 13060.