# Foraminifers in the Holkerian Stratotype, regional substage in Britain: key taxa for the Viséan subdivision

**Pedro Cózar[1], Ian D. Somerville[2], Mark W. Hounslow[3]**

**Author Affiliations.**

[1] Instituto de Geociencias (CSIC-UCM), c/ Severo Ochoa 7, 28040 Madrid, Spain; p.cozar@igeo.ucm-csic.es

[2] UCD School of Earth Sciences, University College Dublin, Ireland; ian.somerville@ucd.ie

[3] Lancaster Environment Centre, Lancaster University, Lancaster, UK. LA1 4YW and Earth, Ocean and Ecological Sciences, University of Liverpool, Jane Herdman Building, Liverpool, L69 3GP; mark.w.hounslow@gmail.com

**Corresponding Author.** Pedro Cózar; Instituto de Geociencias (CSIC-UCM), c/ Severo Ochoa 7, 28040 Madrid, Spain; p.cozar@igeo.ucm-csic.es

**Abstract.** Foraminiferal revision of the Holkerian Stratotype of Britain at Barker Scar, Holker Hall, south Cumbria, UK, allows the subdivision of the section into the Cf4δ, Cf5α and Cf5β subzones (the latter being further subdivided into a lower Cf5β1 and upper Cf5β2 intervals). The base of Cf5α subzone at the base of bed C and base of Cf5β subzone from the middle part of bed C, occur at 14 m and 10.5 m, respectively, below the traditional basal boundary of the Holkerian at bed K. The lower boundaries of these foraminiferal subzones occur within the main interval affected by dolomitization in the section, which poses problems in defining precisely the bases for these subzones.

Nevertheless, in spite of the dolomitization, a more or less continuous foraminiferal record allows a solid correlation of the base of the Cf5β with the preserved succession in the Livian Substage (defined in Belgium, but also used in France), and it is assumed that the base of this substage should correspond to the base of the Cf5α subzone. The base of the Cf5α can be correlated with the base of the Russian Tulian Substage, since it contains many taxa in common with the Holkerian. However, further investigation is needed to establish other levels of correlation (e.g., base of the Cf5β subzone) higher up in the Holkerian substage.

All of these problems suggest that the Holkerian, as it is currently recognised, and the Barker Scar stratotype section, in particular, should be reconsidered, and a new para-stratotype section, ideally devoid of dolomitization, should be located and investigated, in order to corroborate the occurrence of the Cf5α and Cf5β foraminiferal subzones compared to those recognised in the Barker Scar Stratotype. These modifications would allow identification of an apparent synchronous faunal event forming the basis of a future subdivision of the Viséan.

**Keywords**. biostratigraphy; endothyrids; Mississippian; middle Viséan; Cumbria

## 1. Introduction

The base of the Holkerian Stratotype was defined by George et al. (1976) at the junction of the Dalton Beds and the Park Limestone at Barker Scar (between beds J and K) (Figs. 1, 2), Holker Hall, south Cumbria, UK [SD 3330 7827 British National Grid; Supplementary Fig. S1]. It was defined to coincide with a change from predominant dark grey/brownish limestones into creamy limestones. Johnson et al. (2001) elevated these limestone units to formation status in their analysis of the Ulverston region of south Cumbria (Fig. 1). These authors proposed to define the base of the Park Limestone at the base of bed J, which although of dark grey colour, shows less-conspicuous stratification, more typical of the Park Limestone Formation than the underlying Dalton Formation (Fig. 2). Recently, Waters et al. (in press), have suggested to reposition the base of the Park Limestone at the base of bed P, and considering the new data presented here, moved the base of the Holkerian to an intermediate position within bed C. The Holkerian has been largely used in Britain as one of the stages in the Dinantian, and the International Commission on Stratigraphy ratified its inclusion as a regional subdivision of the Carboniferous, as a substage of the Viséan (Heckel and Clayton 2006), a fact admitted in the British literature (Holliday and Molineux 2006).

Since the original definition by George et al. (1976), the validity of the Viséan stratotypes defined in Britain has been questioned by many authors (e.g., Riley 1993; Cossey et al. 2004; Waters 2011), and the Holkerian Barker Scar section is the only Viséan section that has not been revised in detail since the published field guide of Ramsbottom (1981) and the work of Strank (1981). In contrast, the Chadian, Arundian, Asbian and Brigantian stratotypes (Fig. 1) have been revised in more recent times (cf.

Simpson and Kalvoda, 1987; Riley 1994; Cózar and Somerville 2004; Aretz and Nudds 2005; McLean et al. 2018).

Diagnostic macrofauna of the Holkerian include the brachiopods *Davidsonina carbonaria* (McCoy), *Composita ficoidea* (Vaughan) and *Linoprotonia corrugatohemisphaerica* (Vaughan), the corals *Axophyllum vaughani* (Salée) and *Lithostrotion araneum* (McCoy) (= *Nematophyllum minus* (McCoy)) (Fig. 2), together with the foraminifers *Archaediscus* spp. at concavus stage (cf. Conil et al., 1980) and bilayered palaeotextulariids (George et al. 1976). However, *Composita ficoidea* was recorded from beds E, F and I, in the Arundian part of the section (Fig. 2). Riley (1993) suggested the occurrence of a non-sequence in the succession, due to the apparent absence of the '*Cyrtina* (=*Davidsonina*) *carbonaria* beds' of Garwood (1913), as well as for the absence of precursors of the corals intermediate in character between *Siphonodendron* and *Lithostrotion*. Conil et al. (1980) assigned the Cf5 foraminiferal zone to the Holkerian and correlated it also with the Livian in Belgium. Ramsbottom (1981) and Strank (1981) considered a similar suite of macrofauna in recognizing the Holkerian, but they added the foraminifers *Koskinotextularia*, abundant *Nibelia* (=*Pojarkovella*) *nibelis* (Durkina), *Holkeria* and *Dainella*? *holkeriana* Conil and Longerstaey as the main guides for the recognition of this substage. However, these are a general list of fauna, and in most cases, their first occurrences do not coincide exactly with the basal beds of the Holkerian. Rose and Dunham (1977) presented a section with limestone beds labelled with letters from bed a up to bed l, later relabelled by Ramsbottom (1981) in capitals letters and including more beds in the upper part of the section, from A to Z (Fig. 2). Nevertheless, the foraminiferal evidence presented by Ramsbottom (1981) was limited to beds A to L. However, looking at the vertical stratigraphic distance from the base of the Holkerian at bed K, some samples labelled as bed L are located up to 30 m above the base of bed L, which corresponds to bed X. The database in Ramsbottom (1981) originated from the work of Strank (1981), where the foraminiferal data and distribution were discussed in more detail. However, Strank (1981) apparently studied three different sets of thin sections, but only one set appears to have been documented in the biostratigraphic table in Ramsbottom (1981, p. 3.5). Strank (1981) in her description of the stratotype section also illustrated samples from 'Old Park Wood Quarry' (See Supplementary Fig. S1) covering some 12 m of the Park Limestone Fm- Urwick Limestone Fm boundary, and she illustrated some foraminifers in her thesis that are not included in the stratigraphic distribution of the foraminifers in the region. Thus, the foraminiferal record in the upper part of the Barker Scar section is somewhat confusing. In addition, as highlighted by Cózar et al. (2020), apparently, there are typical Holkerian taxa in the Arundian part of the section, including *Archaediscus* at concavus stage, *Lituotubella* and *Omphalotis minima* (Rauzer-Chernousova and Reitlinger). Cózar et al. (2020) considered that the older occurrence of those taxa allowed the subdivision of the Cf5 Zone into a lower Cf5α subzone (and defined a new suite of foraminifers) and an upper Cf5β subzone (characterised by the classical markers for the Cf5 *Koskinotextularia-nibelis* Zone recorded in Conil et al. 1980).

The correlation of the Holkerian with the Livian regional substage in Belgium has been traditionally accepted (Poty and Hance, 2006), although Cózar et al. (2020) only recognized foraminifers of the Cf5β subzone in the preserved limestones of the Lives Formation in the Lives section. Foraminifers of the Cf5α subzone were not recognized, and it could be assumed that they should be represented in the basal bentonite and overlying dolomite beds, located in the lower 14 m of the Lives Formation. Furthermore, foraminifers described in Western Europe do not allow a clear correlation with the regional substages in Russia, and the Tulian has been commonly correlated with the Livian or Holkerian in the past (e.g., Conil et al. 1977), and more currently (Alekseev 2009; Davydov et al. 2012; Aretz et al. 2020). However, as demonstrated in Cózar et al. (2020), the likely equivalence of the Tulian and Holkerian needs to be further investigated, whereas, owing to the absence of data at the base of the Livian, this correlation can never be proved nor supported biostratigraphically. The importance of establishing precise correlations between these regional substages is important for the informal subdivision of the Viséan in Western Europe into lower, middle and upper divisions.  As numerous authors have claimed (e.g., Poty et al. 2014), the Viséan Stage represents a large time interval (*c*. 17 Myr sensu Aretz et al. 2020), and there is a developing trend to formally define much shorter and distinctive time units useful for global correlations. The Holkerian, as representative of the middle Viséan in Western Europe, is included at the base of the upper Viséan in Russia, where the Viséan is informally subdivided only into lower and upper Viséan intervals (e.g., Reitlinger et al. 1996). Hence, it is necessary to establish precise correlations between these regional substages to enable possible formal subdivisions, such as the middle Viséan, or base of the upper Viséan to be recognised. Moreover, the stratigraphic interval analysed in this study provides a clear opportunity for potential subdivision~~s~~ of the Viséan for the future.

Owing to these inconsistencies and the potential relevance of this stratigraphic interval, a new sampling campaign from the Barker Scar section was undertaken, in order to clarify the first occurrences of the most important foraminifers, as well as to establish the international correlation of the foraminifers with biozonations in Europe. The main aim of this study is ultimately to assess the validity of Barker Scar as the Holkerian stratotype, and for this, purpose we assesses if the foraminiferal assemblages are representative enough for global correlations, as well as to clarify if the biostratigraphical and lithostratigraphical units can be consistently identified. For this objective, the section has been measured and sampled (at approximately every metre), following a continuous enumeration and metrics from the base of the Dalton Limestone Formation outcrop to Capes Head (Fig. 2), some 800 m south. These samples were primarily collected as part of an ongoing regional palaeomagnetic project, but a sub-sample of each was studied here for determining the biostratigraphy. In total, there are *c*. 86 m of limestones in the section (Fig. 2), including 8 m of limestones above bed Z in the log presented by Ramsbottom (1981). Beds D to K are readily apparent from fig 3.6 in Ramsbottom (1981), and C/D, V/W, W/X and Y/Z bed boundaries are still marked on the section. Other beds are estimated from the thickness/description and our log. The bases of beds L to V were determined in our log on the basis of data in Ramsbottom's log on thicknesses and prominent bedding surfaces (Ramsbottom, 1981, p. 3.3). Bed positions A, B and C are revised, based on thicknesses in Rose and Dunham (1977) and major lithological changes we observed. These are documented on photos of the section in supplementary material Fig. S2 and the complete suite of foraminifers recorded are included in supplementary Table S1.

## 2. Foraminiferal assemblages and distribution in Barker Scar

The assemblages in the basal bed and in the overlying bed A are very rich and contain common primitive archaediscids (*Ammarchaediscus*, *Lapparentidiscus*, *Glomodiscus*, *Uralodiscus* and *Conilidiscus*), *Archaediscus* at involutus stage (e.g., *A. eurus* Conil and Longerstaey, *A. vischerensis* Grozdilova and Lebedeva), including also transitional forms between the involutus and concavus stages (e.g. *A. pusillus* Rauzer-Chernousova), and primitive foraminifers ranging from the Tournaisian and lower

Viséan (*Brenckleites*, *Eosinopsis*, *Eoparastaffella*, *Dainella*, *Lysella*, *Paralysella* and *Bessiella*). In addition, the assemblages contain numerous specimens of *Omphalotis*, some of the species ranging up from the Tournaisian, but where it is highlighted, the primitive forms are assigned to *Omphalotis* aff. *minima* (this taxon includes small specimens, but with diameters included as the minimum in the original description), recorded from bed A, and in the same levels, *Lituotubella glomospiroides*? Rauzer-Chernousova first occurs (Figs. 2, 3), which is confirmed higher up in sample BS31 (bed C). Both species occur at equivalent levels where Strank (1981) also recorded them. These horizons are highlighted by common endothyranopsids and *Nodosarchaediscus*. The former family is represented by some species of *Plectogyranopsis* (including *P. moraviae* Conil and Longerstaey), *Latiendothyranopsis* (including *L. menneri solida* Conil and Lys), *Cribranopsis fossa* Conil and Longerstaey, as well as the ancestral forms of *Endothyranopsis* aff. *compressa* (Rauzer-Chernousova and Reitlinger) (which includes smaller specimens and with thinner septa than the nominal species). The genus *Nodosarchaediscus* is represented by up to 5 species, as well as many oblique sections, including species with many whorls presenting nodes and occlusion.

These assemblages contain most of the taxa considered as markers for the Cf4δ or MFZ11γ subzone sensu Cózar et al. (2020), where the only missing taxon is the primitive palaeotextulariid *Consobrinellopsis*, that is recorded from the upper part of bed C (Fig. 2). Significantly, the mention of bilayered palaeotextulariids by George et al. (1976) has to be considered as erroneous, surely they should have indicated monolayered palaeotextulariids, because, as it is well established in Western Europe, the bilayered genera of this family are widespread in the Asbian and younger strata (Conil et al. 1980). *Archaediscus* at concavus stage is recorded from bed C, and transitional forms from bed A (Fig. 3), and thus, the questionable records of some species typically at concavus stage by Strank (1981), e.g. *A. varsanofievae* Grozdilova and Lebedeva, could be attributed to these transitions and not to the true species recorded higher in the section in bed C.

This Cf4δ or MFZ11γ subzone was assigned to the early Viséan (Cózar et al. 2020), and has been commonly recorded in Arundian rocks of Britain (Conil et al. 1980).

Limestone bed B is a thick unit (c. 12.5 m thick), which is greatly affected by dolomitization (Fig. 2). Some of the samples show destructive dolomitization which does not preserve any original texture or fauna. However, many horizons sampled although partly affected by dolomitization, yielded rather impoverished foraminiferal assemblages. In most samples from bed B, the preserved foraminifers do not differ significantly from the underlying beds, apart from their abundance. The foraminifers would suggest that the Cf4δ/MFZ11γ subzone could be extended to this bed B. It is noteworthy, that many of the most primitive forms have disappeared at the top of this bed (*Paralysella*, *Glomodiscus*, *Conilidiscus*, *Eoparastaffella* and *Pseudolituotubella*), whereas other ancestral forms disappeared in bed A (*Lysella* and *Uralodiscus*).

Bed C, in contrast, is a much thinner limestone (c. 3.5 m thick) with the upper part also affected by destructive dolomitization. The basal sample (BS31) is a well-preserved limestone, and contains a rich assemblage, yielding common *Archaediscus* at involutus stage, transitional forms to the concavus stage and *Nodosarchaediscus*, typical foraminifers from the underlying beds.  However, this horizon also contains the first occurrences of *Archaediscus* at concavus stage (including *A. moelleri* Rauzer-Chernousova, *A. krestovnikovi* Rauzer-Chernousova), *Nodosarchaediscus* (*N. pirleti* (Bozorgnia), *N. tchalussensis* (Bozorgnia)) and an ancestral form of *Koskinotextularia* aff. *cribriformis* Eickhoff (Figs. 2-3). The latter taxon is a much more primitive species, having a few paired chambers and a rather rudimentary cribrate aperture, only composed of two apertures in thin-section. The assemblage is assigned to the Cf5α or MFZ12α subzone of Cózar et al. (2020).

In higher samples of bed C, the same *Archaediscus* spp. at concavus stage are recorded, as well as *A. convexus* Grozdilova and Lebedeva (another typical species at concavus stage). However, sample BS33 contains common *Pojarkovella* species (Fig. 2), including smaller and simpler species such as *P. occidentalis* Vachard and Cózar, *P. ketmenica* Simonova and Zub and *P. pura* Simonova, as well as larger *P. honesta* Simonova and *P. nibelis* (Fig. 4). The occurrence, together, of all these species suggests that the smaller and simpler forms should first occur in older levels (as proposed by Cózar et al. 2020), and thus, they should first occur in the Cf5α subzone. According to most authors (e.g., Conil et al. 1977, 1980, 1991; Strank 1981; Kalvoda 2002; Poty et al. 2006), the occurrence of *P. nibelis* allows us to assign bed C to the typical Cf5 or MFZ12 zones, but identified as Cf5β or MFZ12β in Cózar et al. (2020). There is a discrepancy, though, because most of those authors also considered the occurrence of the genus *Koskinotextularia* as a marker of this subzone. However, the species of the genus mentioned and illustrated in the literature are usually more evolved forms, such as *K. cribriformis* and *K. bradyi* (Moeller). However, these well-developed *Koskinotextularia* are only recorded in the younger beds in Barker Scar (top of bed J).

The interval between beds D to the top of bed J is another problem in Barker Scar, because samples from these beds are dolomitized or do not contain important foraminiferal assemblages. At the top of bed J, most of the taxa recorded previously also occur, but additionally, it is noteworthy for the first occurrence of typical *Endothyranopsis compressa* (large specimens with thick wall and septa), *Koskinotextularia bradyi*, and *K. cribriformis* (Fig. 2). Those foraminifers are also typical markers of the middle Viséan elsewhere, and act as guides for the classical Cf5 zone of Conil et al. (1980) (now Cf5β). It must be highlighted that all the taxa described previously are in beds that were considered as Arundian, because the first macrofauna and microfauna assigned previously to the Holkerian were from bed K.

The upper part of bed K is also dolomitized, and taxa previously mentioned in bed J are present, but rare, and even the larger species of *Koskinotextularia* have not been recorded by us. However, Strank (1981) recorded *K. cribriformis* and *P. nibelis* from bed K. Nevertheless, this bed K is noteworthy for the first occurrence of *Holkeria* (another typical marker genus defined in Strank 1981), where *H. avonensis* (Conil and Longerstaey), *H. daggeri* Strank and *H. topleyensis* Strank occur, as well as the first occurrence of *Koskinotextularia obliqua* (Conil and Lys) (Figs. 2, 4).

As mentioned previously, there is a problem with the location of the samples in Ramsbottom (1981) and Strank (1981) from bed L upwards. Fortunately, these authors did not record any biostratigraphically significant foraminifers, except for *Archaediscus karreri* Brady in the uppermost samples, which is a notable latest Asbian to Brigantian species in Britain (Cózar and Somerville 2004). However, it was not illustrated and it could be a misidentification. Strank (1981) illustrated specimens of *Cribrospira mira* Rauzer-Chernousova and *Pseudoendothyra* from the upper part of the Park Limestone in the region, although it is not possible to determine the exact horizon within the stratotype section.

From beds L to S, there is no major change in the fauna, but first occurrences of biostratigraphically significant taxa include *Endostaffella* (*E. fucoides* Rozovskaya from bed L), *Vissarionovella* (*V. holkeriana* from bed N), *Cribrospira*? (from bed N) and *Klubonibelia* (from bed O) (Fig. 2), all of them also markers of the middle Viséan (Conil et al. 1980, 1991; Cózar and Vachard 2001). As discussed in Cózar and Vachard

(2001), *Dainella*? *holkeriana* was transferred to *Vissarionovella* due to the differentiated tectum. In bed O, typical large and evolved forms of *Omphalotis minima* are recorded.

The main change recognised in the Park Limestone Formation is observed from bed T (Fig. 2), where the first occurrence of "*Millerella*" ("*M.*" *excavata* Conil and Lys), several species of *Pseudoendothyra* (*P. struvei* (Moeller), *P*. sp. 1 and *P*. sp. 5) are recorded, as well as *Globoendothyra globula* (Eichwald). In bed U, other evolved species of *Pojarkovella* (*P. evolutica* Simonova and Zub), *Endostaffella* (*E. parva* (Moeller)) and *Lituotubella magna* Rauzer-Chernousova are recorded (Figs. 2, 5). Within this cluster of successive new occurrences, it is difficult to confirm if any of them has biostratigraphic implications for the British zonation because, in general, those species have been used only to recognise the middle Viséan, not any particular interval within the middle Viséan (i.e. lower, middle or upper). The most striking feature is the occurrence of the genus *Pseudoendothyra*, which in many Western Europe biozonations, is used as a guide for the upper part of the early Asbian or Cf6β zone (Conil et al. 1977, 1980, 1991; Poty et al. 2006). However, locally, Strank (1981) and Fewtrell et al. (1981) documented *Pseudoendothyra* from the middle Viséan in Britain and Cózar and Somerville (2020) documented the genus from the preserved top of the Holkerian in the Gower Peninsula (South Wales). The occurrence of *Pseudoendothyra*, with numerous species, is interpreted as an important characteristic at Barker Scar, which surely should be present in other sections of Britain, and which would allow a subdivision of Cf5β, into a lower Cf5β1 interval, characterised by the classical markers of the Cf5 zone, and an upper Cf5β2 interval, characterised by the first occurrence of *Pseudoendothyra* (Fig. 2). This possible subdivision needs to be further examined in other sections in Britain. Other first occurrences recorded in similar levels to those of

*Pseudoendothyra,* are *Archaediscus* spp. transitional forms between the concavus and angulatus stage, *Lituotubella magna*, *Magnitella porosa* Malakhova, *Spinothyra pauciseptata* (Rauzer-Chernousova) and *Globoendothyra globula*, which would need to be further investigated as potential auxiliary markers for defining a possible Cf5β2 subzone.

In spite of the plausible unconformities described by previous authors based on mapping relationships, lithological changes and the apparent absence of some key macrofossils, the foraminiferal succession from the base to top of the Barker Scar section is more or less complete, ranging from the Cf4δ to the Cf5β (Cf5β2?) subzones, and if any unconformities might be present (i.e., at the base of Bed F), they do not seem to be of biostratigraphic significance. The main shortcoming of the Barker Scar section is the large intervals with dolomitized or partly dolomitized carbonates, lacking fossils or yielding impoverished foraminiferal assemblages (e.g. beds B, D-J).

## 3. Arundian-Holkerian boundary reassessment

Utilising the foraminiferal data from this study, the base of the Holkerian, as it is currently understood, should be moved down to a lower horizon, at least to the upper part of bed C (Fig. 2), where prolific *Pojarkovella* species occur, including *P. nibelis*. The lower part of bed C should be equated with the Cf5α subzone and the upper part of bed C to Cf5β subzone of Cózar et al. (2020). However, the poor preservation of foraminifers in the extensively dolomitized bed B does not allow to confirm if the Cf5α subzone could extend further down. Comparatively, the thickness of limestone represented by the Cf5α subzone is very much thinner than the interval represented by the Cf5β subzone (*c.* 4 m versus *c.* 120 m thick in the region).

Riley (1993) proposed the search for a new stratotype section due to the absence of the early Holkerian fauna, up to the occurrence of *Lithostrotion araneum* (= *Nematophyllum minus* subzone sensu Garwood 1913). This 'hiatus' was located at the base of bed I. However, some authors have suggested that this faunal gap in the succession might be a result of dolomitization rather than an actual missing interval (e.g. Cossey et al. 2004). *Lithostrotion araneum* first occurs in bed P, and hence, beds C to O have to be considered as early Holkerian. The dolomitization in beds D-J does not give us detailed foraminiferal records, but the foraminifers recorded do not support the presence of an important hiatus in the succession. In fact, there does not appear to exist any significant biostratigraphic hiatus in the entire section, taking into consideration the more or less continuous foraminiferal record.

Thus, dolomitization has had a marked influence in: (i) defining the base of the Cf5α subzone, due to the poor data in bed B; and (ii) the low number of taxa and individuals from beds C to J. These problems readily suggest that the Holkerian stratotype, apart from some modifications derived from the foraminiferal evidence presented herein, would need a new para-stratotype section to be defined in the region, with better preserved limestones of the Dalton Formation, and more comprehensive foraminiferal records.

Several scenarios can be proposed: (i) To relocate the base of the Holkerian to the base of bed C in Barker Scar (column 2 in Fig. 2), to coincide with the base of Cf5α subzone (sample BS31) to achieve a wider international correlation (although the poorly constrained base of this subzone is a potential problem); (ii) To relocate the base of the Holkerian to the upper part of bed C (sample BS33), to coincide with the Cf5β subzone (column 1 in Fig. 2) (although the dolomitized bed just above also creates a potential drawback); (iii) to search for a para-stratotype section to confirm the evidence resulting from the lower part of the Barker Scar section; or, (iv) to search for a new stratotype section dominated by limestone, to minimize the effect of dolomitization and to show more continuous micro- and macrofaunal successions. Currently we favour scenarios i and iii.

## 4. International correlation of the Holkerian with European substages

A correlation of the Holkerian with the Livian in Belgium was recently suggested by Cózar et al. (2020). There, the guides for the recognition of this substage were proposed earlier by Conil et al. (1977) as *Koskinotextularia* and *Pojarkovella nibelis*, the same as the Cf5 zone. The occurrence of *P. nibelis* was recorded 14.3 m above the base of the Lives Formation, and *Koskinotextularia* much later (Poty and Hance 2006). Unfortunately, this lower 14.3 m of the formation is barren in foraminifers, due to the bentonites of the Banc d'Or de Bachant and completely dolomitized beds, whereas the underlying Neffe Formation contains foraminifers of the Cf4δ subzone. Thus, although the boundary cannot be precisely recognised due to the absence of data, the Cf5α subzone can be approximately correlated with the base of the Lives Formation, and the Cf5β subzone with the non-dolomitized part of the formation, i.e. from 14.3 m upwards (Fig. 6). Nevertheless, the base of the Banc d'Or de Bachant is not a synchronous event, and depending on the section, it also implies parts of the Moliniacian (Poty et al. 2014), a fact corroborated by the absolute ages using zircons by Pointon et al. (2021). The latter authors proposed to search for a new stratotype for the Livian, and thus, owing to the hiatus represented by this bentonite, a precise correlation level with the Cf5α subzone will be never achieved.

In the Moscow Basin, the Tulian is composed of an alternation of shales and limestones, and the latter become more abundant in the upper part. Furthermore, there is an unconformity at the base, and thick basal parts of the succession can be missing (Alekseev 2009). Although numerous studies have been published since the late 1940's with fragmentary records of the Tulian (e.g., Rauzer-Chernousova 1948), the basis for the established foraminiferal guides were summarised by Lipina and Reitlinger (1970), which included this substage within the *Endothyranopsis compressa* Zone. This zone is characterised by the first occurrence of *Endothyranopsis* s.s., *Globoendothyra* s.s., *Lituotubella*, *Mstinia* (as *Haplophragmella*), *Eostaffella*, *Pseudoendothyra* (as *Parastaffella*), *Vissariotaxis exilis* (Vissarionova), *Archaediscus krestovnikovi*, *Archaediscus moelleri* (both species representative of the concavus stage), primitive *Cribrospira* and *Omphalotis minima*. *Vissariotaxis exilis* in Western Europe first occurs in the Asbian (Conil et al. 1980), and it is difficult to know which is exactly the first *Globoendothyra* s.s., when probably they did not consider the subgenus *Globoendothyra* (*Eogloboendothyra*).

Makhlina et al. (1993) also considered as markers for the Tulian: *Palaeotextularia* s.s., *Praeostaffella* (as species of *Endostaffella*), primitive species of *Eostaffellina*, *Magnitella porosa*, *Koskinotextularia*, *Cribrostomum eximium* Moeller and *Eostaffella mosquensis* Vissarionova, as well as other species of *Archaediscus* (which are also at concavus stage). Although some of these species and genera first occur much later in Western Europe (*Palaeotextularia* and *Cribrostomum*), the majority of the described taxa are also guides for the Holkerian in Britain. Surprisingly, *Pojarkovella* ex gr. *nibelis* is only recorded from the upper Viséan Mikhailovian Substage (Makhlina et al. 1993).

Reitlinger et al. (1996) summarised the data mostly from the Moscow Basin and Urals. They considered that in addition to typical markers, the first occurrence of *Lituotubella* from the Bobrikian Substage (Fig. 6), which would coincide with the earlier occurrence in the Dalton Formation in Barker Scar (Fig. 2), and *L. magna* from the Tulian, as well as considering *Archaediscus krestovnikovi,* first occurring rarely from the Bobrikian Substage (as previously considered by Vdovenko et al. 1990), but it is typical of the Tulian Substage. These authors also considered *Globoendothyra globula* as a marker.

More recent studies in the Urals (e.g. Kulagina and Klimenko 2014), contain some of the above-listed taxa for the recognition of the Tulian, but also noteworthy is the occurrence of *Pojarkovella nibelis* from younger beds. These authors also considered *Archaediscus koktjubensis* Rauzer-Chernousova as a marker of the Tulian (Klimenko et al. 2018; Kulagina et al. 2019). In the Urals, there are more continuous carbonate successions, but unfortunately, the foraminiferal assemblages in the Tulian Substage are not as rich as in the Moscow Basin.

The basal boundary of other local substages in Europe do not coincide approximately with the above described substages (e.g., in Ukraine; Poletaev et al. 1990), and with the available data, it is not possible to propose a correlation.

Owing to the fragmentary record of the Tulian in the Moscow Basin and the scarcer data from the Urals, it is not feasible to make a detailed correlation of the Cf5α and Cf5β subzones with the stratigraphic record in Russia. However, the base of the Tulian can be confidently correlated with the base of the Cf5α (Fig. 6) due to the first occurrence of *Koskinotextularia*, *Endothyranopsis* s.s., *Consobrinellopsis* and some species of *Archaediscus* (at concavus stage). The occurrence of species of *Lituotubella*, and *Omphalotis* might be additional potential markers of levels immediately below the base of the Holkerian and Tulian. In contrast, there is no obvious horizon that could be correlated with the Cf5β subzone. Further investigation should be necessary to establish if there is any other potential level of correlation based on the successive first occurrences of the guides for this interval in Russia, Belgium/France and Britain.

In summary, if the Holkerian Substage should have international counterparts, this substage in Britain should be reconsidered, the Cf5α subzone should be the level to redefine the Holkerian Substage, instead of the use of the Cf5β subzone to mark the base. These substantial differences in the definition of the British substages compared to the international chronostratigraphical units are not new, and it has been already demonstrated at other levels (Cózar and Somerville, 2014). As a secondary consideration, due to the poor preservation in bed B at Barker Scar, this section should be supplemented with data from a para-stratotype, to confirm any possible extension of the Cf5α subzone as the base of the Holkerian.

## 5. Conclusions

Foraminiferal revision of the Holkerian Stratotype of Britain at Barker Scar, Holker Hall, south Cumbria, shows much richer assemblages than previously known. These allow the subdivision of the section into the Cf4δ, the Cf5α and the Cf5β subzones (the latter being subdivided into a lower Cf5β1 and upper Cf5β2 intervals). The occurrence in bed C of the Cf5α subzone is c. 14 m below the traditional basal boundary of the Holkerian at bed K, whereas the Cf5β subzone from the upper part of bed C is more than 10 m below the current boundary.  The boundaries of the foraminiferal subzones coincide with the main interval affected by dolomitization in the section, which poses problems in defining the precise bases for these subzones.

In spite of the dolomitization, a more or less continuous foraminiferal record allows a correlation of the base of the Cf5β with the preserved succession in the Livian Substage (defined in Belgium, but also used in France), and it is assumed that the base of this substage should correspond in part to the base of the Cf5α subzone, although it also includes in some sections, part of the Cf4δ subzone. Compared to the Russian Tulian Substage, the base of the Cf5α subzone can be correlated with the base of the Tulian, and although it contains many taxa in common with the Holkerian, further investigation is needed to establish other levels of correlation higher up in the substage.

All these problems suggest that the Holkerian, as it is currently recognised, and the Barker Scar section should be reconsidered, and at least, a para-stratotype section devoid of dolomitization should be investigated, and to re-locate the base of the Holkerian established on the base of the Cf5α foraminiferal subzone (column 2 in Fig. 2). These modifications would allow an apparent synchronous faunal event which would form the basis of a future subdivision of the Viséan.

## 6. Acknowledgements

We would like to thank D. Vachard and C. N. Waters for their constructive comments. PC is grateful to the financial support by the project CGL2016-78738 of the Spanish Ministry of Research and Innovation. MWH was funded by NERC (grant NE/P00170X/1). Vassil Karloukovski, Tereza Kamenikova, David Mindham and Courtney Sprain helped collect the samples. Holker Hall Estate, and Natural England allowed access and permits to collect samples from Barker Scar.

## References

Alekseev, A.S., 2009. Geological setting and Carboniferous stratigraphy of Moscow Basin. In: Alekseev, A.S. Goreva, N.N. (Eds.), Type and reference Carboniferous sections in the south part of the Moscow Basin. Field Trip Guidebook of International Field Meeting of the I.U.G.S. Subcommission on Carboniferous Stratigraphy. Borissiak Paleontological Institute of Russian Academy of Sciences, Moscow, p. 5-12.

Aretz, M., Nudds, J.R., 2005. The coral fauna of the Holkerian/Asbian boundary stratotype section (Carboniferous) at Little Asby Scar (Cumbria, England) and its implications for the boundary. Stratigraphy 2, 167-190.

Aretz, M., Herbig, H.G. and Wang, X.D. 2020. The Carboniferous Period. In: Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G.M. (Eds.), Geologic Time Scale 2020. Elsevier, p. 811-874.

Conil, R., Groessens, E., Pirlet, H., 1977. Nouvelle charte stratigraphique du Dinantien type de la Belgique. Annales de la Société Géologique du Nord 96, 363-371.

Conil, R., Longerstaey, P.J., Ramsbottom, W.H.C., 1980. Matériaux pour l´étude micropaléontologique du Dinantien de Grande-Bretagne. Mémoires de l'Institut de Géologie de l´Université de Louvain 30, 1-187 (imprinted 1979).

Conil, R., Groessens, E., Laloux, M., Poty, E., Tourneur, F., 1991. Carboniferous guide foraminifera, corals and conodonts in the Franco-Belgian and Campine basins. Their potential for widespread correlation. Courier Forschungsinstitut Senckenberg 130, 15-30.

Cossey, P.J, Adams. A.E, Purnell, M.A, Whiteley, M.J., Whyte, M.A., Wright, V.P., 2004. British Lower Carboniferous Stratigraphy. Geological Conservation Review Series 29**.** Joint Nature Conservation Committee, Peterborough, 636 p.

Cózar, P., Somerville, I.D., 2004. New algal and foraminiferal assemblages and evidence for recognition of the Asbian–Brigantian boundary in northern England. Proceedings of the Yorkshire Geological Society 55, 43-65.

Cózar, P., Somerville, I.D. 2014. Latest Viséan-Early Namurian (Carboniferous) foraminifers from Britain: implications for biostratigraphic and glacioeustatic correlations. Newsletters on Stratigraphy 47, 355-367.

Cózar, P., Somerville, I.D. 2020. Foraminifers in upper Viséan–lower Serpukhovian limestones (Mississippian) from South Wales: regional correlation and implications for British foraminiferal zonal schemes. Proceedings of the Yorkshire Geological society 63, pygs2020-009.

Cózar, P., Vachard, D., 2001. Dainellinae Subfam. Nov. (Foraminiferida du Carbonifère infèrieur), révision et nouveaux taxons. Geobios 34, 505-526.

Cózar, P., Vachard, D., Somerville, I.D., Izart, A., Coronado, I., 2020. Lower-Middle Viséan boundary interval in the Palaeotethys: refinements for the foraminiferal zonal schemes. Geological Magazine 157, 513-526.

Davydov, V.I., Korn, D., Schmitz, M.D., Gradstein, F.M., Hammer, O., 2012. Chapter 23: the Carboniferous Period. In: Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G.M. (Eds), The Geologic Time Scale 2012, Elsevier, p. 603-651.

Fewtrell, M.D., Ramsbottom, W.H.C., Strank, A.R.E., 1981. Carboniferous. In: Jenkins, D.G., Murray, J.W. (Eds.), Stratigraphical atlas of fossil Foraminifera. British Micropalaeontological Society Series, Ellis Horwood, Chichester, p. 13-69.

Garwood, E.J., 1913. The Lower Carboniferous succession in the north-west of England. Quarterly Journal of the Geological Society of London 68, 449-572.

Garwood E.J. 1916. The faunal succession in the Lower Carboniferous rocks of Westmorland and north Lancashire. Proceeding of the Geologists Association, 27, 1-43.

George, T.N., Johnson, G.A.L., Mitchell, M., Prentice, J.E., Ramsbottom, W.H.C., Sevastopulo, G.D., Wilson, R.B., 1976. A correlation of Dinantian rocks in the British Isles. Geological Society, London, Special Report **7**, 87 p.

Heckel , P.H., Clayton, G., 2006. The Carboniferous System. Use of the new official names for the subsystems, series and stages. Geologica Acta 4, 403-407.

Holliday, D.W., Molyneux, S.G., 2006. Editorial statement: new official names for the subsystems, series and stages of the Carboniferous System – some guidance for contributors to the Proceedings. Proceedings of the Yorkshire Geological Society 56, 57-58.

IGS, 1979. Geological map of the United Kingdom South at 1:625.000-scale. 3rd edn. Institute of Geological Sciences, Ordenance Survey, Southampton.

Johnson, E.W., Soper, N.J., Burgess, I.C., 2001. Geology of the country around Ulverston. Memoir of the British Geological Survey, Sheet 48 (England and Wales). HMSO, London, 129 p.

Kalvoda, J., 2002. Late Devonian-Early Carboniferous foraminiferal fauna: zonations, evolutionary events, paleobiogeography and tectonic implications. Folia Facultatis scientiarium naturalium Universitatis Masarykianae Brunensis, Geologia 39, 1-213.

Klimenko, T.V., Kulagina E., Gorozhanina, E.N., Kochetova, N.N., Zhernovkova, T.V., 2018. Upper Itkulovo Subformation of the Viséan Stage of the Carboniferous in the South Urals: lithological and paleontological characteristics. In: Puchkov, V.N. (Ed.), Geologiya, poleznyye iskopayemyye i problemy geoekologii Bashkortostana, Urala i sopredel’nykh territoriy. 12-ya Mezhregionalnaya nauchno-prakticheskaya konferentsiya. Ufa, Russian Federation, p. 105-115 (in Russian).

Kulagina, E.I., Klimenko, T.V., 2014. Upper Viséan Foraminiferal assemblages of the Sikaza River on the western Slope of the Southern Urals. In: Geologicheskikh Sbornik Institut Geologii, Ufimski Nauchno Tsentr, 11 Yubileinyi vyp., Ufa, DizainPoligrafServis, p. 48-56 (in Russian).

Kulagina, E.I., Gorozhanina, E.N., Gorozhanin, V.M., Filimonova, T.V., 2019. Upper Viséan and Serpukhovian biostratigraphy and lithofacies of the southeast of the East European Platform. Stratigraphy and Geological Correlation 27, 613-637.

Lipina, O.A., Reitlinger, E.A., 1970. Stratigraphie zonale et paléozoogeographie du Carbonifère inférieur d’après les foraminifères. In: Compte Rendu VI Congrès International de Stratigraphie et Géologie du Carbonifère, Sheffield, vol. 3, p. 1101-1112.

Makhlina, M.Kh., Vdovenko, M.V., Alekseev, A.S., Byvsheva, T.V., Donakova, L.M., Zhulitova, V.E., Kononova, L.I., Umnova, N.I., Chik, E.M., 1993. Nizhnii Karbon Moskovskoi sineklizy i Voronezhskoi anteclizy (Early Carboniferous of the Moscow Synclise and Voronezh anteclise). Rossiiskaya Akademiya Nauk, P Moskovskoe Obshchestvo Ispytatelei Pridory, Komitet po Geologii i Ispolzonalniyu Nedr Pri Pravitelstve Rossiikoi Federalii, Moskva "Nauka", 223 p. (in Russian).

McLean, D., Owens, B., Bodman, D. J., McLean, F. D. (2018). Miospores from the Brigantian stratotype section at Janny Wood, Cumbria. Proceedings of the Yorkshire Geological Society 62, 89-100.

Pointon, M. A., Chew, D. M., Ovtcharova, M., Delcambre, B., Sevastopulo, G. D., 2021. Uranium-lead dates from Livian (middle Viséan) bentonites of the Namur-Dinant Basin, Belgium. Newsletters on Stratigraphy. DOI: 10.1127/nos/2021/0622

Poletaev, V.I., Brazhnikova, N.E., Vasilyuk, N.P, Vdovenko, M.V., 1990. Local zones and major Lower Carboniferous biostratigraphic boundaries of the Donets Basin (Donbass), Ukraine, U.S.S.R. Courier Forchungs-institut Senckenberg 130, 47-59

Poty, E., Hance, L., 2006. Livian. Geologica Belgica 9, 133-138.

Poty, E., Devuyst, F.-X., Hance, L., 2006. Upper Devonian and Mississippian foraminiferal and rugose coral zonations of Belgium and Northern France: a tool for Eurasian correlations. Geological Magazine 143, 829-857.

Poty, E., Aretz, M., Hance, L., 2014. Belgian substages as a basis for an international chronostratigraphic division of the Tournaisian and Visean. Geological Magazine 151, 229-243.

Ramsbottom, W.H.C., 1981. Field guide to the boundary stratotypes of the Carboniferous stages in Britain. Biennial Meeting of the Subcommission of Carboniferous Stratigraphy, Leeds, 110 p.

Rauzer-Chernousova, D.M., 1948. Foraminifera and stratigraphy of Viséan and Namurian stages of central part of Russian Platform and Cis-Urals. Akademiya Nauk SSSR, Trudy Instituta Geologicheskikh Nauk, 62, geologicheskaya seriya 19, 102-142 (in Russian).

Reitlinger, E.A., Vdovenko, M.V., Gubareva, V.S., Shcherbakov, O.A., 1996. European part of the USSR: Lower Carboniferous. In: Wagner, R.H., Winkler Prins, C.F., Granados, L.F. (Eds.), The Carboniferous of the World III, The former USSR, Mongolia, Middle Eastern Platform, Afghanistan and Iran. IUGS Publication No.

33. Instituto Geológico y Minero de España/Nationaal Natuurhistorisch Museum, Madrid, p. 23-54.

Riley, N.J., 1993. Dinantian (Lower Carboniferous) biostratigraphy and chronostratigraphy in the British Isles. Journal of the Geological Society of London, 150, 427-446.

Riley, N.J., 1994. Foraminiferal Biostratigraphy of the Chadian Stage stratotype (Dinantian), Chatburn, Northwest England. Bulletin de la Société belge de Géologie 103, 13-49.

Rose, W.C.C., Dunham, K.C., 1977. Geology and Hematite deposits of South Cumbria. Economic Memoir of the Geological Survey of Great Britain, Sheets 58 and part of 48. HMSO, London, 170 p.

Simpson, J., Kalvoda, J., 1987. Sedimentology and foraminiferal biostratigraphy of the Arundian (Dinantian) stratotype. In: Hart, M.B. (Ed.), Micropalaeontology of Carbonate Environments. British Micropalaeontological Society series. Ellis Horward Ltd, Chicester, p. 226-237.

Strank, A.R.E., 1981. Foraminiferal biostratigraphy of the Holkerian, Asbian and Brigantian stages of the British Lower Carboniferous. Ph.D. Thesis, University of Manchester, Manchester, 391 p. (unpublished).

Vdovenko, M.V., Aisenverg, D.Ye., Nemirovskaya, T.I., Poletaev, V.I., 1990. An overview of Lower Carboniferous biozones of the Russian Platform. Journal of Foraminiferal Research 20, 184-194.

Waters, C. N., 2011. Chapter 2. Definitions of chronostratigraphic subdivisions: geochronology and event stratigraphy. In: Waters, C.N., Somerville, I.D., Jones, N.S., et al. (Eds.), A revised correlation of Carboniferous rocks in the British Isles. The Geological Society, London, Special Report 26, p. 3-10.

Waters, C. N., Burgess, I. C., Cózar, P., Holliday, D. W., Somerville, I. D., in press. Reappraisal of Arundian–Asbian successions of the Great Scar Limestone Group across northern England. Proceedings of the Yorkshire Geological Society.

## Captions

**Fig. 1.** Tournaisian-Viséan sketch-map of Northern England with the location of the Chadian (Chatburn), Holkerian (Barker Scar), Asbian (Little Asby) and Brigantian (Janny Wood) stratotypes. Adapted from IGS (1979).

**Fig. 2.** Log of Barker Scar section showing first occurrences of selected foraminifers and macrofauna (in blue). Letters for the beds according to Ramsbottom (1981). Column 1 (bottom right) is the amended position of the base of the Holkerian as it is currently understood (dashed line below red arrow tip), based on the foraminifers proposed by Ramsbottom (1981), representative of the Cf5β subzone. Column 2 is the position proposed herein for the base of the Holkerian, based on the Cf5α subzone (solid line below blue arrow tip). Column 3 is the correlation with the lower-middle (Moliniacian/Livian) Viséan boundary in Western Europe. Abbreviations: C mud = calcareous mudstone, M = mudstone, W = wackestone, P = packstone, G = grainstone, SST = sandstone, R & D beds = Rose and Dunham (1977) beds.

**Fig. 3.** Selected foraminifers representative of the top Cf4δ and Cf5α subzones. Scale bar = 400 microns except for fig. 1 = 800 microns. **1**) *Lituotubella glomospiroides*? Rauzer-Chernoussova (oblique section), BS11. **2, 3**) *Endothyranopsis* aff. *compressa* (Rauzer-Chernousova and Reitlinger), BS16, BS15. **4**) *Omphalotis* aff. *minima* (Rauzer-Chernousova and Reitlinger), BS11. **5, 6**) *Koskinotextularia* aff. *cribriformis* Eickhoff, BS31, BS40. **7, 8**) *Archaediscus moelleri* Rauzer-Chernoussova (concavus stage),

BS31, BS57. **9**) *Archaediscus operosus* Shlykova (involutus transitional to concavus stage), BS40. **10, 11**) *Archaediscus krestovnikovi* Rauzer-Chernoussova (concavus stage), BS40, BS31. **12, 13**) *Archaediscus* sp. at concavus stage, BS32. **14**) *Archaediscus* aff. *krestovnikovi* (involutus transitional to concavus stage), BS24. **15**) *Archaediscus pusillus* Rauzer-Chernoussova (involutus transitional to concavus stage), BS14.

**Fig. 4.** Selected foraminifers from the lower part of the Cf5β subzone. Scale bar = 400 microns except for fig. 8 = 800 microns. **1, 2**) *Pojarkovella pura* Simonova, BS33, BS42. **3, 4**) *Pojarkovella ketmenica* Simonova and Zub, BS33. **5, 6**) *Pojarkovella nibelis* (Durkina), BS33. **7**) *Pojarkovella honesta* Simonova, BS33. **8**) *Holkeria daggeri* Strank, BS42. **9**) *Endothyranopsis compressa* (Rauzer-Chernousova and Reitlinger), BS40. **10**) *Koskinotextularia obliqua* (Conil and Lys), BS42. **11**) *Koskinotextularia bradyi* (Moeller), BS40. **12**) *Koskinotextularia cribriformis* Eickhoff, BS40. **13**) *Archaediscus* aff. *chernoussovensis* Mamet (concavus stage), BS41. **14**) *Holkeria avonensis* Conil and Longerstaey, BS42. **15**) *Holkeria topleyensis* Strank, BS42.

**Fig. 5.** Selected foraminifers from the upper part of the Cf5β subzone. Scale bar = 400 microns except for figs 11, 14, 16 = 800 microns. **1**) *Cribrospira*? sp., BS49. **2**) *Vissarionovella holkeriana* Conil and Longerstaey, BS49. **3**) *Kublonibelia immanis* Conil, BS51. **4**) *Pseudoendothyra struvei* (Moeller), BS68. **5**) *Pseudoendothyra* sp. 2, BS69. **6**) *Pseudoendothyra* cf. *illustria* (Vissarionova), BS76x. **7**) *Rhodesinella pansa* (Conil and Lys), BS78. **8**) *"Millerella" excavata* Conil and Lys, BS62. **9**) *Pseudoendothyra* sp. 1 (*P*. aff. *struvei* (Moeller)), BS62. **10**) *Omphalotis minima* (Rauzer-Chernousova and Reitlinger), BS76. **11**) *Globoendothyra globula* (Eichwald),

BS75. **12**) *Magnitella porosa* Malakhova, BS77. **13**) *Endothyranopsis compressa* Rauzer-Chernousova and Reitlinger transitional to *E. crassa* (Brady,), BS83. **14**) *Lituotubella magna* Rauzer-Chernousova, BS69. **15**) *Pojarkovella evolutica* Simonova and Zub, BS62. **16**) *Koskinotextularia eximiformis* (Lipina)*,* BS78. **17**) *Nodosarchaediscus pirleti* (Bozorgnia)*,* BS73. **18, 19**) *Archaediscus krestovnikovi* Rauzer-Chernoussova morphotype 2 (transitional to the angulatus stage), BS84. **20**) *Eostaffellina*? *accepta* (Ganelina)*,* BS89.

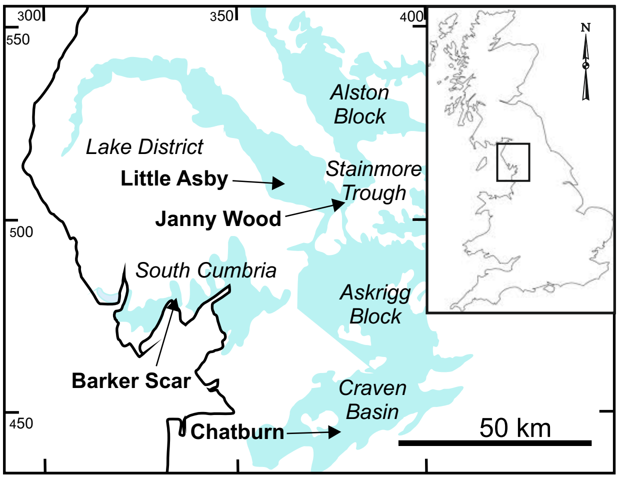
**Fig. 6.** Correlation of the main substages equivalent to the Holkerian in Europe. Absolute ages are based on Aretz et al. (2020). Diagonal striped lines correspond to the hiatus at the base of the Livian and in the early Asbian in the south Cumbria stratigraphical column (Formations). Arrows mark the necessary movement down in the Holkerian stratotype section to coincide with the base of the Livian and Tulian. Dashed line of correlation at the base of the upper Viséan has never been studied in detail. The base of the Park Limestone Formation is considered at the base of bed J of Fig. 2. Abbreviation Ur = Urswick Limestone Formation.

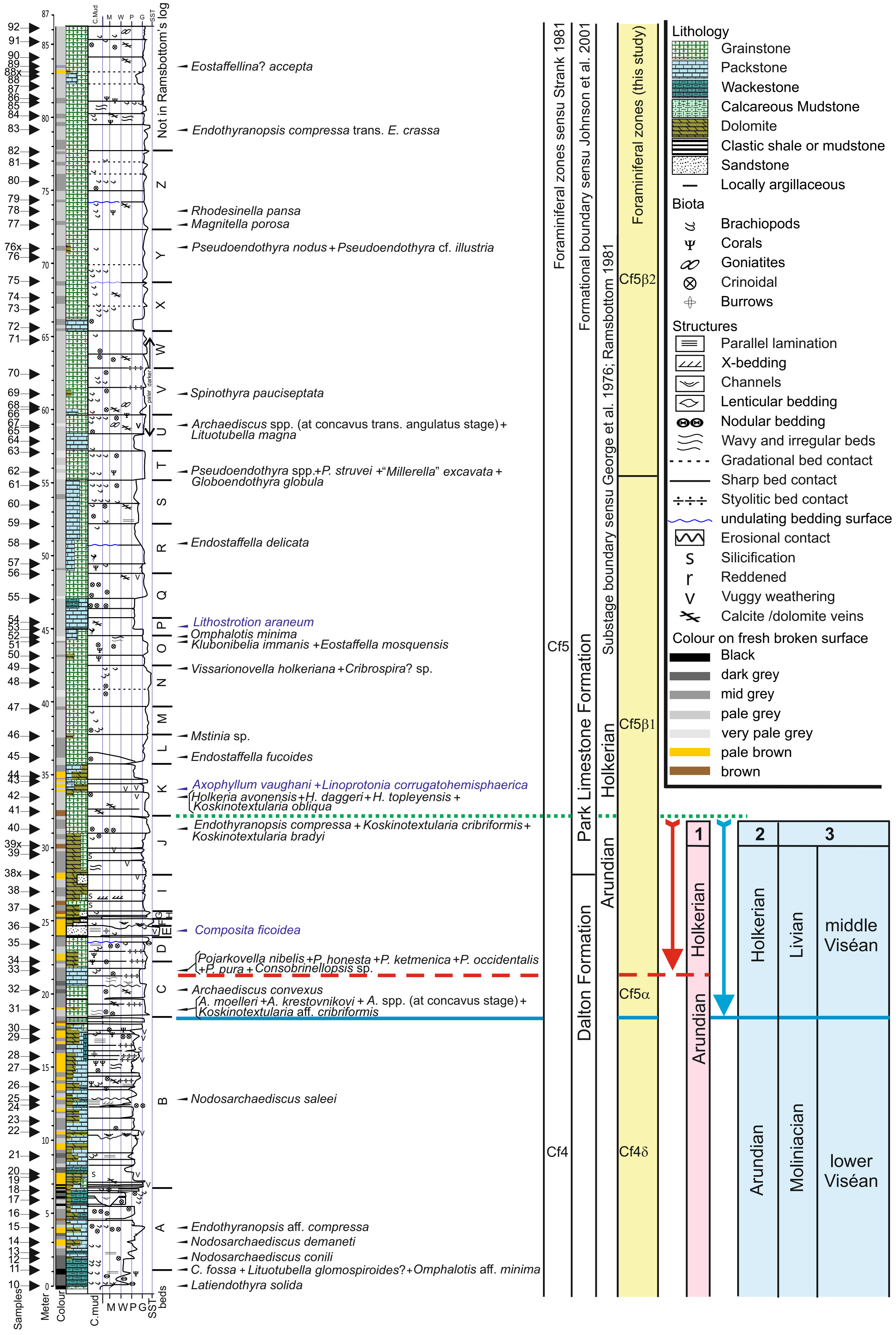
**Supplementary material:**

**Table S1.** Foraminiferal distribution in Barker Scar.

**Table S2**

**Figures S1 to S4.** Photos of the Barker Scar section with bed boundaries shown.


300
350
400
550
500
450
Alston Block
Lake District
Little Asby
Stainmore Trough
Janny Wood
South Cumbria
Askrigg Block
Barker Scar
Craven Basin
Chatburn
50 km
N


Samples
Meter
Colour
C.mud
M W P G
SST
beds
Not in Ramsbottom's log
paler darker
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Eostaffellina? accepta
Endothyranopsis compressa trans. E. crassa
Rhodesinella pansa
Magnitella porosa
Pseudoendothyra nodus + Pseudoendothyra cf. illustria
Spinothyra pauciseptata
Archaediscus spp. (at concavus trans. angulatus stage) + Lituotubella magna
Pseudoendothyra spp. + P. struvei + "Millerella" excavata + Globoendothyra globula
Endostaffella delicata
Lithostrotion araneum
Omphalotis minima
Klubonibelia immanis + Eostaffella mosquensis
Vissarionovella holkeriana + Cribrospira? sp.
Mstinia sp.
Endostaffella fucoides
Axophyllum vaughani + Linoprotonia corrugatohemisphaerica
Holkeria avonensis + H. daggeri + H. topleyensis + Koskinotextularia obliqua
Endothyranopsis compressa + Koskinotextularia cribriformis + Koskinotextularia bradyi
Composita ficoidea
Pojarkovella nibelis + P. honesta + P. ketmenica + P. occidentalis + P. pura + Consobrinellopsis sp.
Archaediscus convexus
A. moelleri + A. krestovnikovi + A. spp. (at concavus stage) + Koskinotextularia aff. cribriformis
Nodosarchaediscus saleei
Endothyranopsis aff. compressa
Nodosarchaediscus demaneti
Nodosarchaediscus conili
C. fossa + Lituotubella glomospiroides? + Omphalotis aff. minima
Latiendothyra solida
Foraminiferal zones sensu Strank 1981
Cf5
Cf4
Formational boundary sensu Johnson et al. 2001
Park Limestone Formation
Dalton Formation
Substage boundary sensu George et al. 1976; Ramsbottom 1981
Holkerian
Arundian
Foraminiferal zones (this study)
Cf5β2
Cf5β1
Cf5α
Cf4δ
1
Holkerian
Arundian
2
Holkerian
Arundian
3
Livian
Moliniacian
middle Viséan
lower Viséan
Lithology
Grainstone
Packstone
Wackestone
Calcareous Mudstone
Dolomite
Clastic shale or mudstone
Sandstone
Locally argillaceous
Biota
Brachiopods
Corals
Goniatites
Crinoidal
Burrows
Structures
Parallel lamination
X-bedding
Channels
Lenticular bedding
Nodular bedding
Wavy and irregular beds
Gradational bed contact
Sharp bed contact
Styolitic bed contact
undulating bedding surface
Erosional contact
S Silicification
r Reddened
V Vuggy weathering
Calcite /dolomite veins
Colour on fresh broken surface
Black
dark grey
mid grey
pale grey
very pale grey
pale brown
brown

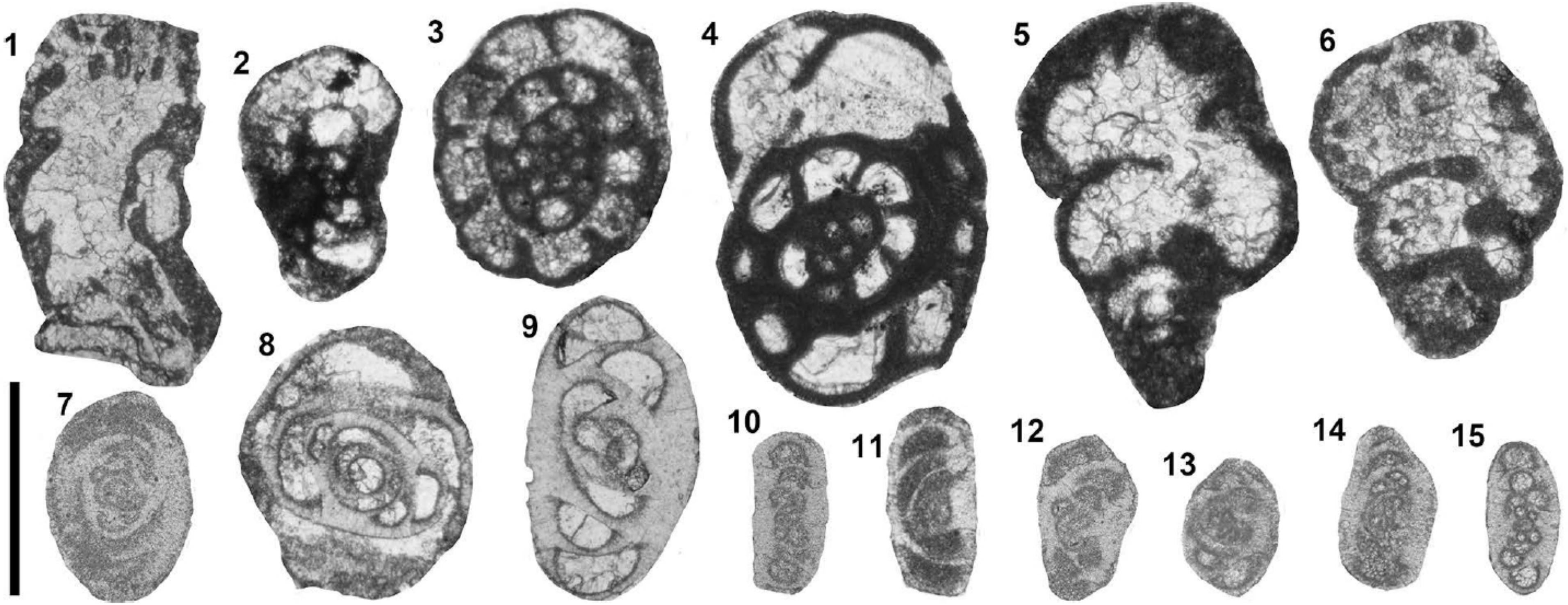


**Fig. 3.** Selected foraminifers representative of the top Cf4δ and Cf5α subzones. Scale bar = 400 microns except for fig. 1 = 800 microns. **1**) *Lituotubella glomospiroides*? Rauzer-Chernoussova (oblique section), BS11. **2**, **3**) *Endothyranopsis* aff. *compressa* (Rauzer-Chernousova and Reitlinger), BS16, BS15. **4**) *Omphalotis* aff. *minima* (Rauzer-Chernousova and Reitlinger), BS11. **5**, **6**) *Koskinotextularia* aff. *cribriformis* Eickhoff, BS31, BS40. **7**, **8**) *Archaediscus moelleri* Rauzer-Chernoussova (concavus stage), BS31, BS57. **9**) *Archaediscus operosus* Shlykova (involutus transitional to concavus stage), BS40. **10**, **11**) *Archaediscus krestovnikovi* Rauzer-Chernoussova (concavus stage), BS40, BS31. **12**, **13**) *Archaediscus* sp. at concavus stage, BS32. **14**) *Archaediscus* aff. *krestovnikovi* (involutus transitional to concavus stage), BS24. **15**) *Archaediscus pusillus* Rauzer-Chernoussova (involutus transitional to concavus stage), BS14.

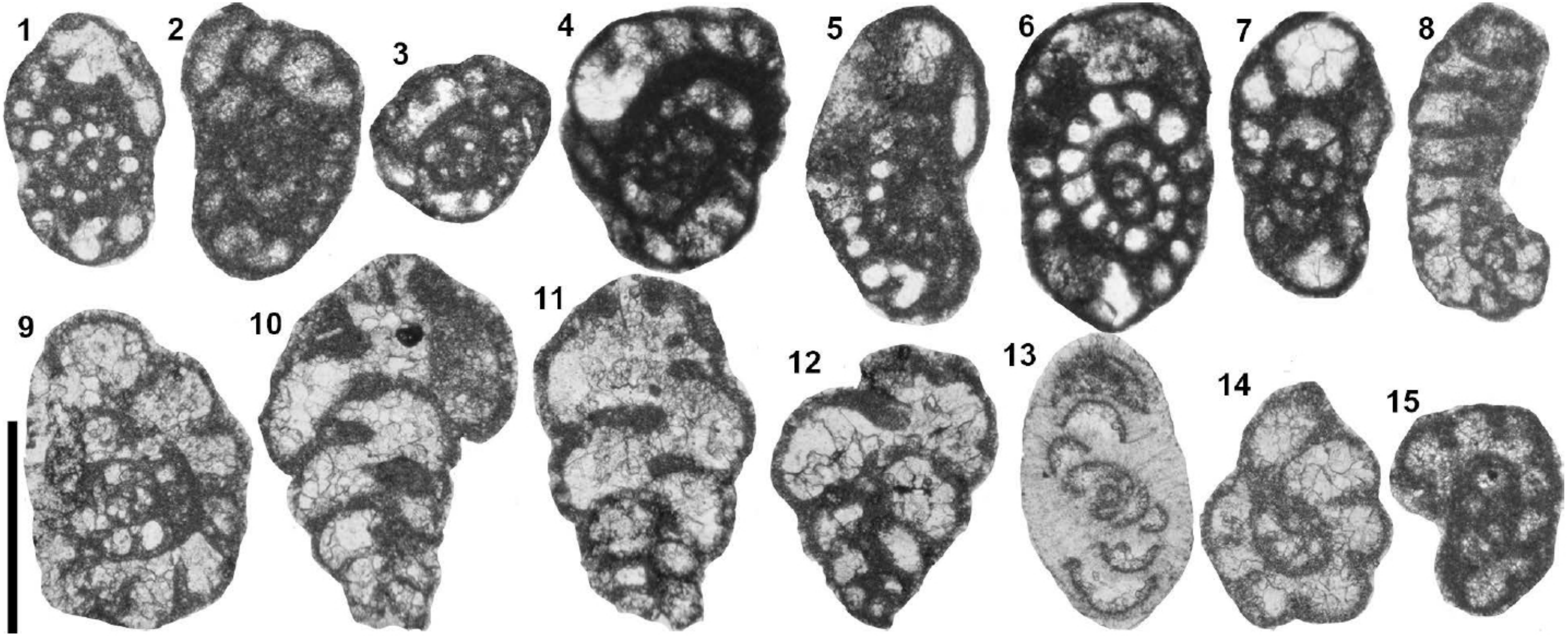


**Fig. 4.** Selected foraminifers from the lower part of the Cf5β subzone. Scale bar = 400 microns except for fig. 8 = 800 microns. **1**, **2**) *Pojarkovella pura* Simonova, BS33, BS42. **3**, **4**) *Pojarkovella ketmenica* Simonova and Zub, BS33. **5**, **6**) *Pojarkovella nibelis* (Durkina), BS33. **7**) *Pojarkovella honesta* Simonova, BS33. **8**) *Holkeria daggeri* Strank, BS42. **9**) *Endothyranopsis compressa* (Rauzer-Chernousova and Reitlinger), BS40. **10**) *Koskinotextularia obliqua* (Conil and Lys), BS42. **11**) *Koskinotextularia bradyi* (Moeller), BS40. **12**) *Koskinotextularia cribriformis* Eickhoff, BS40. **13**) *Archaediscus* aff. *chernoussovensis* Mamet (concavus stage), BS41. **14**) *Holkeria avonensis* Conil and Longerstaey, BS42. **15**) *Holkeria topleyensis* Strank, BS42.

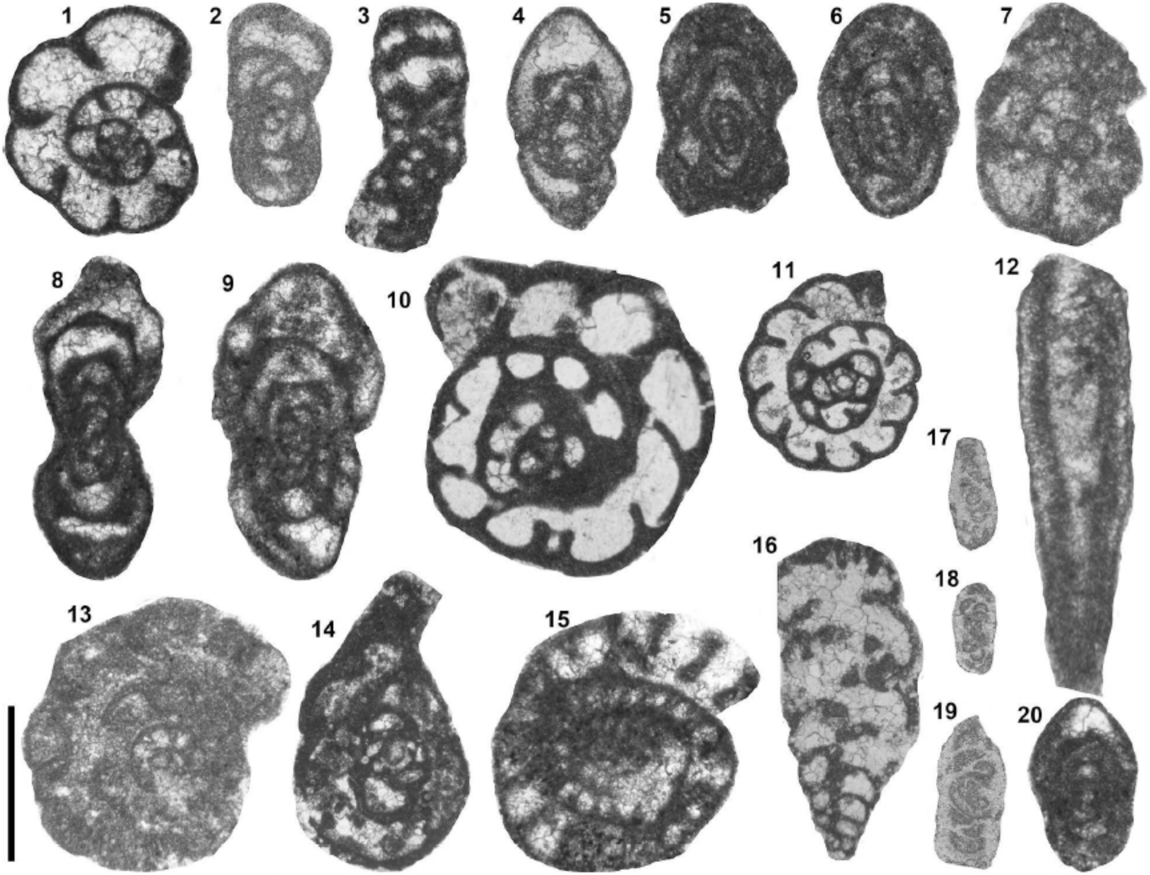
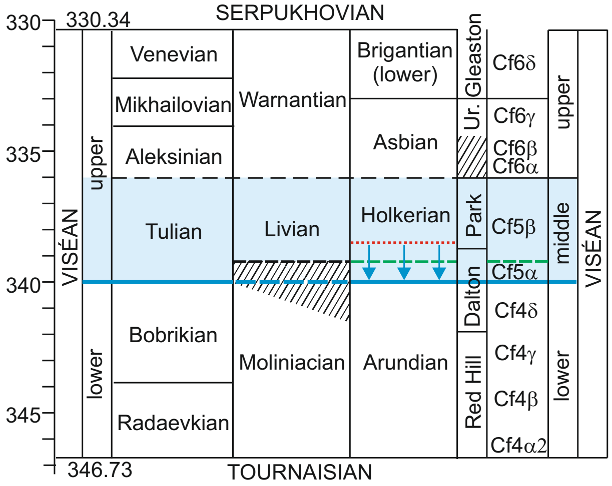


**Fig. 5.** Selected foraminifers from the upper part of the Cf5β subzone. Scale bar = 400 microns except for 11, 14, 16 = 800 microns. **1**) *Cribrospira*? sp., BS49. **2**) *Vissarionovella holkeriana* Conil and Longerstaey, BS49. **3**) *Kublonibelia immanis* Conil, BS51. **4**) *Pseudoendothyra struvei* (Moeller), BS68. **5**) *Pseudoendothyra* sp. 2, BS69. **6**) *Pseudoendothyra* cf. *illustria* (Vissarionova), BS76x. **7**) *Rhodesinella pansa* (Conil and Lys), BS78. **8**) *"Millerella" excavata* Conil and Lys, BS62. **9**) *Pseudoendothyra* sp. 1 (*P.* aff. *struvei* (Moeller)), BS62. **10**) *Omphalotis minima* (Rauzer-Chernousova and Reitlinger), BS76. **11**) *Globoendothyra globula* (Eichwald), BS75. **12**) *Magnitella porosa* Malakhova, BS77. **13**) *Endothyranopsis compressa* Rauzer-Chernousova and Reitlinger transitional to *E. crassa* (Brady), BS83. **14**) *Lituotubella magna* Rauzer-Chernousova, BS69. **15**) *Pojarkovella evolutica* Simonova and Zub, BS62. **16**) *Koskinotextularia eximiformis* (Lipina), BS78. **17**) *Nodosarchaediscus pirleti* (Bozorgnia), BS73. **18**, **19**) *Archaediscus krestovnikovi* Rauzer-Chernoussova morphotype 2 (transitional to the angulatus stage), BS84. **20**) *Eostaffellina*? *accepta* (Ganelina), BS89.


330
330.34
SERPUKHOVIAN
335
340
345
346.73
TOURNAISIAN
VISÉAN
upper
lower
Venevian
Mikhailovian
Aleksinian
Tulian
Bobrikian
Radaevkian
Warnantian
Livian
Moliniacian
Brigantian (lower)
Asbian
Holkerian
Arundian
Gleaston
Ur.
Park
Dalton
Red Hill
Cf6δ
Cf6γ
Cf6β
Cf6α
Cf5β
Cf5α
Cf4δ
Cf4γ
Cf4β
Cf4α2
upper
middle
lower
VISÉAN

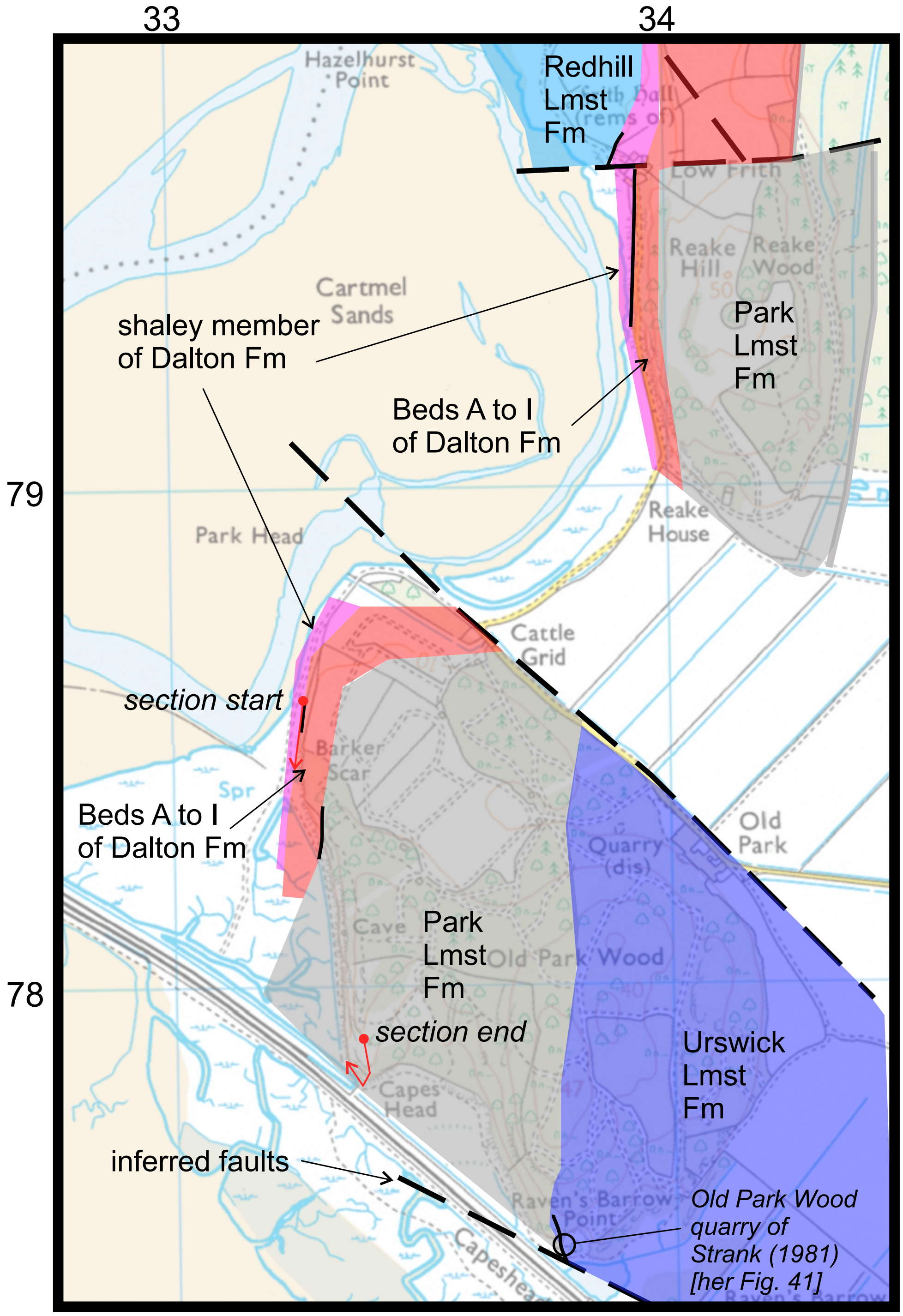


Fig. S1. Simplified geological map of the area around the Barker Scar section (none coloured areas are drift covered). On base topographic map from bing.co.uk. Grid squares are 1 km. Modified from Johnson et al. (2001).

Fig. S2a. Beds A and B of Dalton Formation at Barker Scar.

Most of Bed B in this outcrop

Fig. S2b. Beds B and C of Dalton Formation at Barker Scar.

Fig. S2c. Beds B through to bed I of the Dalton Formation, and lowest part of the Park Limestone Formation at Barker Scar.

Fig. S2d. Beds L through to Bed W of the Park Limestone Formation at Barker Scar.

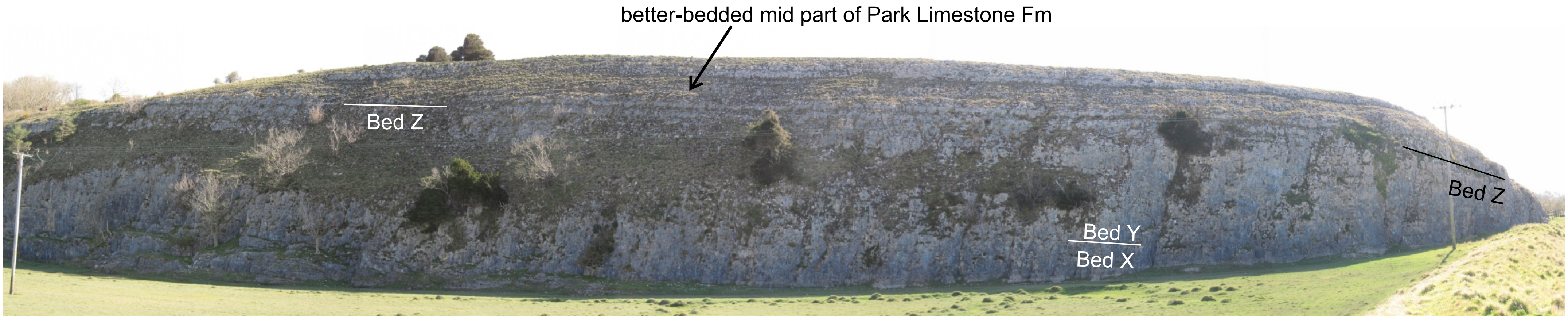


Fig. S2e. Beds from the upper part of the Park Limestone Formation exposure at Barker Scar. Above Bed Z the limestone is rather better bedded- a feature typical of the mid parts of the Park Limestone.

**Table 1.** Foraminiferal distribution in Barker Scar

| Formation | Dalton Formation | | | | | | | | | | | | | | | | | | | | | | | | | | | | Park Limestone Formation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Member | M2 | Member 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | not subdivided in members | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Foraminiferal zones with the notation of Conil | 4δ1 | Cf4$\delta_2$ | | | | | | | | | | | | | | | | | | | | Cf5α | | Cf5β1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Cf5β2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Foraminferal subzones with the notation of Poty et al | 11γ1 | MFZ11$\gamma_2$ | | | | | | | | | | | | | | | | | | | | MFZ12α | | MFZ12β | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| limestone bed | | A | A | A | A | A | A | A | A | B | B | B | B | B | B | B | B | B | B | B | B | C | C | C | C | D | E | I | I | J | J | J | J | K | K | K | K | L | L | M | N | N | O | O | O | P | P | Q | Q | R | R | R | S | S | T | T | U | U | U | U | U | V | V | W | X | X | X | Y | Y | Y | Z | Z | Z | Z | Z | Z | not in Ramsbotoms log | | | | | | | | | | |
| Sample | BS10 | BS11 | BS12 | BS13 | BS14 | BS15 | BS16 | BS17 | BS18 | BS19 | BS20 | BS21 | BS22 | BS23 | BS24 | BS25 | BS26 | BS27 | BS28 | BS29 | BS30 | BS31 | BS32 | BS33 | BS34 | BS35 | BS36 | BS37 | BS38 | BS38x | BS39 | BS39x | BS40 | BS41 | BS42 | BS43 | BS44 | BS45 | BS46 | BS47 | BS48 | BS49 | BS50 | BS51 | BS52 | BS53 | BS54 | BS55 | BS56 | BS57 | BS58 | BS59 | BS60 | BS61 | BS62 | BS63 | BS64 | BS65 | BS67 | BS66 | BS68 | BS69 | BS70 | BS71 | BS72 | BS73 | BS74 | BS75 | BS76 | BS76x | BS77 | BS78 | BS79 | BS80 | BS81 | BS82 | BS83 | BS84 | BS85 | BS86 | BS87 | BS88 | BS88x | BS89 | BS90 | BS91 | BS92 |
| metres from the base | 0 | 1.1 | 1.9 | 2.3 | 3 | 4 | 4.9 | 5.9 | 6.55 | 7.45 | 7.7 | 8.9 | 10.55 | 11.3 | 12.4 | 12.75 | 13.66 | 14.85 | 15.72 | 16.95 | 17.55 | 18.9 | 20.25 | 21.6 | 22.2 | 23.42 | 24.55 | 25.8 | 27 | 28.15 | 29.55 | 30.14 | 31.3 | 32.5 | 33.4 | 34.55 | 34.9 | 36.18 | 37.65 | 39.5 | 41.27 | 42.33 | 43.12 | 44.1 | 44.41 | 44.94 | 45.43 | 47.05 | 48.72 | 49.43 | 50.81 | 52.19 | 53.47 | 54.8 | 55.69 | 57.06 | 57.82 | 58.76 | 58.91 | 60.01 | 60.21 | 61.11 | 62.36 | 64.8 | 65.63 | 66.84 | 67.65 | 68.77 | 70.4 | 71.02 | 72.6 | 73.55 | 74.33 | 75.58 | 76.82 | 78.83 | 79.15 | 80.08 | 80.99 | 81.25 | 82.11 | 82.78 | 83.09 | 83.48 | 84.06 | 85.16 | 86.08 |
| | | | | | | | | | | Dolomitized | | | Dolomitized | partly dolomitized | | | | | partly dolomitized | | | | | | partly dolomitized | | | partly dolomitized | Dolomitized | | Dolomitized | | | | | | Dolomitized | | | | | | | | | | | | | | | | | Dolomitized | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Taxa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammarchaediscus monstratus* | X | X | | | | | | | | | | | | | | | | | | | | X | | | | X | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammarchaediscus* spp. | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaediscus eurus* | X | X | | | | | | | | | | | | | X | | | | | | | | X | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | X | | X | | X | | | | | | | X | | |
| *Archaediscus* aff. *krestovnikovi* | X | | | | | | | | | | | | | | X | | | | | | | X | | | | X | | | | | | | X | X | | | | | | | | X | X | | | | | | | | X | | | | | | | | | | | | | X | X | | X | | | | X | | | | | X | X | | | X | | | | | | | X |
| *Archaediscus mohae* | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaediscus pusillus* | X | | | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | X | | | | | | | | | | X | X | | | | | | | | X | | | | | | | X | | | | | | | | | X |
| *Archaediscus* spp. at involutus stage | X | X | | X | X | | | | X | | | X | | | X | | X | | | | | X | | | X | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| *Archaediscus* spp. involutus trans. concavus | X | X | X | X | X | | X | X | X | | | | | | | | | | | X | | X | X | | X | X | | | | | | | X | X | | | | X | X | X | X | | X | X | X | X | X | X | | X | X | X | X | | | | X | X | | X | X | X | X | | X | X | X | X | X | X | X | | X | | X | X | X | X | X | X | X | | | X | | | |
| *Archaediscus stilus* | X | X | X | | X | | | | | | | | | | | X | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | X | | | | | | | X | | X | | | | | | | | | | | | | | | X | | | | X | | | X | | | | | X | | | | | | | |
| *Archaediscus vischerensis* | X | | | | | | | | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Brenckleites fragilis* | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dainella?* sp. | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Earlandia elegans* | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | X | | | | | | | | | | | | | | X | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | X | | | | | | | X |
| *Earlandia moderata* | X | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| *Endothyra* spp. | X | | | | X | | | X | X | | | X | | | X | | | | | | | X | | | | | | | | | | | X | X | X | | | X | X | X | X | | X | X | X | X | X | | | | X | | | | X | | | X | X | | X | X | | | X | X | X | | X | | | X | X | X | X | X | | | | | X | | | X | X | | |
| *Eoparastaffella concinna* | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eoparastaffella iniqua* | X | X | X | | X | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eoparastaffella simplex* | X | | X | | X | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eosinopsis primaeva* | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eosinopsis* sp. 3 | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eostaffella radiata* | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | X | | | X | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | X | X | | | | | X | X | | | | | X | |
| *Forschia mikhailovi* | X | X | X | | X | X | | | X | | | | | | X | | | | | | | X | | | | | | | | | | | X | X | X | | | X | | | | X | | X | X | | | | X | | X | | X | | X | | | | | X | | | X | | | | | | X | | X | | | | | | | X | | | | | | | | | |
| *Forschia parvula* | X | X | | | | X | X | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | | | | | X | | X | | | | | X | X | | | | | | X | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | |
| *Glomodiscus oblongus* | X | X | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lapparentidiscus bokanensis* | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Latiendothyranopsis menneri solida* | X | X | X | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Mediocris mediocris* | X | | X | | X | | | | | | | X | | | X | | | | | | | | | | | | X | | | | | | X | X | X | | | X | | | | X | | | | | | | | | | | | | | | X | X | | | | | X | | | | X | | | X | | X | | X | | | | | | X | X | | | X | X | | |
| *Omphalotis frequentata* | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | X | | | X | | | | | | | X | | | | | | X | | | | | | | |
| *Plectogyranopsis ampla* | X | X | X | | X | X | X | | | | | X | | | X | | | | | | | | | | | | X | | | | | | X | X | X | | | X | X | | X | X | X | X | | | | | | | | | | | X | | X | | X | | | X | | X | X | | X | X | X | X | X | | X | | X | X | | X | | X | X | | | X | X | | X |
| *Plectogyranopsis paraconvexus* | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Plectogyranopsis* sp. | X | | X | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | X | | X | | | | | X | X | | | | | | | | | | | | | | | X | | | | | | | | X | | | | | | | X | | | | X | | |
| *Pseudoammodiscus volgensis* | X | X | X | | X | X | X | X | X | | | X | | | X | | | | | | | X | X | | | X | | X | | | | | | X | X | | | X | | | X | | | | X | | | | X | | X | X | X | | X | | | X | X | | X | X | X | | | | | | | | X | | | | | | | X | X | | X | | | | X | X | X |
| *Uralodiscus elongatus* | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Conilidiscus bucculentus* | aff | | aff | X | X | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaediscus* aff. *convexus* | | X | X | | X | X | X | | X | | | | | | X | | X | | | | | | X | X | X | | | | | | | | X | | | | | | | | | | | | | | | X | X | | X | X | X | | | | X | X | | X | X | X | | | X | | | | | X | X | | X | | | X | | | | | | | | | | | | | |
| *Archaediscus koktjubensis* | | X | | X | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Condrustella modavensis* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cribranopsis fossa* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Earlandia minor* | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | |
| *Endothyra bowmani* | | X | X | | X | | | X | X | | | X | | | X | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | X | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | |
| *Endothyra similis* | | X | X | | X | X | X | | | | | | | | | X | | | | | | X | | | | | | | | | | | | X | X | X | | | | X | X | | X | | | | | | | | X | X | | | | | | | | X | | | | | X | X | | | | | | | X | | | | | | | X | | | | X | | |
| *Eostaffella nalivkini* | | X | | | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Forschiella prisca* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Globoendothyra inconstans* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glomodiscus miloni* | | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glomodiscus* aff. *miloni* | | X | | | X | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glomodiscus rigens* | | X | | X | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lituotubella glomospiroides* | | ? | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | X | X | X | X | | X | | | | X | X | | | | | | | X | | X | | X | | |
| *Lysella gadukensis* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodosarchaediscus ? cornua* | | X | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodosarchaediscus ? viae* | | X | | X | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | |
| *Omphalotis koktjubensis* | | X | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | X | | | | | | | | | | | | | |
| *Omphalotis* aff. *minima* | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | | X | | X | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pseudolituotubella scalaeformis* | | X | | | X | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Tetrataxis* spp. | | X | | X | | | X | | X | | | | | | X | | | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | X | | X | | | | | X | X | | X | | | | | | X | | | X |
| *Ammarchaediscus eospillinoides* | | | X | | X | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammarchaediscus* sp. 1 | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaediscus piesis* | | | X | | X | | | | X | | | | | | X | | | | | | | X | X | | | X | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | X | | | | X | | | | | X | | X | | X | | | | | | | X |
| *Bessiella* sp. | | | X | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | X | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Earlandia vulgaris* | | | X | | X | X | | | X | | | | | | X | | | X | | | | | | | | X | | | | | | | | | | | | | | X | | | | X | | | | | X | X | | | | | | | X | | | | | | X | | X | | | | | | X | | | | | | | | | X | | | | | | | |
| *Mediocris evoluta* | | | X | | X | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Mediocris ovalis* | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodosarchaediscus conili* | | | X | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | X | | X | X | | | | X | X | | X | X | | | | | | | X | X | | | | | X | | | | | | | | | | | | | | X | | | | | | | |
| *Uralodiscus rotundus* | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaediscus teres* | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | |
| *Bessiella rectiformis* | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Brunsia spirillinoides* | | | | | X | X | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | | |
| *Eoparastaffella evoluta* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Latiendothyranopsis* sp. | | | | | X | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodosarchaediscus demaneti* | | | | | X | X | | | | | | X | | | | | X | | | | | X | X | | | X | | | | | | | X | | | | | | | X | | X | X | | | X | X | | X | | | X | | | X | X | | | | | | | | | X | | X | X | | | | | | | X | X | X | X | | X | | | X | | | | X |
| *Paralysella crassisepta* | | | | | X | | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Plectogyranopsis moraviae* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | X | | | | | | | |
| *Plectogyranopsis* sp. 1 | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | | | | X | | | | | | | | | X | | | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | | | | | |
| *Uralodiscus adindani* | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Brunsia pulchra* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | |
| *Endothyranopsis* aff. *compressa* | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | X | | | | X | | X | | | | | | | | | | | | | | X | X | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| *Koktjubina minima* | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | X | | | | | X | | | | | X | | X | X | | | | | X | |
| *Nodosarchaediscus rostratus* | | | | | | X | | | X | | | | | | X | | | | | | | X | X | X | | X | | | | | | | | | | | | | | X | | X | X | | X | | X | X | | | | | X | | | | X | X | X | X | X | | X | | X | | | | | X | | | | | X | | X | X | | X | | | | | | | |
| *Nodosarchaediscus* spp. | | | | | | X | | | | | | | | | | | X | | X | | | X | X | X | X | X | | | | | | | X | X | | X | | X | X | X | X | X | | | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | | X | X | X | | | X | X | | | X | X | | | X | X | | | | | | | X | |
| *Omphalotis* spp. | | | | | | | X | | | | | | | | | | | X | | | | | | | | | | X | | | | | | X | | X | | | | X | | | | | | | | | X | | | | | | X | | | X | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | |
| *Paralysella multicamerata* | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pseudotaxis eominima* | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | X | | X | | | | | | | | | | | |
| *Valvulinella tchotchiai* | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Omphalotis chariessa* | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | X | | | | | | X | | | | | | | | | | | |
| *Conilidiscus ?* sp. | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nodosarchaediscus exiguus* | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | X | | | | | | | | | | | | | |
| *Mediocris breviscula* | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | X | | X | | | | | | | | | X | | X | | | X | | | | | | | | | | | |
| *Nodosarchaediscus saleei* | | | | | | | | | | | | | | | | X | X | | | | | X | X | X | X | | | | | | | | X | X | | | | | | X | | | | | | | | X | X | | | X | | | | | | X | X | | X | | | | | X | | X | X | | X | | | | X | | | X | | | | | | | | | | X | |
| *Nodosarchaediscus?* sp. 1 | | | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Archaediscus moelleri* | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | | X | | | | | | |
| *Archaediscus krestovnikovi* | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | | | | X | | X | X | | | | | X | X | X | X | | | | | | | | | | |
| *Archaediscus* spp. at concavus stage | | | | | | | | | | | | | | | | | | | | | | X | X | X | | X | | | | | | | X | | | | | | | | | | | | | | | | X | X | | | | | X | X | | X | X | | X | | X | | X | | | | | X | X | X | X | X | X | X | X | X | X | | X | | X | X | X | X | |
| *Koktjubina* spp. | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | | | | | | X | | | | | | X | | X | X | X | | | | | | | | | | | | | | | X | | | | | | | X | | | | | | | | | | | X | | | | | | | | | | | |
| *Koskinotextularia* aff. *cribriformis* | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | X | X | | | X | | | X | | | | | X | | | | | X | | | | | | | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | |
| *Nodosarchaediscus pirleti* | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | X | | | | | | X | X | X | | X | X | | | X | X | | | | X | | X | | | | X | | X | X | X | X | X | X | X | | | | X | X | | X | | | | | | | | | | |
| *Nodosarchaediscus tchalussensis* | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| *Archaediscus convexus* | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | | X | | | X | | X | | | X | | | | X | | X | | | | | | | | | X | | | | | | | | | X | X | | X | | | X | | | X | X | | | | | X | X |
| *Consobrinellopsis* spp. | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | X | | | X | | | | X | X | X | | | X | | X | | X | | | | | | | | | | | | | | | | | | | | X | X | X | | X | | | | X | X | | | | | | | |
| *Pojarkovella honesta* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pojarkovella occidentalis* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | X | | | | | | X | | | X | | X | | | | | | | | | X | | | | | | | X | | | X | | | X | | X | X | | | | | | | | | | X | | | | | | |
| *Pojarkovella pura* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pojarkovella ketmenica* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | X | | | | | | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | X | | X | X | X | | X | | | | | | | X | | | X | | | |
| *Pojarkovella nibelis* | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | | X | | | | | | | | | X | | | | | | | | | | | | X | | | X | | X | | | | X | | X | | | | X | | | | X | | | X | | | |
| *Plectogyranopsis convexa* | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | |
| *Archaediscus krestovnikovi ampla* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | | | X | X | | | | | | | | | | | | | | | X | | | | X | | | | X | | X | | | | | | X |
| *Archaediscus operosus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | |
| *Consobrinellopsis minima* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | | | X | | X | X | | X | X | | X | | | | | | | | | | | X | X | | | X | | X | | | X | | X | X | | | X | X | | | | | | X | | X | | | X | | |
| *Endothyranopsis compressa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | X | | | X | | | X | | | X | | X | X | X | X | | | | | X | | | ? | X | X | | | | | | | | | | | |
| *Koskinotextularia bradyi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | X | | | | | | | | | | | | | X | | | X | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | | |
| *Koskinotextularia cribriformis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | X | | | | X | | | | | X | | | X | | X | | X | X | | | X | | X | X | | | | | | X | X | | | | X | | |
| *Archaediscus* aff. *chernoussovensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | X | X | X | X | X | | | X | X | | | | X | | | | | | | | | | | | X | X | | X | | X | | | X | X | X | | | X | | X |
| *Globoendothyra* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | X | | | | | | | | | X | X | | | | | | | | | | | |
| *Koskinotextularia obliqua* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Holkeria avonensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | X | X | | X | X | | | | | | | | | | | | | | X | | | | | X | | | | | X | | X | X | | | | | | | | X | X | | | | | |
| *Holkeria daggeri* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | aff | aff | | | | | | | | | | | | | | | |
| *Holkeria topleyensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | | | | X | X | | | X | | | | | | X | | | | | | |
| *Palaeospiroplectammina conili* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| *Plectogyranopsis settlensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | X | | | | X | | X | | | | | X | | | | | | | X | | | | | | | | | X | X | | X | | X | X | X | X | | | | X | | | X | | X | X | | |
| *Pojarkovella* spp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| *Consobrinellopsis consobrina* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | X | X | | | | | | | | | | X | | | | | | | | | | | | | X | | | | X | | X | | | | X | X | X | X | | | X | X | | X |
| *Endostaffella fucoides* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | X | X | | | | X | | X | | X | | | | | X | | | | | X | |
| *Endothyranopsis* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Palaeospiroplectammina mellina* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Spinobrunsiina* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | X | | | | | | | | | | |
| *Mstinia* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eblanaia michoti* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lituotubella* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Consobrinellopsis lipinae* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | X | | | | | | | | | X | | | | | | X | | | | | | | X | X | | X | | | | X | | | X | | | | X | | | | | | |
| *Endostaffella* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | | | | | | | | | | X | X | | |
| *Cribrospira ?* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Vissarionovella holkeriana* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eostaffella mosquensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | X | | | | | | | | | | | | | | |
| *Klubonibelia inmanis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | X | | | | | | |
| *Omphalotis minima* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | X | | X | | X | | | | | | X | | | | | | | X | X | X | X | | X | | | | X | | X | | | | | | | | | X | |
| *Archaediscus globosus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | X | X | X | | X | | | | X | | | | X | | | | X | | | | | | | X | X |
| *Archaediscus krestovnikovi ovalis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | X | X | | | | | | | | | | | | | | | | | X | | X | | | | | | | | |
| *Endostaffella delicata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | X | | X | | | | | | | | | | | X | X | | | | | X | X | | | | | | |
| *Archaediscus krestovnikovi reditus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | |
| *Eostaffella* aff. *parastruvei* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | X |
| *"Millerella" excavata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | X | | | | | | | | | | | | X | | X | | | | | | | | | | |
| *Pseudoendothyra* sp. 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | X | | | | | | X | | | | | | X | | X | X | | | X | | | X | X | X | |
| *Pseudoendothyra* sp. 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | X | | | X | | X | | | | | | | | | | | | | | | | | | | | | | |
| *Pseudoendothyra struvei* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | X | | X | X | X | | X | X | | X | | | X | | | X | | | | | | | X | X | | X |
| *Globoendothyra globula* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | X | | | X | | | | | | | | |
| *Pseudoendothyra* spp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | X | X | | X | | | X | X | X | X | X | | | X | X | | X | | X | | X | X | | | | | | | |
| *Pojarkovella evolutica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | X | X | | | | | X | X | X | X | X | X | | | | | | | X | | | | | | |
| *Archaediscus* spp. concavus trans angulatus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | X | | X | X | X | | | | | | | | |
| *Endostaffella parva* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | X | | | | | | |
| *Pseudotaxis sussaicus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lituotubella magna* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | X | | | X | X | | | | | X | X | | | | | X | X | | | X | | X | X |
| *Archaediscus varsanofievae* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cf | | | | | | | | | | X | X | X | | | X | | | | X | | | | | | | | X |
| *Pseudoendothyra* sp. 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | X | | | | | X | | | | X | | | | | | |
| *Pseudoendothyra* sp. 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | X | | | | | | | | | | | | | | | | | | | | | |
| *Spinothyra pauciseptata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | X | | |
| *Nodosarchaediscus tchaboksarensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | X | | | | | | | | | | | | | | | | | | | |
| *Archaediscus grandiculus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | X | X | | X | X | X | X | | X | | X | | | | X |
| *Nodosarchaediscus hirta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | X | | | | | | | | | X | | | | X | |
| *Pseudoendothyra nodus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| *Pseudoendothyra illustria* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cf | | | | | | | | | | | | | | | | | |
| *Magnitella porosa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | |
| *Pojarkovella mutabile* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| *Rhodesinella pansa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| *Koskinotextularia exiformis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | X |
| *Archaediscus subangustus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | X | X | X | | | | | X | |
| *Koskinotextularia* sp. 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | |
| *Archaediscus inflexus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | |
| *Archaediscus itinerarius* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| *Archaediscus densaspira ?* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | |
| *Endothyranopsis compressa* trans. *crassa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| *Nodosarchaediscus maximus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | |
| *Archaediscus krestovnikovi* morph. 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | |
| *Mikhailovella ?* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| *Eostaffellina ? accepta* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| *Praeplectostaffella* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |