

A middle Cambrian (Series 3, Stage 5) microfaunal assemblage from the Torgau-Doberlug Syncline (Central Germany) and its palaeogeographic implications for the configuration of West Gondwana

ABUBAKER ATNISHA

*TU Bergakademie Freiberg, Geological Institute, Department of Palaeontology, Bernhard-Von-Cotta 2,
Freiberg, D-09599, Germany. E-mail: aatnisha1977@gmail.com*

ABSTRACT:

Atnisha, A. 2019. A middle Cambrian (Series 3, Stage 5) microfaunal assemblage from the Torgau-Doberlug Syncline (Central Germany) and its palaeogeographic implications for the configuration of West Gondwana. *Acta Geologica Polonica*, **69** (1), 1–25. Warszawa.

A microfauna of small shelly fossils (SSF) is reported here for the first time from middle Cambrian (Series 3, Stage 5) subsurface strata of the Torgau-Doberlug Syncline (TDS), Central Germany. Considering that this microfauna is strongly limited and poorly preserved the material is quite abundant and diverse. The assemblage consists of molluscs (pelagiellids, bivalves), coeloscleritophorans (chancelloriids, halkieriids), poriferids, protoconodonts, cambroclaves, hyoliths, brachiopods, and disarticulated echinoderm remains. Additionally, a probable pterobranch hemichordate is noted. The assemblage is dominated by epifaunal suspension feeders from mid- to outer shelf depositional settings. Stratigraphically it represents (together with rare trilobites) the oldest middle Cambrian (Series 3, Stage 5) fauna known from Central Germany and the entire Saxothuringian Zone. Regardless the taphonomic problems related to the SSF occurrence, close palaeobiogeographic relations are indicated with the Mediterranean shelf of West Gondwana (especially with the areas of southwestern Europe and Morocco). The reported microfauna coupled with recent trilobite and palynomorph research supports assumptions that the Cambrian succession in the TDS is by far more complete than hitherto suggested, emphasizing its importance as a region yielding Cambrian rocks in Central Europe.

Key words: Small shelly fossils; Cambrian; Torgau-Doberlug Syncline; Germany; West Gondwana.

INTRODUCTION

During the early and middle Cambrian (Terreneuvian to Series 3), skeletal fossils appeared for the first time in great diversity and abundance (e.g., Bengtson 2004; Maloof *et al.* 2010; Kouchinsky *et al.* 2012; Skovsted *et al.* 2014). Many of these small skeletonised microfossils have been informally categorized as ‘small shelly fossils’ (SSF’s; Matthews and Missarzhevsky 1975). Although most of the skeletons

were originally calcareous, others were aragonitic or phosphatic (Landing *et al.* 1989; Bengtson and Conway Morris 1992; Landing 1992; Porter 2010), or diagenetically phosphatised allowing for chemical extraction from the carbonate host rock.

SSF’s containing a large number of mineralized metazoan microremains, often of uncertain systematic affinity (Yang 2014), occur from the latest Ediacaran to the Cambrian, and according to Dzik (1994) even until the Ordovician. SSF’s are known from Cambrian

successions worldwide and represent important biostratigraphic tools especially for the lower and lower middle Cambrian (Terreneuvian to lower Series 3) (Qian and Bengtson 1989; Elicki 1994; Qian *et al.* 1999; Steiner *et al.* 2007; Parkhaev 2008; Elicki and Gürsu 2009; Vendrasco *et al.* 2009; Parkhaev and Demidenko 2010; Elicki 2011; Yang 2014; Betts *et al.* 2016), even though the viability of various SSF taxa for correlation has been challenged by some authors (e.g., Conway Morris 1988; Landing 1994).

Diverse assemblages have been documented from Cambrian successions worldwide, including: Siberia (e.g., Parkhaev 2004; Kouchinsky *et al.* 2017), Mongolia (Esakova and Zhegallo 1996), Australia (e.g., Bengtson *et al.* 1990; Betts *et al.* 2016), Antarctica (e.g., Wrona 2009), North America (e.g., Landing 1995; Landing *et al.* 2002; Skovsted and Peel 2010; Wotte and Sundberg 2017), Germany (Sdzuy 1962; Freyer and Suhr 1987, 1992; Elicki and Schneider 1992; Elicki and Debrenne 1993; Elicki 1994, 1996, 1998, 1999b, 2003, 2005, 2007), Spain (Geyer 1986; Fernández-Remolar 2005; Wotte 2009), France (Kerber 1988; Álvaro *et al.* 2002; Devaere *et al.* 2013), Sardinia (Elicki and Wotte 2003; Elicki and Pillola 2004), Turkey (Sarmiento *et al.* 2001; Elicki and Gürsu 2009), Morocco (Geyer 1986; Skovsted *et al.* 2014), China (e.g., Yang 2014; Chang *et al.* 2017), Iran (Hamdi *et al.* 1989), Jordan (Shinaq and Elicki 2007; Elicki 2011), and India (Brasier and Singh 1987).

The SSF's documented so far from Cambrian Series 2 strata in the Torgau-Doberlug Syncline (Elicki 1994, 2005, 2007) show some relation to the other faunas from Cambrian successions in West Gondwana, which palaeogeographically assign the region to the European shelf of Gondwana (Geyer and Peel 2011; Elicki and Geyer 2013; Geyer *et al.* 2014; Table 1). This paper presents observations on the skeletonised microfossil record from dissolved limestone interbeds and lenses of micropalaeontologically hitherto non-investigated middle Cambrian drill cores of the Torgau-Doberlug Syncline, and discusses their biostratigraphic and palaeogeographic implications.

GEOLOGICAL AND STRATIGRAPHIC BACKGROUND

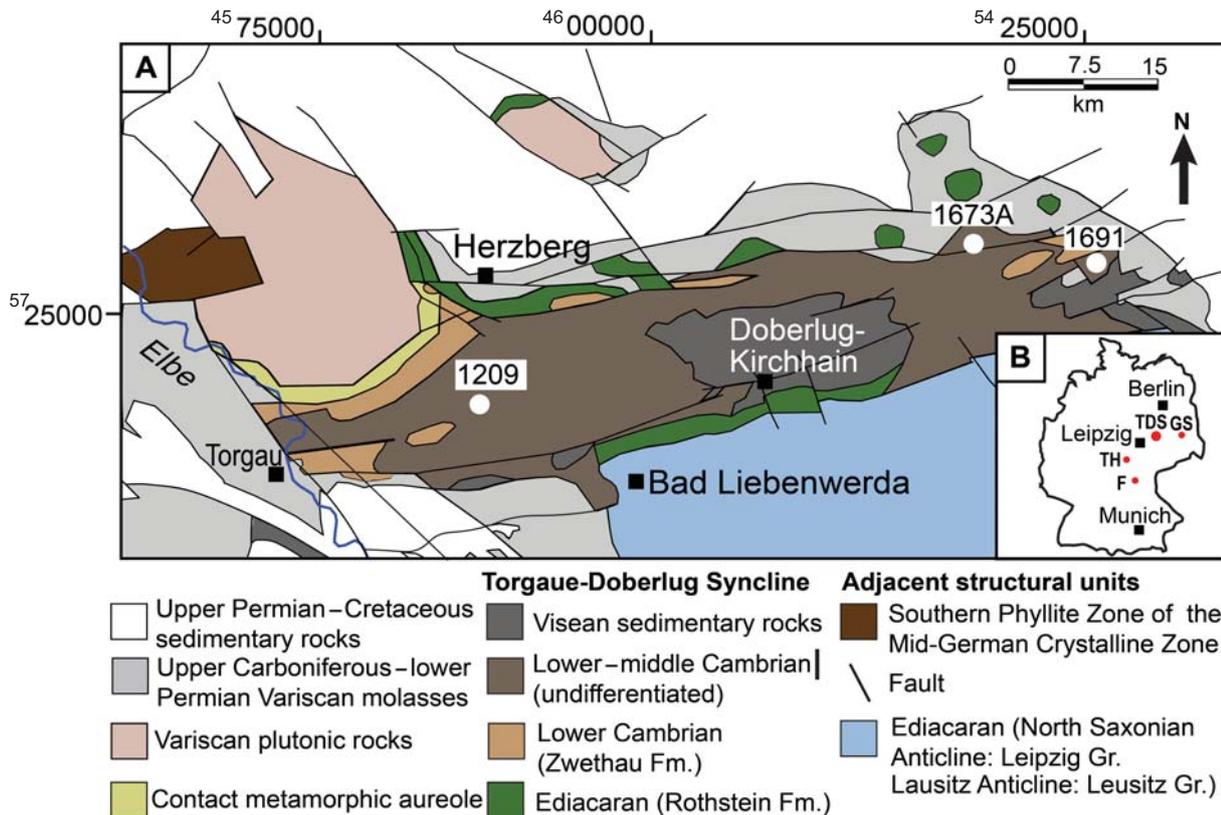
Fossiliferous Cambrian rocks are rare in Germany. They are known from the Görlitz area, the Franconian Forest, Thuringia, and from the Torgau-Doberlug Syncline (TDS) in the vicinity of Leipzig (see Elicki 2007; Geyer *et al.* 2008 and references therein; Text-fig. 1). The latter region exhibits the most complete

Cambrian succession (Text-fig. 2). Here, fossiliferous Cambrian Series 2 and 3 sequences containing skeletal fauna and archaeocyathan-calcimicrobial reef mounds have been recognized in drill cores since the 1950s (see Elicki 1997; Geyer *et al.* 2014 for the history of research).

Tectonostratigraphically, the TDS is part of the Saxothuringian Zone of Central Europe (Text-fig. 1), and represents one of the Variscan zones defined by Kossmat (1927). In the TDS, Proterozoic and Palaeozoic strata represent subsurface units known only from boreholes, except for a very localized outcrop of Proterozoic rocks. The Proterozoic to Palaeozoic succession is covered by up to 200 m of Cenozoic sediments (Elicki 2007; Geyer *et al.* 2014). The Ediacaran rocks (Rothstein Formation) are unconformably overlain by Cambrian Series 2 (Zwethau Formation) and Series 3 strata (Tröbitz and Delitzsch formations, known as the Arenzhain Group; Freyer and Suhr 1987; Brause and Elicki 1997; Elicki 1999a; Geyer *et al.* 2014; Text-fig. 2).

Palaeogeographically, the TDS was part of the Mediterranean facies realm of the European shelf of West Gondwana during Epochs 2 and 3 (Text-fig. 3). This Mediterranean facies is characterized by a transition of marine environments from siliciclastic (deeper and shallow shelf areas) to carbonate (archaeocyathan-bearing shallow ramps and shelves) under equatorial to subequatorial conditions in Cambrian Series 2 (e.g., Elicki 1999b; Álvaro *et al.* 2000; Elicki and Wotte 2003). In Cambrian Series 3, the Mediterranean facies were predominantly siliciclastic with few carbonates deposited at the beginning of the drowning of shelves and ramps (e.g., Elicki 2001; Elicki and Wotte 2003). Facies changes are complex and not fully understood (Elicki and Wotte 2003). This general sedimentological evolution at the transition between Cambrian Series 2 and 3 produced a rather uniform stratigraphic pattern over most of the Mediterranean region (e.g., Geyer and Landing 1995; Elicki 1997; Elicki and Wotte 2003). According to Elicki and Wotte (2003), the TDS represents the northernmost occurrence of this palaeogeographic facies belt.

The Rothstein Formation represents the oldest unit and consists of very low-grade metasedimentary rocks, dominated by dark-grey to black distal turbidites, intercalating with greywacke and mudstone beds and thick layers of massive chert (Buschmann 1995). The formation is interpreted as a fragment of a Cadomian back-arc basin developed on thinned continental crust, slightly deformed during the Cadomian Orogeny (Buschmann 1995; Linnemann *et al.* 2000, 2007). Fossils are generally lacking except for some



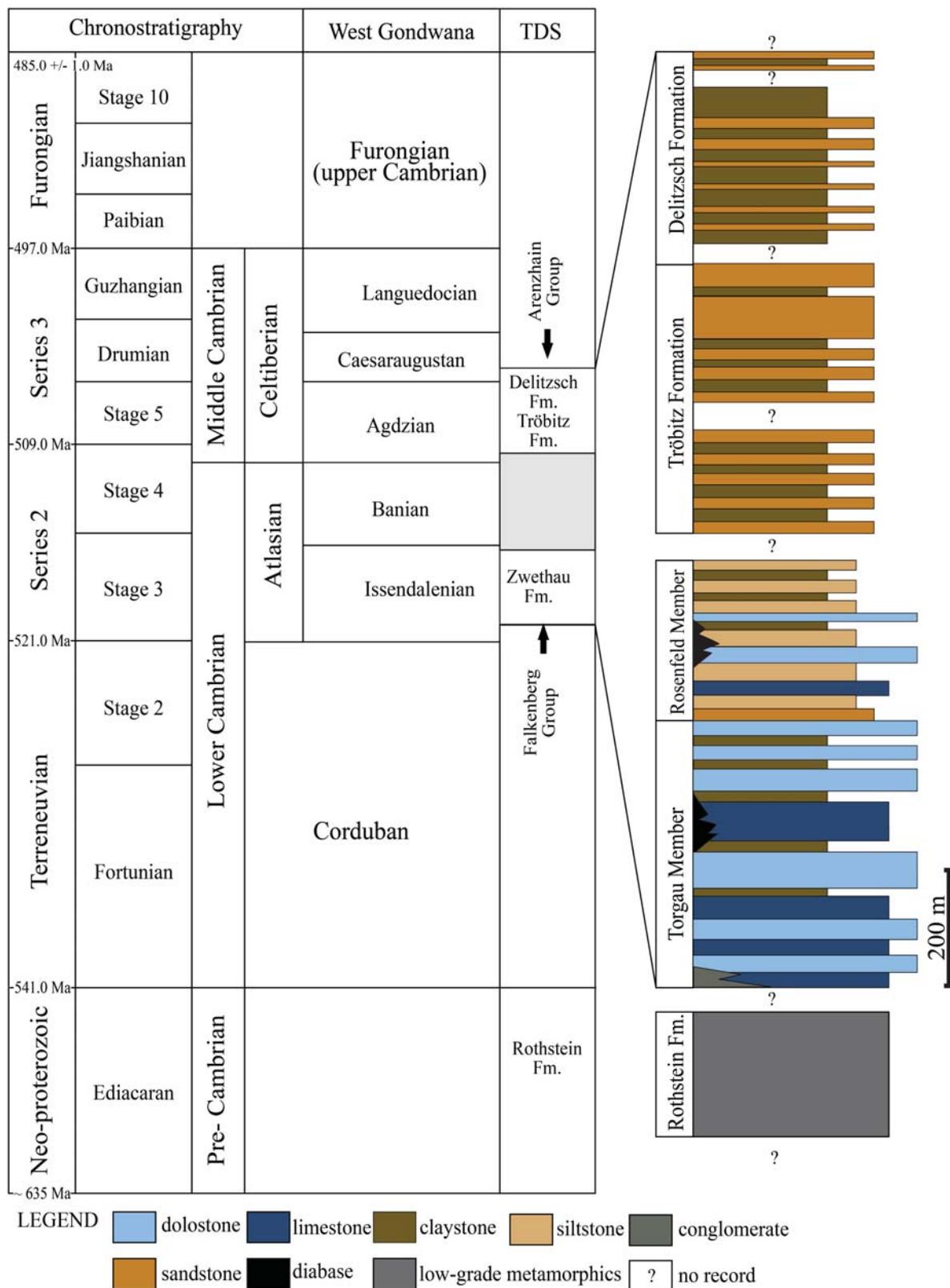
Text-fig. 1. A – Geological map of the Torgau-Doberlug Syncline (TDS) with core localities indicated by white circles (modified from Linnemann *et al.* 2010). B – Sketch map of Germany indicating regions with Cambrian successions (red circles: TDS – Torgau-Doberlug Syncline; GS – Görlitz Syncline; F – Franconian Forest; TH – Thuringia)

non-significant pyritized spherical and filamentous microforms (Buschmann *et al.* 2006). Radiometric dating of an ash layer from the middle part of the formation yielded ages between 570 and 565 Ma, which assigns the formation to the late Ediacaran (Buschmann 1995; Linnemann *et al.* 2000, 2007).

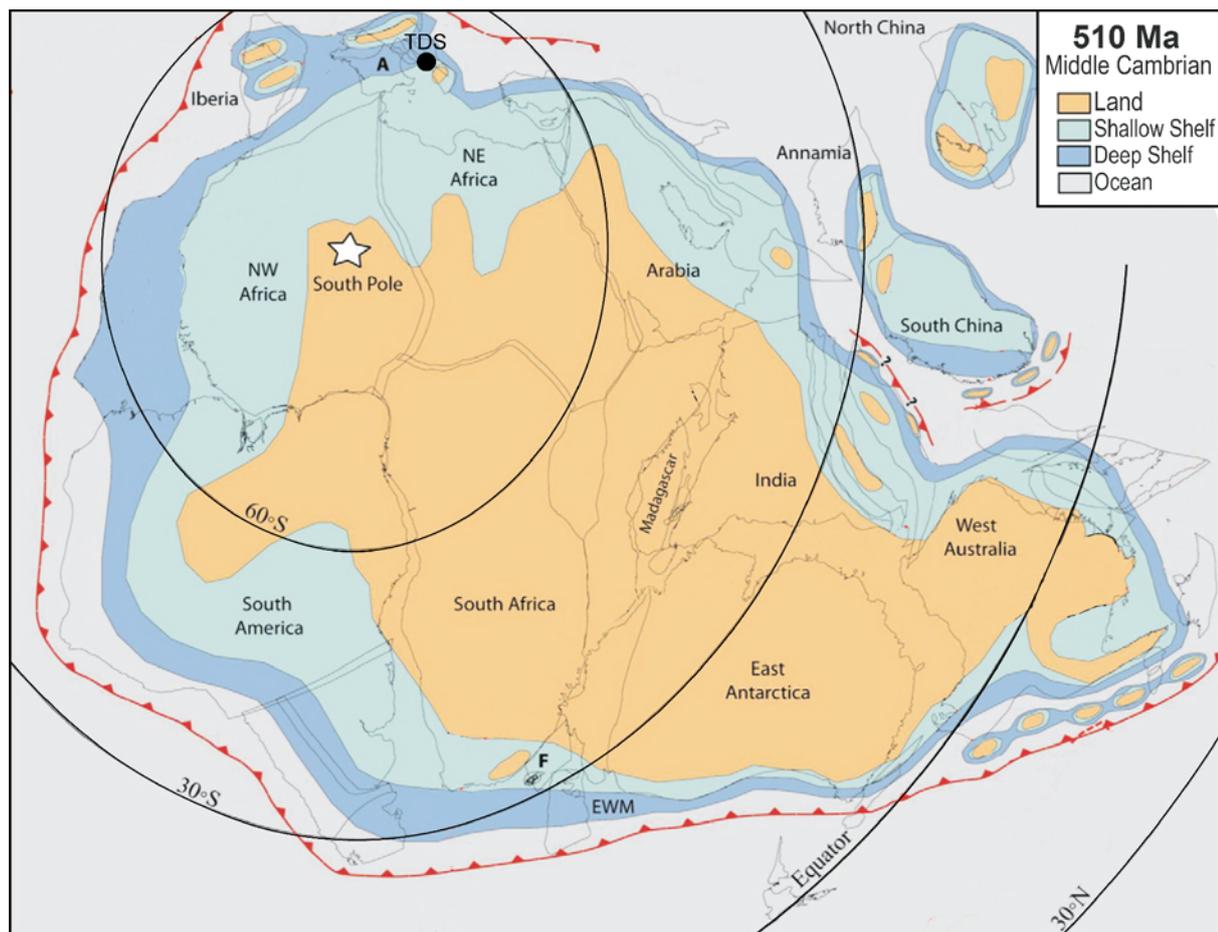
Cambrian deposition started after a stratigraphic and structural gap termed the Cadomian unconformity (Buschmann *et al.* 2006; Linnemann *et al.* 2008; Geyer *et al.* 2014). The succession commences with local conglomeratic debris flow deposits, followed by approximately 700 m of shallow marine carbonates and minor siliciclastics with common calcimicrobial biogenic carbonates that contain archaeocyaths (Zwethau Formation, Cambrian Series 2, Stage 3; Brause 1969; Freyer and Suhr 1987, 1992; Elicki and Debrenne 1993; Buschmann *et al.* 1995; Elicki 1997; Geyer *et al.* 2014; Atnisha *et al.* 2017a; Text-fig. 2).

The Zwethau Formation comprises the Torgau and Rosenfeld members. The Torgau Member consists of approximately 500 m of fossiliferous limestones and

dolostones. Calcimicrobial, oolitic, and intraclastic limestones are common. Cyanobacteria (*Epiphyton*, *Renalcis*, *Girvanella*, *Proaulopora*, *Kordephyton*, *Botomaella*, *Subtifloria*), archaeocyaths [*Retecoscinus* aff. *guadalquivirensis* Perejon, 1976, *Neoloculicyathus magnus* Debrenne, 1978, *Afiacyathus paracompositus* (Perejon, 1989) and others], rare trilobites (*Dolerollichia pretiosa* Sdzuy, 1962), and small shelly fossils (*Archiasterella hirundo* Bengston in Bengston *et al.*, 1990, *A. pentactina* Sdzuy, 1962, *Allonia tripodophora* Doré and Reid, 1965, *A. tetrathallis* Qian and Bengston, 1989, *Cambroclavus* sp., *Chancelloria* sp., *Halkieria* sp. and *Hipponicharion elickii* Gozalo and Hinz-Schallreuter, 2002) have been described (Sdzuy 1957a, b, 1962, 1970; Elicki 1994, 1999b, 2007; Geyer *et al.* 2014). The sedimentary setting of this member is interpreted as a carbonate-dominated subtidal ramp with calcimicrobial–archaeocyathan buildups succeeded by a shallow subtidal to intertidal mixed ramp regime with oolitic shoal complexes and restricted areas (Elicki 1994, 1999b; Buschmann *et al.* 2006;



Text-fig. 2. Stratigraphic scheme, lithological column, and detailed profiles for the early Palaeozoic sedimentary succession of the Torgau-Doberlug Syncline (TDS) (modified from Elicki 2015)



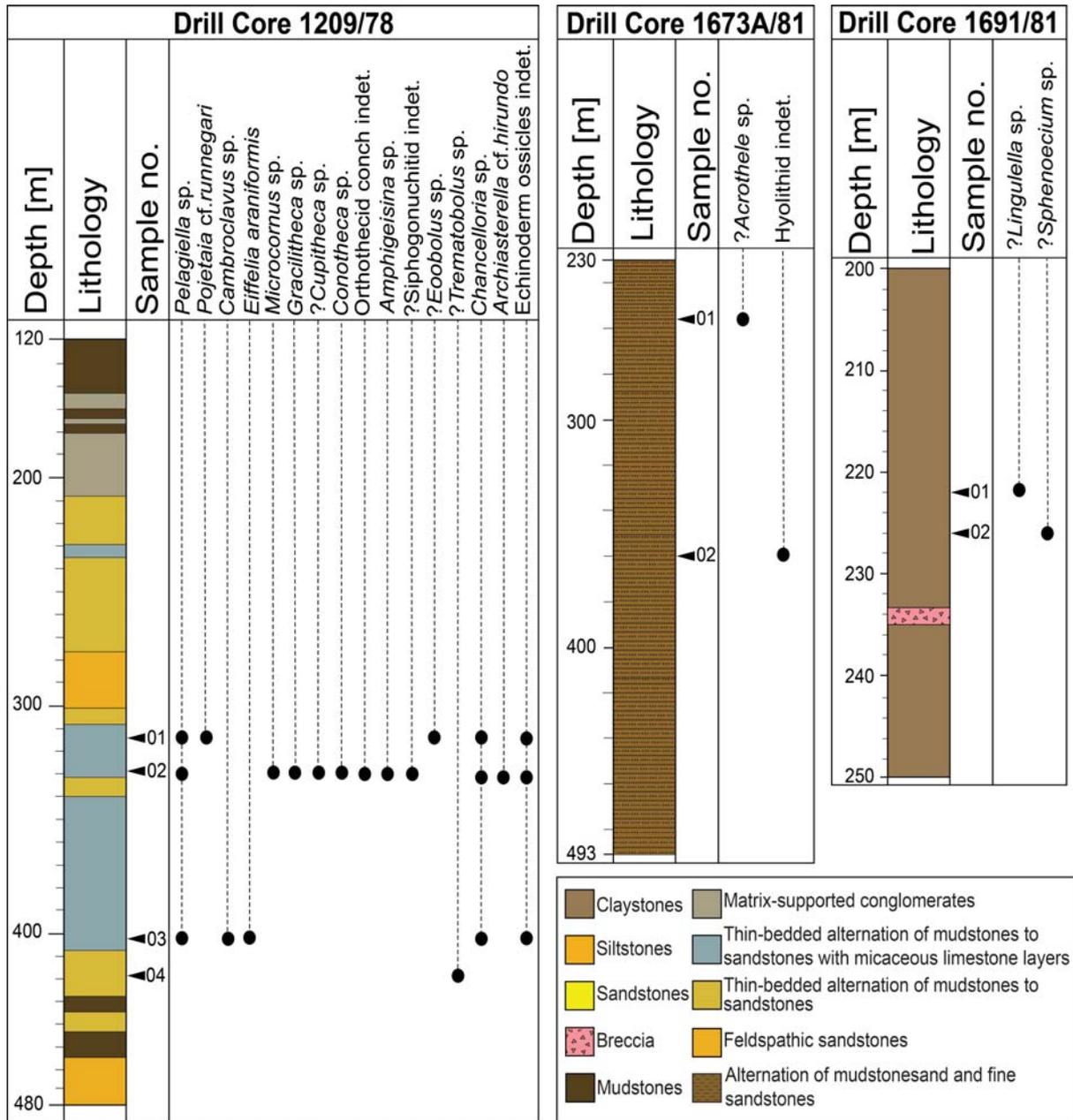
Text-fig. 3. Palaeogeographic map of Gondwana during middle Cambrian times (modified after Torsvik and Cocks 2017). Solid red lines are subduction zones; TDS: Torgau-Doberlug Syncline; A: Armorica; F: Falkland Islands; EWM: Ellsworth-Whitmore Mountains

Atnisha *et al.* 2017a). The biostratigraphic position of the Torgau Member is Cambrian Series 2 (Stage 3) as indicated by archaeocyaths (corresponding to the lower Ovetian of Iberia, which is correlated with the middle Issendalenian of Morocco; see Elicki 1997; Geyer and Landing 2004).

The overlying Rosenfeld Member (up to 280 m thick) is dominated by siliciclastics with occasional carbonate intercalations. The fossil content consists of re-deposited non-determinable archaeocyaths, algae and shelly remains (Elicki 1999a). The depositional environment is poorly constrained and was assigned to a deeper basinal area by Freyer and Suhr (1987), although the occurrence of coarser siliclastic sediments might rather reflect climatically induced run-off changes under neritic conditions and a palaeogeographic dislocation of the area (Elicki 2003). Moreover, the TDS succession of Cambrian Series 2 (Stage 3) carbonate-dominated strata,

abruptly overlain by Cambrian Series 3 (Stage 5) siliciclastics is identical to other coeval successions in West Gondwana (Landing *et al.* 2015).

The Cambrian Series 3 strata (Arenzhain Group) are represented by siliciclastics with extremely rare intercalations of very thin limestone beds (Brause 1969, 1970; Elicki 1997; Geyer *et al.* 2014; Atnisha *et al.* 2017a; Text-fig. 2). The Tröbitz Formation (lower Arenzhain Group) is dominated by alternating quartzitic sandstones and minor dark-grey micaceous claystones, including thin limestone layers near the transition to the overlying Delitzsch Formation (Brause 1970; Geyer *et al.* 2014; Atnisha *et al.* 2017a). The fauna is composed of trilobites [*Acadoparadoxides brausei* Sdzuy, 1970, *A. saxonicus* Sdzuy, 1970, *Cambrunicornia saxonica* Geyer, Buschmann and Elicki, 2014, *Condylopyge regia* Sdzuy, 1970, *Paradoxides aff. enormis* Sdzuy, 1968, *Parasolenopleura lusatica* Sdzuy, 1970, *Protolenus*



Text-fig. 4. Generalized lithostratigraphic columns with the lithology and occurrence of the fauna in the studied drill cores from the TDS. Location of selected samples indicated by black triangles

(*Hupeolenus*) *bergstroemi* Geyer, Buschmann and Elicki, 2014, and others], inarticulate brachiopods, and few hyoliths (Schmidt 1942; Sdzuy 1957a, b, 1970; Elicki 2007; Geyer *et al.* 2014). The trilobites indicate a stratigraphic level of Cambrian Stage 5 corresponding to the middle to upper Agdzian (lower part of Celtiberian *sensu* Geyer and Landing 2004 and Buschmann *et al.* 2006; see Geyer *et al.* 2014).

The overlying Delitzsch Formation is dominated by quartzitic sandstones alternating with micaceous claystones and by a decrease of the sandstone contribution towards the top. The fauna is similar to that of the Tröbitz Formation and is assigned to Cambrian Series 3. The fauna is composed of trilobites (*Acadoparadoxides brausei* Sdzuy, 1970, *A. cf. insularis* Westergård, 1936, *Acanthomicmacca ano-*

mocaroides Schmidt, 1942, *Badulesia tenera* Hartt in Dawson, 1868, *Bailiella* cf. *emarginata* Linnarsson, 1877, *Condylopyge regia* Geyer, Buschmann and Elicki, 2014, *C. rex* Barrande, 1846, *Jincella?* cf. *sulcata* Sdzuy, 1968, *Paradoxides* aff. *asturianus* Sdzuy, 1968, *P.* aff. *enormis* Sdzuy, 1968, *Parasolenopleura lusatica* Sdzuy, 1970, *Peronopsella inaequalis* Schmidt, 1942, *Solenopleura picardi* Schmidt, 1942 and others), helcionelloid molluscs, brachiopods, and few hyoliths (Schmidt 1942; Sdzuy 1957a, b, 1970; Elicki 2007; Geyer *et al.* 2014). Stratigraphically, two levels can be distinguished. The older level has an early middle Cambrian age, equivalent to the younger fauna of the Tröbitz Formation. The younger level characterizes a relatively narrow stratigraphic interval corresponding to the upper part of Cambrian Series 3 (Stage 5), respectively to the late Agdzian to early Caesaraugustan (Celtiberian) of West Gondwana (Buschmann *et al.* 2006; Geyer *et al.* 2014; Atnisha *et al.* 2017a).

MATERIAL AND METHODS

The material described herein was collected from drill cores nos. 1209/78, 1673A/81, and 1691/81 (Text-figs 1, 4). The drill cores are archived in the central repository of the Brandenburg Geological Survey in Wünsdorf (Landesamt für Bergbau, Geologie und Rohstoffe – LBGR). The location of the studied samples and the reported fauna are shown in Text-fig. 4. Samples from core 1209/78 were dissolved in 10% acetic acid. Residues were sieved and dried, and the microfossil specimens were hand-picked. Fossil specimens were mounted, sputter-coated with gold and examined under a scanning electron microscope (SEM). The macro specimens from drill cores 1673A/81 and 1691/81 were coated with magnesium oxide for palaeontological studies. All figured specimens and residues of samples are housed in the Institute of Geology, TU Akademie Freiberg, Germany, under collection number FG 682.

SYSTEMATIC PALAEOLOGY

Phylum Mollusca Cuvier, 1797
 Class Helcionelloida Peel, 1991
 Order Pelagielliformes Parkhaev, 2017
 Family Pelagiellidae Parkhaev, 2017
 Genus *Pelagiella* Matthew, 1895

TYPE SPECIES: *Cyrtolites atlantoides* Matthew, 1894 from the Terreneuvian, New Brunswick, Canada.

Pelagiella sp.
 (Pl. 1, Figs 1–6)

MATERIAL: Six internal moulds: FG 682-1209/01, 02, 03, 04, 05 and 06, drill core 1209/78.

REMARKS: The small, dextrally coiled univalve internal moulds have 1–1.5 whorls. The spiral side is nearly flat or slightly depressed, and the umbilical side is narrow. The last whorl is wide. The cross-section is oval to sub-triangular and the protoconch is hook-shaped. The aperture is often broken. *Pelagiella* is characterized by high morphological variation, often with unclear differences (Gravestock *et al.* 2001; Skovsted 2004; Wotte and Sundberg 2017). According to Dzik and Mazurek (2013), the discovery of specimens of *Pelagiella* with bunches of setae, and the presence of the mucronate embryonic shell of its early Cambrian relatives make its molluscan nature questionable. The observed TDS specimens are represented by internal moulds without shell material, which makes specific determination difficult. The morphologies of the TDS specimens are shared by several species of *Pelagiella*.

The studied specimens are internal moulds and an affiliation with *Costipelagiella* Horný, 1964 cannot be excluded. The specimens are not compressed laterally, which excludes them from *C. nevadense* Skovsted, 2006. The discussed material shows some morphological affinity to *P. subangulata* Tate, 1892, which is characterized by a wide range of variability. Due to the poor preservation (steinkerns), taxonomic assignment only in open nomenclature is possible.

OCCURRENCE: *Pelagiella* has been reported from Terreneuvian to Cambrian Series 3 strata worldwide.

Class Bivalvia Linnæus, 1758
 Order uncertain
 Family Fordillidae Pojeta, 1975
 Genus *Pojetaia* Jell, 1980

TYPE SPECIES: *Pojetaia runnegari* Jell, 1980 from the Terreneuvian Parara Limestone, South Australia.

Pojetaia cf. *runnegari* Jell, 1980
 (Pl. 1, Fig. 7)

MATERIAL: One figured phosphatic mould: FG 682-1209/07 from core 1209/78.

REMARKS: One internal mould with a length less than 1.2 mm, compressed laterally, equivalved, irreg-

ularly oval in outline. The ligament is usually straight with an umbo, which is central to subcentral, and each valve holds between one or two teeth (Pl. 1, Fig. 7c). The specimens are preserved as steinkerns, therefore growth lines are not observed.

The taxonomic identification of Cambrian bivalves is often problematic because they are small and usually preserved only as internal moulds (Elicki and Gürsu 2009). *Pojetaia runnegari* was first described by Jell (1980), but later Pojeta (2000) suggested that its origin was roughly contemporaneous with that of *Fordilla* Barrande, 1881. *Pojetaia runnegari* and *Fordilla* spp. are the oldest Cambrian bivalves (Elicki and Gürsu 2009; Vendrasco *et al.* 2011).

Specimens of *Pojetaia* and *Fordilla* can be reliably distinguished from one another by the total size (*Fordilla* is larger) and the ratio of anterior length to total length, which is significantly larger in *Pojetaia* (Elicki and Gürsu 2009). The dimensions of the TDS specimen fit those of *Pojetaia* (Elicki and Gürsu 2009) and are significantly different from those of *Fordilla*. The TDS specimen may be referred to *P. runnegari*, the most widespread of the early Cambrian bivalves (Elicki and Gürsu 2009), but poor preservation makes clear designation on a species level somewhat problematic.

OCCURRENCE: The species is known from many Terreneuvian to Cambrian Series 3 successions: Germany (Elicki 1994), Turkey (Elicki and Gürsu 2009), China (Li and Zhou 1986), Australia (Jell 1980), Newfoundland (Skovsted and Peel 2007), Mongolia (Esakova and Zhegallo 1996), Greenland (Skovsted 2006), and Morocco (Geyer and Streng 1998).

Phylum uncertain

Class Cambroclavida Conway Morris and Chen, 1991

Family Zhijinitidae Qian, 1978

Genus *Cambroclavus* Mambetov in Mambetov and Repina, 1979

TYPE SPECIES: *Cambroclavus antis* Mambetov in Mambetov and Repina, 1979, Cambrian Series 2, Stage 3, Kazakhstan.

Cambroclavus sp.

(Pl. 1, Fig. 8)

MATERIAL: One phosphatized sclerite: FG 682-1209/08 from core 1209/78.

REMARKS: Elongate sclerite. The anterior shield is circular and separated from the elongated poste-

rior region by variable lateral contraction, giving the sclerite a dumbbell shape. The upper surface of the sclerite is rounded and shows a median ridge that originated in the posterior field. The dorsal spine is vertical, elongate, gently recurved and located on the anterior shield, with a more or less circular cross-section. The posterior shield is elongate. The upper surface of the sclerite, including the base, is smooth.

Cambroclaves are a group of enigmatic, phosphatized, hollow, spine-shaped sclerites, known from widespread Terreneuvian to Cambrian Series 3 fossil assemblages (Wotte 2009). The cambroclave specimens described by Conway Morris in Bengtson *et al.* (1990) have more affinity to a dumbbell shape, which is a fundamental feature of the sclerite described herein, and point to a possible affiliation with *C. absonus* Conway Morris, 1990 or *C. antis*. The sclerite shows no distinct furrow around the anterior spine, as figured in Mambetov and Repina (1979, pl. 14, figs 1, 2). No lateral corrugation of the anterior spine is observed, which rules out affiliation of the described sclerite to *Cambroclavus ludwigsdorfensis* Elicki, 1994, *C. clavus* Mambetov in Mambetov and Repina, 1979, and *C. undulatus* Mambetov in Mambetov and Repina, 1979. Due to poor preservation, the specimen is retained in open nomenclature.

OCCURRENCE: Cambroclavids are known from Cambrian Series 2 (Stage 3) to Series 3 (Stage 5) successions from Germany (Elicki and Schneider 1992; Elicki 1994, 2005; Elicki and Wotte 2003), Sardinia (Elicki and Wotte 2003; Elicki 2005, 2006), Spain (Wotte 2009), France (Devaere *et al.* 2013), Australia (Betts *et al.* 2016), China (Bengtson *et al.* 1990; Li *et al.* 2016), and Canada (Landing 1991).

Phylum Porifera Grant, 1836

Class Calcarea Bowerbank, 1864

Order Heteractinidae Hinde, 1888

Family Eiffeliidae Rigby, 1986

Genus *Eiffelia* Walcott, 1920

TYPE SPECIES: *Eiffelia globosa* Walcott, 1920; Burgess Shale Formation, Cambrian Series 3 (Stage 5), British Columbia, Canada.

Eiffelia araniformis

(Pl. 1, Fig. 9)

MATERIAL: One isolated phosphatized spicule: FG 682-1209/09 from core 1209/78.

REMARKS: The spicule has a regular six-rayed disk, with the rays diverging at c. 60–80°. All rays are arranged and set at a low angle to the plane of the central disk. The rays are slender with length at 60–90 µm. The central ray is short and occurs on the convex side, subperpendicularly to the plane of the six rays.

Bengtson *et al.* (1990) provided a full discussion of this species. The spicule with a regular six-rayed disk and perpendicular central rays can be compared with Cambrian (Terreneuvian to Series 2) specimens of *E. araniformis* from South Australia (Bengtson *et al.* 1990, fig. 12). Bengtson in Bengtson *et al.* (1990) argued that the species of *Actinoites* Duan, 1984, *Lenastella* Missarzhevsky and Mambetov, 1981, and *Niphadus* Duan, 1984 are synonyms of *E. araniformis*. The morphology of the spicule from the TDS is similar to the specimens described in Bengtson *et al.* (1990) and therefore the spicule is referred to *E. araniformis*.

OCCURRENCE: *Eiffelia araniformis* has been reported from Terreneuvian to Cambrian Series 3 strata worldwide.

Phylum uncertain
Class Hyolitha Marek, 1963
Order Hyolithida Sysoev, 1957
Family Nelegerocornidae Meshkova, 1974
Genus *Microcornus* Mambetov, 1972

TYPE SPECIES: *Microcornus parvulus* Mambetov, 1972, Cambrian Series 2, Stage 3, Kazakhstan.

Microcornus sp.
(Pl. 2, Figs 1–4)

MATERIAL: Four internal moulds: FG 682-1209/10, 11, 12, and 13 from core 1209/78.

REMARKS: The conchs are incomplete remains of the more-or-less apical area, a slightly curved, tapering cone with curvature toward the dorsum. The apical angle is small and creates a narrow appearance for the conch. The surface of the internal mould is smooth. The cross-section is sub-triangular in shape (Pl. 2, Figs 1a, 2a, 3a, 4a). The dorsal side is more strongly rounded, grading into tightly rounded lateral edges and then into straight flanks; flanks meet at prominent dorsal ridge; dorsum low, giving the conch a depressed rounded triangular cross-section.

The specimens from the TDS are slightly concave

to nearly round on the ventral side, and the subtriangular cross-section indicates their assignment to *Microcornus*. They are similar to *M. eximius* Duan, 1984. *Microcornus petilus* Bengtson in Bengtson *et al.*, 1990 has a large apical angle and generally a finer ornamentation on the shell. These characteristics are not observed in the TDS specimens. They are more rounded compared to *M. breviligulatus* Qian, 1989 and *M. egregius* Demidenko in Gravestock *et al.*, 2001. Generally, according to Dzik (1978), the affiliation of the *Microcornus* specimens seems to be a problem because *Microcornus* should represent hyolithid larval stages. Due to poor preservation, the specimen is retained in open nomenclature.

OCCURRENCE: The genus *Microcornus* is reported from Cambrian Series 2 to Series 3 of Australia (Bengtson *et al.* 1990; Gravestock *et al.* 2001), Siberia (Kouchinsky *et al.* 2015), Mongolia (Missarzhevsky 1981), Greenland (Malinky and Skovsted 2004), North America (Wotte and Sundberg 2017), South China (Yang 2014), Antarctica (Wrona 2003), Germany (Elicki and Schneider 1992; Elicki 2007), Spain (Wotte 2006) and Turkey (Sarmiento *et al.* 2001).

Hyolithid indet.
(Pl. 2, Fig. 5)

MATERIAL: One specimen: FG 682-1673A/01 from core 1673A/81.

REMARKS: The conch is preserved in dorsal view as a composite mould. The operculum is poorly preserved and difficult to delimit from the surface of the conch. The conch exhibits an apical angle of about 15–20°; it is 6 mm long and the average width is 2 mm.

The specimen is poorly preserved, which prevents precise taxonomic assignment. Martí Mus and Bergström (2005) described the best preserved hyolithid conchs with articulated helens and an operculum of *Maxilites* Marek, 1972 from the Cambrian Series 3 of the Czech Republic (Peel 2010; Valent *et al.* 2013). The Czech specimens are preserved as moulds and exquisite details of the musculature and internal structures can be observed. Such details are not present in the TDS specimen. The general shape of the TDS specimen is similar to *Haplophrentis* Babcock and Robison, 1988, but due to very poor preservation, the specimen is only generally assigned as a hyolithid remain.

Order Orthothecida Marek, 1966
 Family Gracilithecidae Sysoev, 1972
 Genus *Gracilitheca* Sysoev, 1968

TYPE SPECIES: *Gracilitheca ternata* Sysoev, 1968,
 Terreneuvian to Cambrian Series 2, Siberia.

Gracilitheca sp.
 (Pl. 2, Figs 6–8)

MATERIAL: Three figured internal moulds: FG
 682-1209/15–17 from core 1209/78.

REMARKS: Phosphatic or silicified fragments of
 internal moulds. They are straight, with a triangular
 cross-section produced by concave ventral and arched
 dorsal sides. The latter is composed of flattened lat-
 eral portions forming a median longitudinal ridge on
 the top. The ventral side is also delimited by longi-
 tudinal ridges. The cross-section acquires a rounded
 triangular shape. The aperture and initial part are not
 preserved. The operculum is not preserved.

This specimen is assigned to *Gracilitheca* based
 on general morphological features and its specific
 triangular cross-section. The TDS specimens are
 preserved as internal moulds and retained in open
 nomenclature as the specimens do not preserve
 enough details.

OCCURRENCE: *Gracilitheca* is known from Siberia
 (Sysoev 1968), North America (Landing 1988),
 Morocco (Marek *et al.* 1997; Malinky and Skovsted
 2004), Czech Republic (Valent *et al.* 2013), and
 Germany (this report).

Family Cupithecidae Duan, 1984
 Genus *Cupitheca* Duan in Xing *et al.*, 1984

TYPE SPECIES: *Paragloborilus mirus* He in Qian,
 1977, Terreneuvian (upper Fortunian to lower Stage 2);
 South China.

?*Cupitheca* sp.
 (Pl. 2, Fig. 9)

MATERIAL: One internal mould: FG 682-1209/18
 from core 1209/78.

REMARKS: The specimen is an elongate tube,
 straight or slightly curved, with the proximal part
 terminating in a thinner and convex inflated sep-
 tum-like transverse wall. The cross-section is circu-

lar (Pl. 2, Fig. 9b). The surface of the tube is smooth.
 The operculum is not observed.

Bengtson in Bengtson *et al.* (1990) used *Actino-
 theca* Xiao and Zhou, 1984 as a generic name for
 decollating tubular fossils from the Terreneuvian to
 Cambrian Series 2. Because the name turned out to
 be occupied by a genus of tabulate corals *Actinotheca*
 French, 1889, Demidenko (2001) suggested that it
 should be replaced by the next valid junior synonym,
Cupitheca Duan in Xing *et al.*, 1984 (*Cupitheca* of
 Demidenko 2001). The generic name was spelled
 “*Cupittheca*” by Duan (in Xing *et al.* 1984, p. 152) but
 this appears to be a print error (Wrona 2003; Malinky
 and Skovsted 2004; see Demidenko in Gravestock
et al. 2001 for a detailed discussion).

The TDS specimen is assigned to *Cupitheca* be-
 cause it has features that fit the diagnosis, such as
 a straight conical tube with an apical termination
 created by a septum, and a circular cross-section.
 The conch is similar to *Actinotheca mira* He in Qian,
 1977 from South China (see discussion of the genera
Actinotheca and *Cupitheca* by Bengtson *et al.* 1990
 and Gravestock *et al.* 2001). According to Bengtson
 in Bengtson *et al.* (1990), the surface sculpture is
 a distinguishing feature of species belonging to
Cupitheca, which makes specific differentiation of
 internal moulds difficult. The TDS specimen rep-
 resents an internal mould with no external ornamen-
 tation, which makes assignment of the specimen to
 some of the taxa defined by Bengtson in Bengtson
et al. (1990) difficult. Nevertheless, the specimen is
 assigned to *Cupitheca* and left in open nomenclature.

OCCURRENCE: *Cupitheca* is known from Cam-
 brian strata in many localities worldwide: Siberia
 (Kouchinsky *et al.* 2017), China (Yang 2014), Antarc-
 tica (Wrona 2003), Australia (Bengtson *et al.* 1990;
 Skovsted *et al.* 2016), Greenland (Malinky and Sko-
 vsted 2004), Western Newfoundland (Skovsted and
 Peel 2007), Himalaya (Gilbert *et al.* 2016), Korea
 (Lee 2008), Spain (Jensen *et al.* 2010), and Germany
 (this report).

Order Orthothecida Marek, 1966
 Family Circothecidae Missarzhevsky in Rozanov *et
 al.*, 1969
 Genus *Conotheca* Missarzhevsky in Rozanov *et al.*,
 1969

TYPE SPECIES: *Conotheca mammilata* Missarzhev-
 sky in Rozanov *et al.*, 1969, Terreneuvian to Cambrian
 Series 2, Siberia.

Conotheca sp.
(Pl. 2, Fig. 10)

MATERIAL: One conch: FG 682-1209/19 from core 1209/78.

REMARKS: The specimen is gently curved with an oval to round cross-section (Pl. 2, Fig. 10b). In dorsal view, the apical angle is c. 15–20°. The shell is covered with closely though irregularly spaced transverse lines of varying intensity in the upper part of the conch.

Conotheca is not identifiable to species level when the operculum is not preserved, because the diagnostic morphologic features of the tubular conch are relatively few; they are limited mostly to the nature of ornamentation, apical angle and cross-section. In the TDS specimen, the absence of the operculum makes assignment of the conch to a species difficult. The TDS material is similar to *C. petasotheca* Landing and Bartowski, 1996, although assignment to *C. australiensis* Bengtson in Bengtson *et al.*, 1990, and *C. laurentiensis* Landing and Bartowski, 1996 cannot be excluded. The TDS conch is assigned to *Conotheca* and left in open nomenclature.

OCCURRENCE: *Conotheca* known from numerous Terreneuvian to Cambrian Series 3 successions: Siberia (Rozanov *et al.* 1969; Kouchinsky *et al.* 2017), Australia (Gravestock *et al.* 2001), China (Yang 2014), Spain (Wotte 2006), Germany (Elicki 2007), France (Devaere *et al.* 2013), Turkey (Sarmiento *et al.* 2001), North America (Landing 1988; Skovsted and Peel 2010), and Greenland (Malinky and Skovsted 2004).

Family and genus uncertain
Orthothecid conch indet.
(Pl. 2, Fig. 11)

MATERIAL: One internal mould: FG 682-1209/20 from core 1209/78.

REMARKS: The specimen is a gently curved tubular conch with an oval, almost circular cross-section, symmetrical about the plane, in which the tube is curved. The outer surface is smooth and no surface ornamentation is visible. The specimen is preserved as a phosphatic or calcareous internal mould. The conch is provisionally regarded as an orthothecid because of the circular cross-section. Due to poor preservation no further taxonomic details are determinable.

Phylum Brachiopoda Duméril, 1806
Class Lingulata Gorjansky and Popov, 1985
Order Lingulida Waagen, 1885
Superfamily Linguloidea Menke, 1828
Family Eoobolidae Holmer *et al.*, 1996
Genus *Eoobolus* Matthew, 1902

TYPE SPECIES: *Obolus triparilis* Matthew, 1902, Cambrian Series 3, Canada.

?*Eoobolus* sp.
(Pl. 3, Fig. 1)

MATERIAL: Fragment of ventral valve: FG 682-1209/23 from core 1209/78.

REMARKS: Incomplete specimen, only the upper shelf is preserved. The fragmentary ventral valve is convex. The pseudointerarea is close to an orthocline, triangular with a prominent deep pedicle groove, widening anteriorly. The ventral visceral area is indistinguishable to faintly discernible.

The brachiopod *Eoobolus* is one of the first representatives of the superfamily Linguloidea in the Terreneuvian (Balthasar 2009). The fragmentary specimen from the TDS resembles *Eoobolus* in some aspects of its general morphology, but not all the features of the species referred to that genus were observed on the specimen due to its incompleteness. The valve fragment described herein is very similar to the material described from Canada (Balthasar 2009), Siberia (Ushatinskaya and Korovnikov 2014), and China (Percival *et al.* 2016). However, the specimens from the TDS are only tentatively assigned to *Eoobolus?* and left in open nomenclature.

OCCURRENCE: *Eoobolus* is known from Cambrian Series 3 successions of Siberia (Ushatinskaya and Korovnikov 2014), Antarctica (Holmer *et al.* 1996), Australia (Betts *et al.* 2016), Greenland (Skovsted and Holmer 2005), Canada (Balthasar 2009), Canada (Matthew 1902), and also known from the Drumian strata of China (Percival *et al.* 2016).

Superfamily Linguloidea Menke, 1828
Family Obolidae King, 1846
Subfamily Obolinae King, 1846
Genus *Lingulella* Salter, 1866

TYPE SPECIES: *Lingula davisii* McCoy, 1851 from the Furongian of Wales, UK.

?Lingulella sp.

(Pl. 3, Fig. 2)

MATERIAL: One ventral valve fragment: FG 682-1691/01 from core 1691/81.

REMARKS: The specimen has a rounded elliptical outline and a wide rounded warble. The valve is gently convex and the shell is small (length 5.7 mm and width 3.6 mm), with the maximum width occurring at or slightly posterior to the mid-length of the valve. A growing strip is clear, other sculpture is not recognizable. Exterior ornament on the valve consists of fine, closely spaced growth lines with frequent small growth disruptions. Growth disruptions aligned laterally give the appearance of a faint radial ornament.

Species of *Lingulella* are geographically widespread, morphologically conservative, and stratigraphically long-ranging, which make this genus a catch for all elongate subacuminate oboliids with prominent external concentric growth lines (Brock and Cooper 1993). The general morphology of the studied specimen is as in *Lingulella*. The shell is not sufficiently characterized for a firm generic assignment, and therefore it is left in open nomenclature.

OCCURRENCE: *Lingulella* has been reported from Cambrian to Ordovician deposits worldwide.

Superfamily Acrotheloidea Walcott and Schuchert in
Walcott, 1908

Family Acrothelidae Walcott and Schuchert in
Walcott, 1908

Genus *Acrothele* Linnarsson, 1876

TYPE SPECIES: *Acrothele coriacea* Linnarsson, 1876, Cambrian Series 3, Sweden.

?Acrothele sp.

(Pl. 3, Fig. 3)

MATERIAL: One dorsal valve: FG 682-1673A/02 from core 1673A/81.

REMARKS: The shell is small and round in outline and the dorsal valve is slightly convex. The brephic shell is rounded and the valve bears two well-pronounced tubercles.

The specimen is poorly preserved, which make taxonomic determination difficult. The specimen from the TDS is similar to *Acrothele yurii* Ushatinskaya and Korovnikov, 2016, because the

umbo of the dorsal valve is near the posterior margin, which distinguishes *A. yurii* from other species of *Acrothele*. In addition, it differs from *A. olenekensis* Pelman and Pereladov, 1986 in having a rounded brephic shell, a small foramen confined to the brephic shell, and the presence of two pairs of tubercles on the brephic dorsal valve. Acrothelids are often determined and described in open nomenclature due to their strong intraspecific variability and incomplete preservation (Ushatinskaya and Korovnikov 2016). Accordingly, the described specimen is assigned to *Acrothele* and left in open nomenclature.

OCCURRENCE: *Acrothele* is reported from many Cambrian Series 3 successions around the world: Germany (Elicki 2007), Spain (Wotte and Mergl 2007), Czech Republic (Mergl and Šlehoverova 1990), North America (Robison 1964), Australia (Engelbretsen 1996), and Siberia (Ushatinskaya and Korovnikov 2016).

Class Obolellata Williams *et al.*, 1996

Order Obolellida Rowell, 1965

Family Trematobolidae Popov and Holmer, 2000

Genus *Trematobolus* Matthew, 1893

TYPE SPECIES: *Trematobolus insignis* Matthew, 1893, Terreneuvian to Cambrian Series 2, New Brunswick, Canada.

?Trematobolus sp.

(Pl. 3, Fig. 4)

MATERIAL: One dorsal valve: FG 682-1209/24 from core 1209/78.

REMARKS: The shell is large, dorsi-biconvex, subcircular in outline, and 14 mm wide. The dorsal valve is slightly convex (deformed specimen), widest at mid-length. Lateral margins are slightly curved (Pl. 3, Fig. 4a). The ornamentation consists of fine growth lamellae. The ventral view of the dorsal valve is subcircular in outline, slightly wider than long, with the maximum width occurring at the mid-length (Pl. 3, Fig. 4b). The posterior slope of the valve is steep, with a small, narrowly triangular pseudointerarea. Growth lines are often distinct over the entire surface of the pseudointerarea. Those growth lines are parallel to the anterior border of the pseudointerarea, which bears a pair of tooth-like, anterodorsally directed small nodes. The visceral area is not defined well.

The TDS specimen is similar to *Trematobolus* sp. described from limestones (3D preservation) by Geyer *et al.* (2014). Both the specimen described by Geyer *et al.* (2014) and the specimen described herein were collected from core 1209/78, at the depth of 305–340 m and 400–420 m, respectively. The specimen described herein is strongly deformed (preservation in siltstone), which make precise determination difficult. However, due to the mentioned characteristics and the similarity between the two specimens, I follow the discussion given by Geyer *et al.* (2014) and tentatively assign the studied specimen to *Trematobolus* sp.

OCCURRENCE: *Trematobolus* is known from Spain (Liñán and Mergl 2001), Germany (Geyer *et al.* 2014), Morocco (Geyer and Mergl 1995), and Jordan (Geyer and Mergl 1995).

Phylum Hemichordata Bateson, 1885

Class Pterobranchia Lankester, 1877

Subclass Graptolithina? Bronn, 1849

Family Rhabdopleuridae? Fowler, 1892

Genus *Sphenoecium* Chapman and Thomas, 1936

TYPE SPECIES: *Sphenothallus filicoides* Chapman, 1917, Cambrian Series 3, Heathcote and Monegeeta districts of Victoria, Australia; by subsequent designation of Bulman (1970, p. V57).

?*Sphenoecium* sp.

(Pl. 3, Fig. 5)

MATERIAL: One specimen: FG 682-1691/02 from core 1691/81.

REMARKS: The tubarium of the specimen is composed of numerous elongate, slender and parallel-sided tubes. Tubes are preserved as thin flat films that lack obvious evidence of folding or wrinkling, and are distinguished from the surrounding shale by their smoother texture and darker brown colour. The tube form is slightly flexuous; definitive branching is not evident. Individual tubes are c. 4–10 mm long. The tube width gradually increases from approximately 0.1 mm in the proximal area to 0.4 mm at mid-length and 0.5 mm at the aperture (Pl. 3, Fig. 5). The apertures are simple, without an obvious lip or ornamentation. Fusellar banding and occasional oblique sutures are not well defined due to poor preservation.

The TDS specimen shares general characteristics with the genus *Sphenoecium*. The genus name

was introduced by Chapman and Thomas (1936) as a replacement for the name *Sphenothallus* Chapman, 1917, recognized as a junior homonym of *Sphenothallus* Hall, 1847. *Fascillitubus* Obut and Sobolevskaya, 1967 can be regarded as a synonym of *Sphenoecium*.

Sphenoecium is a tubarium construction of colonial pterobranchs from short creeping and branching, slowly widening organic tubes; the tubes are formed from fusellar half-rings or full-rings with irregularly developed oblique sutures (Maletz and Steiner 2015). The construction of the tubarium of *Sphenoecium* is known from chemically isolated fragments of *S. johanssoni* Bengtson and Urbanek, 1986 (see Maletz and Steiner 2015). Individual thecae in the TDS specimen are smaller than in *S. mesocambrius* Öpik, 1933 and *S. discoidalis* Chapman and Thomas, 1936. The erect thecal tubes are not widely spaced, which excludes the TDS specimen from *S. obuti* Durman and Sennikov, 1993. The specimen described herein is most similar to *S. wheelerensis* Maletz and Steiner, 2015. Due to the poor preservation, the specimen is retained in open nomenclature.

OCCURRENCE: Pterobranch remains are known from all continents, except for Antarctica, and commonly found in the Cambrian Series 3, Stage 5 strata (Maletz and Steiner 2015). They are known from the Cambrian Series 3 to Furongian of Sweden (Öpik 1933), Siberia (Obut 1964, 1974), Australia (Rickards *et al.* 1990), China (Zhao *et al.* 2011; Maletz and Steiner 2015), North America (Walcott 1919; LoDuca *et al.* 2015), Spain (Sdzuy 1974), Czech Republic (Maletz *et al.* 2005), and Germany (this report).

Phylum uncertain

Class Coeloscleritophora Bengtson and Missarzhevsky, 1981

Order Chancelloriida Walcott, 1920

Family Chancelloriidae Walcott, 1920

Genus *Chancelloria* Walcott, 1920

TYPE SPECIES: *Chancelloria eros* Walcott, 1920, Burgess Shale Formation, Cambrian Series 3, Canada.

Chancelloria sp.

(Pl. 4, Figs 1–4)

MATERIAL: Four figured internal moulds of isolated sclerites: FG 682-1209/25, 26, 27, and 28 from core 1209/78, plus many additional isolated single rays.

REMARKS: Due to the presence of isolated sclerites, poor preservation and broken nature of the specimens, no detailed systematic affiliation can be given. The sclerites have three to five lateral rays (3–5+0). Such forms are relatively rare in *Chancelloria*. Sclerites of 4–5+0 type are similar to those of *Chancelloria eros* Walcott, 1920 (Bengtson *et al.* 1990). The sclerite of 3+0 type (Pl. 4, Fig. 3) may derive from *Allonnia* sp. Generally, the morphology of the TDS material may suggest affinity to the genus *Chancelloria* and is retained in open nomenclature.

OCCURRENCE: *Chancelloria* is extremely common among Cambrian microfaunas worldwide.

Genus *Archiasterella* Sdzuy, 1969

TYPE SPECIES: *Archiasterella pentactina* Sdzuy, 1969, Terreneuvian to Cambrian Series 2, Cazalla de la Sierra, Ossa Morena, Spain.

Archiasterella cf. *hirundo* (Bengtson in Bengtson *et al.*, 1990)
(Pl. 4, Fig. 5)

MATERIAL: One single spicule: FG 682-1209/29 from core 1209/78, plus numerous probably related single rays.

REMARKS: The sclerite has 4+0 rays and is distinctly bilaterally symmetrical. The lateral rays typically meet in a sagittal suture. The two lateral rays are slightly recurved upwards away from the basal plane. The vertical ray is strongly curved upward. The posterior ray is long and straight.

The TDS sclerite resembles the well-characterized species *A. hirundo* (Bengtson *et al.* 1990). Many *Archiasterella* species have the ray formulae other than the 4+0 condition. The TDS sclerite has 4+0 rays, therefore comparison with other species is restricted only to species with this condition. *Archiasterella tetractina* Duan, 1984 has 4+0 rays, but lacks a recurved adapical ray suggesting that it may not actually belong within *Archiasterella* (Randell *et al.* 2005). Two specimens of Vasil'eva and Sayutina (1988) were illustrated as the new species *A. tetractina* (non Duan, 1984) that was later renamed as *A. tetraspina* (Vasil'eva in Vasil'eva and Sayutina, 1993). According to Moore *et al.* (2014), this material may also not represent *Archiasterella*. Lee and Lee (1988) described a new species based upon a single incomplete sclerite with a 4+0 con-

dition. This sclerite is too incomplete to determine whether any of the rays is oriented differently from the others, and thus its assignment to *Archiasterella* remains uncertain. However, the configuration and arrangement of rays of the TDS spicule suggest a most probable affiliation with *A. hirundo*. Due to the poor preservation (no surface structures), the TDS spicule is referred to as *Archiasterella* cf. *hirundo*.

OCCURRENCE: *Archiasterella hirundo* is known from Cambrian Series 2 of South Australia, Germany, Spain, Turkey, and southern China (Bengtson *et al.* 1990; Elicki 1994, 2011; Fernández-Remolar 2001; Sarmiento *et al.* 2001).

Phylum Echinodermata Klein, 1734

Class, order and family uncertain
Echinoderm ossicles indet.

(Pl. 4, Figs 6–15)

MATERIAL: Nine figured specimens: FG 682-1209/30–38 from core 1209/78, plus several indeterminate echinoderm ossicles.

REMARKS: The specimens recovered from the TDS samples show a wide range of morphology of disarticulated plates with a microporous stereome microstructure. The morphology of the thecal plates ranges from platy, irregular brick-like segments to rounded or polygonal in outline. This morphology is typical for eocrinoids and edrioasteroids. However, no assignment to a particular taxon is possible. It is generally difficult to determine the systematic affinity of such disarticulated thecal plates. Also, the value of echinoderm residues preserved as isolated ossicles is generally limited. Only in some cases, it is possible to suggest some wider systematic affinity. The specimens are illustrated here for a complete record of the microfaunal assemblage.

OCCURRENCE: Reported from Cambrian successions worldwide.

Class Polyplacophora De Blainville, 1816

Order Sachitida He, 1980

Family Siphogonuchitidae Qian, 1977

Genus *Siphogonuchites* Qian, 1977

?Siphogonuchitid indet.

(Pl. 2, Fig. 13)

MATERIAL: One phosphatic internal mould: FG 682-1209/22 from core 1209/78.

REMARKS: The phosphatic specimen is flattened, elongated, and curved. The upper side carries one prominent longitudinal ridge that continues all the way from the base to the top. The lower side is concave and has a flattened surface. The cross-section is angled to irregularly subtriangular with a rounded corner. The apex is unknown due to poor preservation.

The Family Siphogonuchitidae was introduced by Qian (1977) with the original generic content of *Siphogonuchites*, *Palaeosulcachites* Qian, 1977, *Carinachites* Qian, 1977, *Lopochites* Qian, 1977, with many genera later added to this family. The main feature which excludes the affiliation of the studied specimen to *Protohertzina* and *Amphigeisina* is the shape of the upper side. One prominent longitudinal ridge is present in the studied specimen, whereas in *Protohertzina* the median ridge is bordered by two usually distinct lateral ridges and in *Amphigeisina* it is flat with two lateral ridges from the base to the top.

The specimen shows similarity to the material reported from Cambrian Series 2 of eastern Greenland (Skovsted 2006), and from southern China and northern Iran (Qian and Bengtson 1989; Steiner *et al.* 2004). The preservation of this specimen is too poor for precise determination. Siphogonuchitids are typical elements of the Cambrian Terreneuvian skeletal fauna and are mostly grouped within the class Coeloscleritomorpha Bengtson and Missarzhevsky, 1981.

OCCURRENCE: Siphogonuchitids are known mainly from Asia: China (Steiner *et al.* 2004), Mongolia (Esakova and Zhegallo 1996), Siberia (Khomentovsky *et al.* 1990), but have been also reported from other Cambrian successions: Australia (Bengtson *et al.* 1990), Greenland (Skovsted 2006), France (Devaere *et al.* 2013), Iran (Hamdi 1995), Jordan (Elicki 2011), and for the first time from Germany (this report).

Phylum Chaetognatha? Leuckart, 1854
Class, order, and family uncertain
Genus *Amphigeisina* Bengtson, 1976

TYPE SPECIES: *Hertzina? danica* Poulsen, 1966; Terreneuvian to Cambrian Series 3, Bornholm, Denmark.

Amphigeisina sp.
(Pl. 2, Fig. 12)

MATERIAL: One sclerite: FG 682-1209/21 from core 1209/78.

REMARKS: The specimen is a long, slender and gently curved, simple, bilaterally symmetrical sclerite. A relatively narrow concave side extends from the tip towards the base. The upper side is broader, flat with two lateral ridges from the base to the top, and opens in the slightly flared basal part. The internal cavity extends to the tip. The wall is probably composed of two layers, but this is not clear because of poor preservation. The surface is smooth. The two sides meet to produce two longitudinal carinae flanked by two thin flanges formed by the outer layer. The flanges reduce gradually towards the tip, where they merge with the carinae.

The specimen described here from the TDS is the first report on the presence of *Amphigeisina* from Germany. The specimen is very similar to *Amphigeisina danica* (Poulsen, 1966) described from Cambrian Series 3 strata in Siberia (Demidenko 2006; Kouchinsky *et al.* 2015). A similar taxon is *Protohertzina* Missarzhevsky, 1973, but the upper side of the latter has a median ridge bordered by two usually distinct lateral ridges, which exclude the affiliation of the TDS specimen to this genus. The TDS specimen is similar to *Amphigeisina danica* but due to the poor preservation it is retained in open nomenclature.

OCCURRENCE: *Amphigeisina* is known from the UK (Hinz 1987), North America (Landing 1974), Denmark (Poulsen 1966; Bengtson 1976), and China (Steiner *et al.* 2007).

DISCUSSION AND CONCLUSIONS

The SSF specimens examined in this contribution were mostly collected from drill core 1209/78 (Text-fig. 4), from very rare and thin carbonate coquina layers that occur occasionally in the lower part of the generally siliciclastic Cambrian Series 3, Stage 5 succession of the TDS. Only a few other taxa are described here from siliciclastic strata of other drill cores (nos. 1673A/81 and 1691/81) that were so far not investigated palaeontologically. The SSF fauna consists of pelagiellid molluscs, bivalves, hyoliths, chancelloriids, poriferids, protoconodonts, cambroclavids, brachiopods, and problematic fossils (siphogonuchitids?), as well as undeterminable echinoderm remains (Table 1; Text-fig. 4). The preservation of the biota is rather poor. Diagenetic overprint led largely

| Region | West Gondwana | | | | | | | | | |
|--|---------------|-----|----|----------|---------|-------|--------|----------------|--------|---|
| | Germany | | | Sardinia | Morocco | Spain | France | Czech Republic | Turkey | |
| | This study | TDS | GS | | | | | | | |
| Molluscs | | | | | | | | | | |
| <i>Pelagiella</i> sp. | × | | × | × | × | × | | | | |
| <i>Pojetaia</i> cf. <i>runnegari</i> | × | | × | | × | | | | | × |
| Cambroclaves | | | | | | | | | | |
| <i>Cambroclavus</i> sp. | × | × | × | × | | × | × | | | |
| Porifers | | | | | | | | | | |
| <i>Eiffelia</i> <i>araniformis</i> | × | | × | | | | | | | × |
| Hyaloliths | | | | | | | | | | |
| <i>Microcornus</i> sp. | × | | × | | | × | | | | × |
| Hyalithid indet. | × | | | | | | | | | |
| <i>Gracilitheca</i> sp. | × | | | | × | | | × | | |
| ? <i>Cupithec</i> a sp. | × | | | | | × | | | | |
| <i>Conotheca</i> sp. | × | | | | | × | × | | | × |
| Orthothecid conch indet. | × | | | | | | | | | |
| Brachiopods | | | | | | | | | | |
| ? <i>Eoobolus</i> sp. | × | | | | | | | | | |
| ? <i>Lingulella</i> sp. | × | × | | | | × | | × | | |
| ? <i>Acrothele</i> sp. | × | × | | | | × | × | | | |
| ? <i>Trematobolus</i> sp. | × | × | | | × | × | | | | |
| Hemichordates | | | | | | | | | | |
| ? <i>Sphenoecium</i> sp. | × | | | | | × | | × | | |
| Chancelloriids | | | | | | | | | | |
| <i>Chancelloria</i> sp. | × | × | × | | | × | × | | | × |
| <i>Archiasterella</i> cf. <i>hirundo</i> | × | × | × | | | × | × | | | × |
| Miscellaneous taxa | | | | | | | | | | |
| Echinoderm ossicles indet. | × | × | × | × | × | × | × | × | × | × |
| ?Siphonochitid indet. | × | | | | | | × | | | |
| <i>Amphigeisina</i> sp. | × | | | | | | | | | |

Table 1. Faunal comparisons and distribution of western Gondwana taxa within the described Cambrian fauna from Germany. Sources: see the text for references. Abbreviations: GS – Görlitz Syncline; TDS – Torgau-Doberlug Syncline

to replacement of the original mineralogy (pseudomorphs) and to the subsequent dissolution of the shells. Additionally, there was loss of pseudomorphs in some cases due to the nature of the applied chemical preparation. However, in the cases when the original mineralogy was transformed into phosphate or when steinkerns were formed, micropalaeontological investigation was possible to some extent.

The microfauna collected from drill cores 1673A/81 and 1691/81 are new for the TDS (Text-fig. 4); some of the SSFs reported from drill core 1209/78 have previously been known from this region (Geyer *et al.* 2014), but others represent the first evidence for these forms in the TDS and in Central Europe in general (Text-fig. 4). The trilobite remains described by Geyer *et al.* (2014) from drill core 1209/78 and the SSFs described here were collected from the same interval. The trilobites such as *Protolenus* (*Hupeolenus*)

bergstroemi, *Cambrunicornia saxonica*, and *Ornamentaspis*? aff. *todraensis* Geyer, 1990 correspond to the earliest middle Cambrian (approximately Cambrian Stage 5). The brachiopod *Trematobolus* with its short stratigraphic range fits very well to this interpretation. As already stated by Geyer *et al.* (2014), based mainly on the trilobite content, the metazoan fauna from drill core 1209/78 represents the oldest middle Cambrian Series 3 (Stage 5) fauna of the whole Saxothuringian Zone. The SSF assemblage reported here is rather typical for the carbonate environments of Cambrian Series 2 and Series 3 (Stage 5) successions from Sardinia, Morocco, Spain, Czech Republic, and Turkey, which means they are similar over the whole of West Gondwana (Elicki 1994, 2007; Fernández Remolar 1999; Sarmiento *et al.* 2001).

Palaeoecologically, the shelly fauna is clearly dominated by epifaunal suspension feeders. The

limited grain size of the sediments and the related sedimentological features point to a rather distal depositional environment (mid- to outer shelf). It can be assumed that areas with a higher carbonate content and an enriched shelly fauna existed more proximally. From there material was redeposited or transported to a distal area by occasional storms producing thin coquina layers.

The described SSF fauna is similar to assemblages reported from more-or-less all West Gondwanan successions (Sardinia, Morocco, Spain, Czech Republic and Turkey) and shows a distinct relation to the Mediterranean shelf of West Gondwana (Table 1). Nevertheless, some of the biota have a rather widespread palaeogeographic distribution. Common molluscs (*Pelagiella* and *Pojetaia*) occurred along the Gondwanan margins (Elicki 1994, 1996, 2007). Cambroclaves are reported from Sardinia, Australia, Kazakhstan, China, Spain, and Germany (Mambetov and Repina 1979; Bengtson *et al.* 1990; Elicki and Wotte 2003; Elicki 2007; Wotte 2009). The graptolite *Sphenoecium* sp. is common from Cambrian Series 3 and known from all continents, except for Antarctica. It has been reported from Central Europe (Czech Republic, Spain; Table 1), and for the first time from Germany (Sdzuy 1974; Maletz *et al.* 2005; Maletz and Steiner 2015). The most robust palaeogeographic indications come from the trilobites as already published by Geyer *et al.* (2014). These data point to close connections with other West Gondwana regions (Morocco, Spain).

According to Elicki (2007), the palaeontological data from Central Europe contradicts the hypothesis of deposition of Cambrian strata within separate pull-apart basins as formerly assumed. The Cambrian fauna known previously from Germany and the new SSF assemblage reported herein indicate a rather wide geographical distribution in other parts of West Gondwana (Table 1). This wide distribution needs not only open-marine conditions but also long-duration migration paths for faunal exchange between these parts of West Gondwana (Sdzuy 1972; Elicki and Debrenne 1993; Elicki 1994, 2007; Geyer and Elicki 1995; Liñán *et al.* 2004).

It is generally concluded that the fauna described herein from the carbonate layers of the TDS is well known from many Cambrian Series 2 to Series 3 successions deposited in low-latitude environments. Nevertheless, some of the taxa may support a somewhat closer relation to West Gondwana (Morocco, Spain, Sardinia, Czech Republic, Turkey; Table 1). The similarity in the biota and the sedimentary facies of Cambrian successions in West Gondwana indi-

cates that these successions were located quite close to each other during the entire Cambrian at least until the beginning of the Early Ordovician (Sdzuy 1972; Elicki and Debrenne 1993; Geyer and Elicki 1995; Álvaro *et al.* 1998; Sarmiento *et al.* 2001; Liñán *et al.* 2004; Elicki 2007).

General progress and more detailed studies of small shelly fossils and also of palynomorphs (see Atnisha *et al.* 2017b) will allow for a more consistent stratigraphic correlation and palaeogeographic reconstruction of the TDS and other West Gondwana regions.

Acknowledgments

Many thanks go to Olaf Elicki (Freiberg University) for helpful discussions and multifaceted support, to the Geological Survey of Brandenburg (LBGR) for permission to sample drill cores from the TDS, and to Michael Göthel (LBGR) for the interest, help and discussions during the project. I am grateful to Ed Landing, Thomas Wotte, and Jerzy Dzik for their reviews and comments. This research was financially supported by the Department of Palaeontology of Freiberg University, by grants from the Libyan Government represented by the Higher Education Section, and by short-time scholarships donated by Freiberg University.

REFERENCES

- Álvaro, J.J., Elicki, O., Debrenne, F. and Vizcaino, D. 2002. Small shelly fossils from the lower Cambrian Lastour Formation, southern Montagne Noire, France. *Geobios*, **35**, 397–409.
- Álvaro, J.J., Liñán, E. and Vizcaíno, D. 1998. Biostratigraphical significance of the genus *Ferralsia* (Lower Cambrian, Trilobita). *Geobios*, **31**, 499–504.
- Álvaro, J.J., Vennin, E., Moreno-Eiris, E., Perejón, A. and Bechstäd, T. 2000. Sedimentary patterns across the Lower Middle Cambrian transition in the Esla nappe (Cantabrian Mountains, northern Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **137**, 43–61.
- Atnisha, A., Fatka, O. and Elicki, O. 2017b. First evidence of middle to late Cambrian deposition by first palynological data from the Torgau-Doberlug Syncline (subsurface Central Germany, Mediterranean shelf of Gondwana). *Journal of Iberian Geology*, **43**, 601–614.
- Atnisha, A., Hofman, M., Gärtner, A., Linnemann, U. and Elicki, O. 2017a. First U-Pb geochronology on detrital zircons from Early–Middle Cambrian strata of the Torgau-Doberlug Syncline (eastern Germany) and palaeogeographic implications. *International Journal of Earth Sciences*, **7**, 2445–2459.

- Babcock, L.E. and Robison, R.A. 1988. Taxonomy and paleobiology of some Middle Cambrian *Scenella* (Cnidaria) and hyolithids (Mollusca) from western North America. *University of Kansas Paleontological Contributions*, **121**, 1–22.
- Balthasar, U. 2009. The brachiopod *Eoobolus* from the Early Cambrian Mural Formation (Canadian Rocky Mountains). *Paläontologische Zeitschrift*, **83**, 407–418.
- Barrande, J. 1846. Notice préliminaire sur le système silurien et les trilobites de Bohême, vi + 96 p. Hirschfeld; Leipzig.
- Bateson, W. 1885. The later stages in the development of *Balanoglossus kowalevskii*, with a suggestion as to the affinities of the Enteropneusta. *Quarterly Journal of Microscopical Science*, **25**, 81–122.
- Bengtson, S. 1976. The structure of some Middle Cambrian conodonts, and the early evolution of conodont structure and function. *Lethaia*, **9**, 185–206.
- Bengtson, S. 2004. Early skeletal fossils. In: Lipps, J.H. and Waggoner, B.M. (Eds), Neo-proterozoic–Cambrian Biological Revolutions. *The Paleontological Society*, **10**, 67–77.
- Bengtson, S. and Conway Morris, S. 1992. Early radiation of biomineralizing phyla. In: Lipps, J.H. and Signor, P.W. (Eds), Origin and Early Evolution of the Metazoa, pp. 447–481. Plenum Press; New York.
- Bengtson, S., Conway Morris, S., Cooper, B.J., Jell, P.A. and Runnegar, B.N. 1990. Early Cambrian fossils from South Australia. *Association of Australasian Palaeontologists Memoir*, **9**, 1–364.
- Bengtson, S. and Missarzhevsky, V.V. 1981. Coeloscleritophora – a major group of enigmatic Cambrian metazoans. *U.S. Geological Survey Open-file Report*, **81-743**, 19–21.
- Bengtson, S. and Urbanek, A. 1986. *Rhabdotubus*, a Middle Cambrian rhabdopleurid hemichordate. *Lethaia*, **19**, 293–308.
- Betts, M.J., Paterson, J.R., Jago, J.B., Jacquet, S.M., Skovsted, C.B., Topper, T.P. and Brock, G.A. 2016. A new lower Cambrian shelly fossil biostratigraphy for South Australia. *Gondwana Research*, **36**, 176–208.
- Bowerbank, J.S. 1864. A Monograph of the British Spongiadae, 289 p. Robert Hardwicke; London.
- Brasier, M.D. and Singh, P. 1987. Microfossils and Pre-Cambrian–Cambrian boundary strata at Maldeota, Lesser Himalaya. *Geological Magazine*, **124**, 323–345.
- Brause, H. 1969. Das verdeckte Altpaläozoikum der Lausitz und seine regionale Stellung. *Abhandlungen der Deutschen Akademie der Wissenschaften Berlin, Klasse für Bergbau, Hüttenwesen und Montangeologie*, **1**, 1–143.
- Brause, H. 1970. Ein neuer wichtiger Aufschluß im Kambrium von Doberlug–Kirchhain. *Geologie*, **19**, 1048–1065.
- Brause, H. and Elicki, O. 1997. Kambrium. In: Steininger, F.F. (Ed.), Stratigraphie von Deutschland, II. Ordovizium, Kambrium, Vendium, Riphäikum, Teil I. *Courier Forschungsinstitut Senckenberg*, **200**, 308–322.
- Brock, G.A. and Cooper, B.J. 1993. Shelly fossils from the Early Cambrian (Toyonian) Wirrealpa, Aroona Creek and Ramsay Limestones of South Australia. *Journal of Paleontology*, **67**, 758–787.
- Bronn, H.G. 1849. Handbuch der Geschichte der Natur. Dritter Band, Zweite Abtheilung. II. Theil: Organisches Leben (Schluß). Index palaeontologicus oder Ueberblick der bis jetzt bekannten fossilen Organisme, 1106 p. Schweizerbart'sche Verlagsbuchhandlung; Stuttgart.
- Bulman, O.M. 1970. Graptolithina. In: Teichert, C. (Ed.), Treatise on Invertebrate Paleontology, Part V (revised), pp. 1–163. Geological Society of America and University of Kansas Press; Lawrence.
- Buschmann, B. 1995. Tectonic facies analysis of the Rothstein Formation (Neoproterozoic, Saxothuringian Zone, E Germany), 167 p. Unpublished PhD Thesis, Technische Universität Bergakademie Freiberg.
- Buschmann, B., Elicki, O. and Jonas, P. 2006. The Cadomian unconformity in the Saxo-Thuringian Zone, Germany: palaeogeographic affinities of Ediacaran (terminal Neoproterozoic) and Cambrian strata. *Precambrian Research*, **147**, 387–403.
- Buschmann, B., Linnemann, U., Schneider, J. and Süß, T. 1995. Die cadomische Entwicklung im Untergrund der Torgau–Doberluger Synklinale. *Zeitschrift für Geologische Wissenschaften*, **23**, 729–749.
- Chang, S., Feng, Q., Clausen, S. and Zhang, L. 2017. Sponge spicules from the lower Cambrian in the Yanjiahe Formation, South China: The earliest biomineralizing sponge record. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **474**, 36–44.
- Chapman, F. 1917. Report on Cambrian fossils from Knowley East, near Heathcote. *Geological Survey of Victoria, Records*, **4**, 87–102.
- Chapman, F. and Thomas, D.E. 1936. The Cambrian Hydroidea of the Heathcote and Monegeeta Districts. *Proceedings of the Royal Society of Victoria, New Series*, **48**, 193–212.
- Conway Morris, S. 1988. Metazoan evolution near the Precambrian–Cambrian boundary: use and misuse of small shelly fossils. *New York State Museum Bulletin*, **463**, 9–10.
- Conway Morris, S. and Chen, M. 1991. Cambroclaves and paracarinachitids, early skeletal problematica from the Lower Cambrian of south China. *Palaentology*, **34**, 357–397.
- Cuvier, G. 1797. Tableau élémentaire de l'histoire naturelle des animaux, 710 p. Baudouin; Paris.
- Dawson, J.W. 1868. Acadian geology. The geological structure, organic remains and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, etc., 2, 694 p. MacMillan and Co.; London.
- De Blainville, H.M. 1816. Prodrome d'une nouvelle distribution systématique du règne animal. *Bulletin de la Société Philomatique de Paris*, **8**, 113–124.
- Debrenne, F. and Debrenne, M. 1978. Archaeocyathid fauna of the lowest fossiliferous levels of Tiout (Lower Cambrian, southern Morocco). *Geological Magazine*, **115**, 1–119.

- Demidenko, Yu.E. 2001. Small shelly fossils. In: Alexander, E.M., Jago, J.B., Rozanov, A.Yu. and Zhuravlev, A.Yu. (Eds), The Cambrian biostratigraphy of the Stansbury Basin, South Australia. *Transactions of the Palaeontological Institute, Russian Academy of Sciences*, **282**, 85–117.
- Demidenko, Yu.E. 2006. New Cambrian lobopods and chaetognaths of the Siberian Platform. *Paleontological Journal*, **40**, 234–243.
- Devaere, L., Clausen, S., Steiner, M., Álvaro, J.J. and Vachard, D. 2013. Chronostratigraphic and palaeogeographic significance of an early Cambrian microfauna from the Heraulia Limestone, northern Montagne Noire, France. *Palaeontologia Electronica*, **16**, 1–91.
- Doré, F. and Reid, R.E. 1965. *Allonnia tripodophora* nov. gen., nov. sp., nouvelle Eponge du Cambrien inférieur de Carteret (Manche). *Comptes Rendus Sommaires des Séances de la Société Géologique de France*, **1**, 20–21.
- Duan, C.H. 1984 (for 1983). Small shelly fossils from the Lower Cambrian Xihaoping Formation in the Shennongjia District, Hubei Province – hyoliths and fossil skeletons of unknown affinities. *Bulletin of the Tianjin Institute of Geology and Mineral Resources*, **7**, 143–188. [In Chinese with English summary]
- Duméril, A.M. 1806. Zoologie analytique, ou méthode naturelle de classification des animaux, 364 p. Allais; Paris.
- Durman, P.N. and Sennikov, N.V. 1993. A new rhabdopleurid hemichordate from the Middle Cambrian of Siberia. *Palaeontology*, **36**, 283–296.
- Dzik, J. 1978. Larval development of hyolithids. *Lethaia*, **11**, 293–299.
- Dzik, J. 1994. Evolution of “small shelly fossil” assemblages. *Acta Palaeontologica Polonica*, **39**, 247–313.
- Dzik, J. and Mazurek, D. 2013. Affinities of the alleged earliest Cambrian gastropod *Aldanella*. *Canadian Journal of Zoology*, **91**, 914–923.
- Elicki, O. 1994. Lower Cambrian carbonates from eastern Germany: palaeontology, stratigraphy and palaeogeography. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, **191**, 69–93.
- Elicki, O. 1996. Die Gastropoden und Monoplacophoren der unterkambrischen Görlitz Fauna. *Freiberger Forschungshefte C*, **464**, 145–173.
- Elicki, O. 1997. Biostratigraphic data of the German Cambrian – present state of knowledge. *Freiberger Forschungshefte C*, **466**, 155–166.
- Elicki, O. 1998. First report of *Halkieria* and enigmatic globular fossils from the central European Marianian (Lower Cambrian, Görlitz Syncline, Germany). *Revista Española de Paleontología, número extraordinario, Homenaje al Prof. Gonzalo Vidal*, 51–64.
- Elicki, O. 1999a. Beitrag zur Lithofacies und zur Lithostratigraphie im Unterkambrium von Doberlug-Torgau. *Freiberger Forschungshefte C*, **481**, 107–119.
- Elicki, O. 1999b. Palaeoecological significance of calcimicrobial communities during ramp evolution: an example from the Lower Cambrian of Germany. *Facies*, **41**, 27–40.
- Elicki, O. 2001. Fazies und Genese kambrischer Knollenkalke des nördlichen Ilesiente (Gutturu Pala, SW-Sardinien, Italien). *Zentralblatt für Geologie und Paläontologie*, **1**, 33–54.
- Elicki, O. 2003. Das Kambrium Sachsens. *Veröffentlichungen des Museums für Naturkunde Chemnitz*, **26**, 41–62.
- Elicki, O. 2005. The utility of late Early to Middle Cambrian small shelly fossils from the western Mediterranean: *Geosciences Journal*, **9**, 161–171.
- Elicki, O. 2006. Microbiofacies analysis of Cambrian offshore carbonates from Sardinia (Italy): environment reconstruction and development of a drowning carbonate platform. *Carnets de Géologie / Notebooks on Geology*, **1**, 1–22.
- Elicki, O. 2007. Paleontological data from the Early Cambrian of Germany and paleobiogeographical implications for the configuration of central Perigondwana. *Geological Society of America, Special Paper*, **423**, 143–152.
- Elicki, O. 2011. First skeletal microfauna from the Cambrian Series 3 of the Jordan Rift Valley (Middle East). *Memoirs of the Association of Australasian Palaeontologists*, **42**, 153–173.
- Elicki, O. 2015. Kambrium. In: Stackebrandt, W. and Franke, D. (Eds), *Geologie von Brandenburg*, pp. 51–59. E. Schweizerbart'sche Verlagsbuchhandlung; Stuttgart.
- Elicki, O. and Debrenne, F. 1993. The Archaeocyatha of Germany. *Freiberger Forschungshefte C*, **450**, 3–40.
- Elicki, O. and Geyer, G. 2013. The Cambrian trilobites of Jordan – taxonomy, systematic and stratigraphic significance. *Acta Geologica Polonica*, **63**, 1–56.
- Elicki, O. and Gürsu, S. 2009. First record of *Pojetaia runnegari* Jell, 1980 and *Fordilla Barrande*, 1881 from the Middle East (Taurus Mountains, Turkey) and critical review of Cambrian bivalves. *Paläontologische Zeitschrift*, **83**, 267–291.
- Elicki, O. and Pillola, G.L. 2004. Cambrian microfauna and palaeoecology of the Campo Pisano Formation at Gutturu Pala (Iglesiente, SW Sardinia, Italy). *Bolletino della Società Paleontologica Italiana*, **43**, 383–401.
- Elicki, O. and Schneider, J. 1992. Lower Cambrian (Atdabanian/Botomian) shallow-marine carbonates of the Görlitz Syncline (Saxony/Germany). *Facies*, **26**, 55–66.
- Elicki, O. and Wotte, T. 2003. Cambroclaves from the Cambrian of Sardinia (Italy) and Germany: constraints for the architecture of western Gondwana and the palaeogeographical and paleoecological potential of cambroclaves. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **195**, 55–71.
- Engelbretsen, M.J. 1996. Middle Cambrian lingulate brachiopods from the Murrawong Creek Formation, northeastern New South Wales. *Historical Biology*, **11**, 69–99.
- Esakova, N.V. and Zhegallo, E.A. 1996. Biostratigraphy and fauna of the Lower Cambrian of Mongolia. In: Rozanov, A.Yu. (Ed.), *Trudy Sovmestnoj Rossijsko-Mongol'skoj Paleontologičeskoj Ekspeditsii*, **46**, 1–216. [In Russian]

- Fernández Remolar, D.C. 1999. The phosphorite limestones of the Lower Ovetiense of the Sierra de Córdoba, Spain. *Bulletin of the Spanish Royal Society of Natural History, Geological Section*, **95**, 15–45.
- Fernández Remolar, D.C. 2001. Chancelloridae del Ovetiense Inferior de la Sierra de Córdoba, España. *Revista Española de Paleontología*, **16**, 39–62.
- Fernández Remolar, D.C. 2005. Primer registro de los géneros *Actinotheca* Xiao & Zou, 1984 y *Conotheca* Missarzhevsky, 1969 en el Cámbrico Inferior de la Península Ibérica. In: Gámez Vintaned, J.A., Liñán, E. and Valenzuela Ríos, J.I. (Eds), *Jornadas Aragonesas de Paleontología* **8**, 71–88. Institución Fernando el Católico, Zaragoza.
- Fowler, G.H. 1892. The morphology of *Rhabdopleura normani* Allm. In: Leuckarts, G.R. (Ed.), *Festschrift zum siebzigsten Geburtstag Rudolf Leuckarts*, pp. 293–297. Engelmann; Leipzig.
- French, F. 1889. Anthozoa. In: Holzapfel, E. (Ed.), *Carbon von Erdbach-Breitscheid bei Herborn. Paläontologische Abhandlungen, Neue Folge I*, **1**, 1–74.
- Freyer, G. and Suhr, P. 1987. Über Archaeocyathinen-Funde und den lithologischen Aufbau des Unterkambriums im Gebiet von Torgau. *Zeitschrift für geologische Wissenschaften*, **15**, 655–680.
- Freyer, G. and Suhr, P. 1992. Über Algengemeinschaften aus der unterkambrischen Zwethauer Folge des Gebietes von Torgau. *Freiberger Forschungsheft C*, **445**, 49–65.
- Geyer, G. 1986. Mittelkambrische Mollusken aus Marokko und Spanien. *Senckenbergiana Lethaia*, **67**, 55–118.
- Geyer, G. 1990. Die marokkanischen Ellipsocephalidae (Trilobita: Redlichiida). *Beringeria*, **3**, 1–363.
- Geyer, G., Buschmann, B. and Elicki, O. 2014. A new lowermost middle Cambrian (Series 3, Stage 5) faunule from Saxony (Germany) and its bearing on the tectonostratigraphic history of the Saxothuringian domain. *Paläontologische Zeitschrift*, **88**, 239–262.
- Geyer, G. and Elicki, O. 1995. Lower Cambrian trilobites from the Görlitz Synclinorium (Germany) – review and new results. *Paleontological Journal*, **69**, 87–119.
- Geyer, G., Elicki, O., Fatka, O. and Žylińska, A. 2008. Cambrian. In: McCann, T. (Ed.), *The Geology of Central Europe*. Volume 1: Precambrian and Palaeozoic, pp. 155–202. Geological Society of London; London.
- Geyer, G. and Landing, E. 1995. The Cambrian of the Moroccan Atlas region. *Beringeria*, Special Issue **2**, 7–46.
- Geyer, G. and Landing, E. 2004. A unified Lower–Middle Cambrian chronostratigraphy for west Gondwana. *Acta Geologica Polonica*, **54**, 179–218.
- Geyer, G. and Mergl, M. 1995. Mediterranean representatives of the obolellid *Trematobolus* Matthew (Brachiopoda) and a review of the genus. *Paläontologische Zeitschrift*, **69**, 181–211.
- Geyer, G. and Peel, J.S. 2011. The Henson Gletscher Formation, North Greenland, and its bearing on the global Cambrian Series 2–Series 3 boundary. *Bulletin of the Czech Geological Survey*, **86**, 465–534.
- Geyer, G. and Streng, M. 1998. Middle Cambrian pelecypods from the Anti-Atlas, Morocco. *Revista Española de Paleontología, número extraordinario, Homenaje al Prof. Gonzalo Vidal*, 83–96.
- Gilbert, I.R., Hughes, N.C. and Myrow, P.M. 2016. Cambrian microfossils from the Tethyan Himalaya. *Journal of Paleontology*, **90**, 10–30.
- Gorjansky, W.J. and Popov, L.Y. 1985. On the origin and systematic position of the calcareous shelled inarticulate brachiopods. *Lethaia*, **19**, 233–240.
- Gozalo, R., and Hinz-Schallreuter, I. 2002. Biostratigraphy and palaeobiogeography of the Cambrian genus *Hipponicharion* (Ostracoda). *Paläontologische Zeitschrift*, **76**, 65–74.
- Grant, R.E. 1836. Animal kingdom. In: Todd, R.B. (Ed.), *The cyclopaedia of anatomy and physiology*, pp. 107–118. Sherwood, Gilbert and Piper; London.
- Gravestock, D.I., Alexander, E.M., Demidenko, Y.E., Esakova, N.V., Holmer, L.E., Jago, J.B., Lin, T.R., Melnikova, L.M., Parkhaev, P.Yu., Rozanov, A.Yu., Ushatinskaya, G.T., Zang, W., Zhegallo, E.A. and Zhuravelv, A.Yu. 2001. The Cambrian biostratigraphy of the Stansbury Basin, South Australia. *Russian Academy of Sciences, Transactions of the Palaeontological Institute*, **282**, 1–344.
- Hall, J. 1847. Paleontology of New York. Volume I. Containing descriptions of the organic remains of the Lower Division of the New-York System (equivalent to the Lower Silurian rocks of Europe), 338 p. C. Van Benthuysen; Albany.
- Hamdi, B. 1995. Precambrian–Cambrian deposits in Iran. *Treatise on the Geology of Iran*, **20**, 1–353.
- Hamdi, B., Brasier, M.D. and Jiang, Z. 1989. Earliest skeletal fossils from Precambrian Cambrian boundary strata, Elburz Mountains, Iran. *Geological Magazine*, **126**, 283–289.
- He, T.G. 1980. Arthropoda. 182–197. In: Yin, J.C., Ding, L.F., He, T.G., Li, S.L. and Shen, L.J. (Eds), *The palaeontology and sedimentary environment of the Sinian system in Emei Ganluo Area, Sichuan*, 1–231. Sichuan Peoples Publishing House; Chengdu. [In Chinese, with English summary]
- Hinde, G.J. 1888. A monograph of the British fossil sponges. Part II: Sponges of the Palaeozoic Group. *Monograph of the Palaeontographical Society, London*, **41** (194), 93–188.
- Hinz, I. 1987. The Lower Cambrian microfauna of Comley and Rushton, Shropshire/England. *Palaeontographica*, **198**, 41–100.
- Holmer, L.E., Popov, L.E. and Wrona, R. 1996. Early Cambrian lingulate brachiopods from glacial erratics of King George Island (South Shetland Islands), Antarctica. *Acta Palaeontologica Polonica*, **55**, 37–50.
- Horný, R. 1964. The Middle Cambrian Pelagiellacea of Bohemia (Mollusca). *Sbornik Národního Muzea v Praze*, **20**, 133–140.

- Jell, P.A. 1980. Earliest known pelecypod on Earth – a new early Cambrian genus from South Australia. *Alcheringa*, **4**, 233–239.
- Jensen, S.R., Palacios, T. and Martí Mus, M. 2010. Revised biochronology of the Lower Cambrian of the Central Iberian zone, Southern Iberian massif, Spain. *Geological Magazine*, **147**, 690–703.
- Kerber, M. 1988. Mikrofossilien aus unterkambrischen Gesteinen der Montagne Noire, Frankreich. *Palaeontographica, Abteilung A*, **202**, 127–203.
- Khomentovskiy, V.V., Valkov, A.K. and Karlova, G.A. 1990. New data on the biostratigraphy of transitional Vendian–Cambrian strata in the middle Aldan River basin. In: Khomentovskiy, V.V. and Gibsher, A.S. (Eds), Late Precambrian and early Palaeozoic of Siberia (Problems of the regional stratigraphy), 3–57. Institut of Geology and Geophysics, Siberian Branch, USSR Academy of Sciences; Novosibirsk. [In Russian]
- King, W. 1846. Remarks on certain genera belonging to the class Palliobranchiata. *Annals and Magazine of Natural History*, **18**, 26–42.
- Klein, J.T. 1734. Naturalis Dispositio Echinodermatum. Accessit Lucubratiuncula de Aculeis Echinorum Marinorum, cum Spicilegio de Belemnitis, 79 p. T.J. Schreiber; Gedani.
- Kossmat, F. 1927. Gliederung des varistischen Gebirgsbaues. *Abhandlungen des Sächsischen Geologischen Landesamtes*, **1**, 1–39.
- Kouchinsky, A., Bengtson, S., Clausen, S. and Vendrasco, M.J. 2015. An early Cambrian fauna of skeletal fossils from the Emyaksin Formation, northern Siberia. *Acta Palaeontologica Polonica*, **60**, 421–512.
- Kouchinsky, A., Bengtson, S., Landing, E., Steiner, M., Vendrasco, M. and Ziegler, K. 2017. Terreneuvian stratigraphy and faunas from the Anabar Uplift, Siberia. *Acta Palaeontologica Polonica*, **62**, 311–440.
- Kouchinsky, A., Bengtson, S., Runnegar, B., Skovsted, C., Steiner, M. and Vendrasco, M.J. 2012. Chronology of early Cambrian biomineralisation. *Geological Magazine*, **149**, 221–251.
- Landing, E. 1974. Early and Middle Cambrian conodonts from the Taconic allochthon, eastern New York. *Journal of Paleontology*, **48**, 1241–1248.
- Landing, E. 1988. Lower Cambrian of eastern Massachusetts: stratigraphy and small shelly fossils. *Journal of Paleontology*, **62**, 661–695.
- Landing, E. 1991. Upper Precambrian through Lower Cambrian of Cape Breton Island: Faunas, paleoenvironments, and stratigraphic revision. *Journal of Paleontology*, **65**, 570–595.
- Landing, E. 1992. Lower Cambrian of southeastern Newfoundland: Epeirogeny and Lazarus faunas, lithofacies-biofacies linkages, and the myth of a global chronostratigraphy. In: Lipps, J.H. and Signor, P.W. (Eds), Origin and early evolution of the Metazoa, pp. 283–309. Plenum Press; New York.
- Landing, E. 1994. Precambrian–Cambrian global stratotype ratified and a new perspective of Cambrian time. *Geology*, **22**, 179–182.
- Landing, E. 1995. Upper Placentian–Branchian Series of mainland Nova Scotia (middle–upper Lower Cambrian): faunas, paleoenvironments, and stratigraphic revision. *Journal of Paleontology*, **69**, 475–495.
- Landing, E. and Bartowski, K.E. 1996. Oldest shelly fossils from the Taconic Allochthon and late Early Cambrian sea-levels in eastern Laurentia. *Journal of Paleontology*, **70**, 741–761.
- Landing, E., Geyer, G. and Bartowski, K.E. 2002. Latest Early Cambrian small shelly fossils, trilobites, and Hatch Hill dysoxic interval on the Quebec continental slope. *Journal of Paleontology*, **76**, 287–305.
- Landing, E., Geyer, G., Buchwaldt, R. and Bowring, S.A. 2015. Geochronology of the Cambrian: A precise Middle Cambrian U–Pb zircon date from the German margin of West Gondwana. *Geological Magazine*, **152**, 28–40.
- Landing, E., Myrow, P., Benus, A.P. and Narbonne, G.M. 1989. The Placentian Series: appearance of the oldest skeletalized faunas in southeastern Newfoundland. *Journal of Paleontology*, **63**, 739–769.
- Lankester, E.R. 1877. Notes on the embryology and classification of the animal kingdom: comprising a revision of speculations relative to the origin and significance of the germ layers. *Quarterly Journal of Microscopical Science*, **68**, 399–454.
- Lee, B.S. 2008. Stratigraphic implications of skeletal microfossils from the Cambrian of Korea: a preliminary report. *Acta Geologica Sinica (English Edition)*, **82**, 1152–1159.
- Lee, B.S. and Lee, H.Y. 1988. Upper Cambrian conodonts from the Hwajeol Formation in the southern limb of the Paekunsan Syncline, Eastern Yeongweol and Samcheog areas, Kangweondo, Korea. *Journal of the Geological Society of Korea*, **24**, 356–375.
- Leuckart, R. 1854. Salpen und Verwandte. Zoologische Untersuchungen, 2, 47–63. J. Ricker'sche Buchhandlung; Giessen.
- Li, L., Zhang, X., Yun, H. and Li, G. 2016. New occurrence of *Cambroclavus absonus* from the lowermost Cambrian of North China and its stratigraphical importance. *Alcheringa*, **40**, 45–52.
- Li, Y. and Zhou, B. 1986. Discovery of old microbivalves in China and its significance. *Chinese Journal of Geology*, **1**, 38–45. [In Chinese with English abstract]
- Liñán, E. and Mergl, M. 2001. Lower and Middle Cambrian brachiopods from the Iberian Chains and Sierra Morena, Spain. *Revista Española de Paleontología*, **16**, 317–337.
- Liñán, E., Perejón, A., Gozalo, R., Moreno-Eiris, E. and de Oliveira, J.T. 2004. The Cambrian system of Iberia. *Publicaciones del Instituto Geológico y Minero de España, Ser. Cuadernos del Museo Geominero*, **3**, 1–63.
- Linnæus, C. 1758. Systema naturae. Editio decimal reformata, 824 p. Laurentii Salvii; Stockholm.

- Linnarsson, G. 1876. On the Brachiopoda of the Paradoxides beds of Sweden. *Bihang till Kongliga Svenska Vetenskaps-Akademiens Handlingar*, **3**, 1–34.
- Linnarsson, G. 1877. Om faunan i lagren med *Paradoxides ölandicus*. *Geologiska Föreningens i Stockholm Förhandlingar*, **3**, 352–375.
- Linnemann, U., D’Lemos, R.S., Drost, K., Jeffries, T.E., Romer, R.L., Samson, S.D. and Strachan, R.A. 2008. Cadomian tectonics. In: McCann, T. (Ed.), *The geology of Central Europe*, Volume 1, Precambrian and paleozoic, pp. 103–154. Geological Society of London; London.
- Linnemann, U., Gehmlich, M., Tichomirowa, M., Buschmann, B., Nasdala, L., Jonas, P., Lützner, H. and Bombach, K. 2000. From Cadomian subduction to Early Palaeozoic rifting: The evolution of Saxo-Thuringia at the margin of Gondwana in the light of single zircon geochronology and basin development (central European Variscides, Germany). In: Franke, W., Haak, V., Oncken, O. and Tanner, D. (Eds), *Orogenic processes: Quantification and modelling in the Variscan belt*. *Geological Society of London, Special Publication*, **179**, 131–153.
- Linnemann, U., Gerdes, A., Drost, K. and Buschmann, B. 2007. The continuum between Cadomian orogenesis and opening of the Rheic Ocean: constraints from LA-ICPMS U-Pb zircon dating and analysis of plate-tectonic setting (Saxo-Thuringian zone, north-eastern Bohemian Massif, Germany). In: Linnemann, U., Nance, D.R., Kraft, P. and Zulauf, G. (Eds), *The evolution of the Rheic Ocean: from Avalonian Cadomian Active margin to Alleghenian–Variscan Collision*. *Geological Society of America Special Papers*, **423**, 61–96.
- Linnemann, U., Hofmann, M., Romer, R.L. and Gerdes, A. 2010. Transitional stages between the Cadomian and Variscan Orogenies: Basin development and tectonomagmatic evolution of the southern margin of the Rheic Ocean in the Saxo-Thuringian Zone (North Gondwana shelf). In: Linnemann, U. and Romer, R.L. (Eds), *Pre-Mesozoic geology of Saxo-Thuringia – from the Cadomian active margin to the Variscan Orogen*, pp. 59–98. Schweizerbart Science Publishers; Stuttgart.
- LoDuca, S.T., Caron, J.B., Schiffbauer, J.D., Shuhai X. and Kramer, A. 2015. A reexamination of *Yuknessia* from the Cambrian of British Columbia and Utah. *Journal of Paleontology*, **89**, 82–95.
- Maletz, J. and Steiner, M. 2015. Graptolites (Hemichordata, Pterobranchia) preservation and identification in the Cambrian Series 3. *Palaeontology*, **58**, 1073–1107.
- Maletz, J., Steiner, M. and Fatka, O. 2005. Middle Cambrian pterobranchs and the question: What is a graptolite? *Lethaia*, **38**, 73–85.
- Malinky, J.M. and Skovsted, C.B. 2004. Hyoliths and small shelly fossils from the Lower Cambrian of North-East Greenland. *Acta Palaeontologica Polonica*, **49**, 551–578.
- Maloof, A.C., Porter, S.M., More, J.L., Dudás, F.Ö., Bowring, S.A., Higgins, J.A., Fike, D.A. and Eddy, M.P. 2010. The earliest Cambrian record of animals and ocean geochemical change. *Geological Society of America Bulletin*, **122**, 1731–1774.
- Mambetov, A.M. 1972. A new Lower Cambrian hyolithid genus from Malyy Karatau (northwestern Tien Shan). *Paleontological Journal*, **2**, 268–269.
- Mambetov, A.M. and Repina, L.N. 1979. The Lower Cambrian of the Talassky Alatau and its correlation with the sections of Malyy Karatau and the Siberian Platform. In: Zhuravleva, I.T. and Meshkova, N.P. (Eds), *Lower Cambrian biostratigraphy and paleontology of Siberia*. *Trudy Instituta Geologii i Geofiziki, SO AN SSSR*, **406**, 98–138. [In Russian]
- Marek, L. 1966. New hyolithid genera from the Ordovician of Bohemia. *Časopis Národního Muzea v Praze*, **135**, 89–92.
- Marek, L. 1963. New knowledge on the morphology of Hyolithes. *Sborník geologických věd, Paleontologie*, **1**, 53–72.
- Marek, L. 1972. Middle Cambrian Hyolithes: *Maxilites* gen. n. *Časopis Národního Muzea v Praze*, **141**, 69–72.
- Marek, L., Malinky, J.M. and Geyer, G. 1997. Middle Cambrian fossils from Tizi n’Tichka, the High Atlas, Morocco. Part 2. Hyolitha. *Journal of Paleontology*, **71**, 638–656.
- Martí Mus, M. and Bergström, J. 2005. The morphology of hyolithids and its functional implications. *Palaeontology*, **48**, 1139–1167.
- Matthew, G.F. 1893. *Trematobolus*. An articulate brachiopod of the inarticulate order. *The Canadian Record of Science*, **5**, 276–279.
- Matthew, G.F. 1894. Illustrations of the fauna of the St. John Group. *Proceedings and Transactions of the Royal Society of Canada*, **11**, 85–129.
- Matthew, G.F. 1895. The *Protolenus* Fauna. *Transactions of the New York Academy of Science*, **14**, 101–153.
- Matthew, G.F. 1902. Notes on Cambrian faunas. *Royal Society of Canada, Transactions*, **8**, 93–112.
- Matthews, S.C. and Missarzhevsky, V.V. 1975. Small shelly fossils of late Precambrian and early Cambrian age: A review of recent work. *Journal of the Geological Society of London*, **131**, 289–304.
- McCoy, F. 1851. On some new Cambro–Silurian fossils. *Annals and Magazine of Natural History*, **8**, 387–409.
- Menke, C.T. 1828. Synopsis methodica molluscorum generum omnium et specierum earum, quae in Museo Menkeano adservantur; cum synonymia critica et novarum specierum diagnosis, 91 p. Henrici Gelpke; Pymonti.
- Mergl, M. and Šlehoferova, P. 1990. Middle Cambrian inarticulate brachiopods from Central Bohemia. *Sborník geologických věd, Paleontologie*, **31**, 9–46.
- Meshkova, N.P. 1974. Lower Cambrian hyoliths of the Siberian Platform. *Trudy Instituta Geologii i Geofiziki, SO AN SSSR*, **97**, 1–110. [In Russian]
- Missarzhevsky, V.V. 1973. Conodont-shaped organisms from Precambrian–Cambrian boundary beds of the Siberian

- Platform and Kazakhstan. In: Zhuravleva, I.T. (Ed.), *Problemy paleontologii i biostratigrafii nizhnego kembriya Sibiri i Dal'nego Vostoka. Trudy Instituta Geologii i Geofiziki SO AN SSSR*, **49**, 53–59. [In Russian]
- Missarzhevsky, V.V. 1981. Early Cambrian hyoliths and gastropods of Mongolia. *Paleontologicheskii Zhurnal*, **1981/1**, 21–28. [In Russian]
- Missarzhevsky, V.V. and Mambetov, A.M. 1981. Stratigraphy and fauna of Cambrian and Precambrian boundary beds of Maly Karatau. *Trudy Instituta Geologii i Geofiziki Akademii Nauk SSSR*, **326**, 1–92. [In Russian]
- Moore, J.L., Porter, S.M. and Li, G. 2014. Two unusual small shelly fossils from the Lower Cambrian of southeastern Shaanxi Province, China. *Journal of Paleontology*, **88**, 348–358.
- Obut, A.M. 1964. Subphylum Stomochordata. Stomokhordovy. In: Orlov, Y.A. (Eds), *Osnovy paleontologii: Echinodermata, Hemichordata, Pogonophora, Chaetognatha*, pp. 279–337. Nedra Press; Moscow. [In Russian]
- Obut, A.M. 1974. New graptolites from the Middle Cambrian of the Siberian Platform. *Special Papers in Palaeontology*, **13**, 9–13.
- Obut, A.M. and Sobolevskaya, R.F. 1967. Some stereostolones of the Late Cambrian and Ordovician of the Norilsk Region. In: Ivanovsky, A.B. and Sokolov, B.S. (Eds), *Novye dannye po biostratigrafii nizhnego paleozoya Sibirskoy platformy*, pp. 1–156. Akademia Nauk SSR, Sibirskoe Otdelenie, Institut Geologii i Geofiziki. [In Russian]
- Øpik, A. 1933. Über einen kambrischen Graptolithen aus Norwegen. *Norsk Geologisk Tidsskrift*, **13**, 8–10.
- Parkhaev, P.Y. 2004. Malacofauna of the Lower Cambrian Bystroya Formation of eastern Transbaikalia. *Paleontological Journal* **38**, 590–608. [translation of *Paleontologicheskii Zhurnal* **2004**, 9–25]
- Parkhaev, P.Y. 2008. The Early Cambrian radiation of Mollusca. In: Ponder, W.F. and Lindberg, D.R. (Eds), *Phylogeny and evolution of the Mollusca*, pp. 33–70. University of California Press; Berkeley and Los Angeles, California.
- Parkhaev, P.Y. 2017. On the position of Cambrian archaeobranchians in the system of the Class Gastropoda. *Paleontological Journal*, **51**, 453–463.
- Parkhaev, P.Y. and Demidenko, Y.E. 2010. Zooproblematica and Mollusca from the Lower Cambrian Meishucun section (Yunnan, China) and taxonomy and systematics of the Cambrian small shelly fossils of China. *Paleontological Journal*, **44**, 883–1161.
- Peel, J.S. 1991. Functional morphology of the Class Helcionelloida nov., and the early evolution of the Mollusca. In: Simonetta, A.M. and Conway Morris, S. (Eds), *The early evolution of Metazoa and the significance of problematic taxa*, pp. 157–177. Cambridge University Press; Cambridge.
- Peel, J.S. 2010. Articulated hyoliths and other fossils from the Sirius Passet Lagerstätte (early Cambrian) of North Greenland. *Bulletin of Geosciences*, **85**, 385–394.
- Pelman, Yu.L. and Pereladov, V.S. 1986. Stratigraphy and brachiopods of the Lower–Middle Cambrian on the Arga-Sala River (southern Anabar region). In: Zhuravleva, I.T. (Ed.), *Biostratigrafiya i paleontologiya kembriya Severnoi Azii. Trudy Instituta Geologii i Geofiziki SO AN SSSR*, **669**, 119–154. [In Russian]
- Perejon, A. 1976. Nuevas faunas de Arqueociatos del Cámbrico de Sierra Morena (II). *Tecniterrae*, **9**, 7–24.
- Perejon, A. 1989. Arqueociatos del Ovetiense en la sección del Arroyo Pedroche, Sierra de Córdoba, España. *Boletín de la Real Sociedad Española de Historia Natural. Sección Geológica*, **84**, 143–247.
- Percival, I.G., Engelbretsen, M.J. and Peng, S. 2016. Drumian and Guzhangian (middle Cambrian) lingulate brachiopods from Hunan Province, China. *Australasian Palaeontological Memoirs*, **49**, 433–446.
- Pojeta, J. 1975. *Fordilla troyensis* Barrande and early bivalve phylogeny. *Bulletins of American Paleontology*, **63**, 363–384.
- Pojeta, J. 2000. Cambrian Pelecypoda. *American Malacological Bulletin*, **15**, 157–166.
- Popov, L.E. and Holmer, L.E. 2000. Obolellata. In: Kaesler, R.L. (Ed.), *Treatise on Invertebrate Paleontology, Part H, Brachiopoda, Revised, Volume 2*, pp. 200–207. Geological Society of America and University of Kansas Press; Boulder and Lawrence.
- Porter, S.M. 2010. Calcite and aragonite seas and the de novo acquisition of carbonate skeletons. *Geobiology*, **8**, 256–277.
- Poulsen, V. 1966. Early Cambrian distacodontid conodonts from Bornholm. *Biologiske Meddelelser udgivet af det Kongelige Danske Videnskabernes Selskab*, **23**, 1–10.
- Qian, Y. 1977. Hyolitha and some problematica from the Lower Cambrian Meishucun Stage in central and SW China. *Acta Palaeontologica Sinica*, **16**, 107–130.
- Qian, Y. 1978. The Early Cambrian hyolithids in central and southwest China and their stratigraphical significance. *Memoirs of Nanjing Institute of Geology and Palaeontology. Academia Sinica*, **11**, 1–50.
- Qian, Y. 1989. Early Cambrian small shelly fossils of China with special reference to the Precambrian–Cambrian boundary, 341 p. Nanjing University Publishing House; Nanjing.
- Qian, Y. and Bengtson, S. 1989. Palaeontology and biostratigraphy of the Early Cambrian Meishucunian Stage in Yunnan Province, south China. *Fossils and Strata*, **24**, 1–156.
- Qian, Y., Chen, M., He, T., Zhu, M., Yin, G., Feng, W., Xu, J., Jiang, Z., Liu, D., Li, G., Di, L., Mao, Y. and Xiao, B. 1999. Taxonomy and biostratigraphy of small shelly fossils in China, 247 p. Science Press; Beijing.
- Randell, R.D., Lieberman, B.S., Hasiotis, S.T. and Pope, M.C. 2005. New chancelloriids from the Early Cambrian Sekwi

- Formation with a comment on chancelloriid affinities. *Journal of Paleontology*, **79**, 987–996.
- Rickards, R.B., Baillie, P.W. and Jago, J.B. 1990. An Upper Cambrian (Idamean) dendroid assemblage from near Smithton, northwestern Tasmania. *Alcheringa*, **14**, 207–232.
- Rigby, J.K. 1986. Sponges of the Middle Cambrian Burgess Shale (Middle Cambrian), British Columbia. *Palaeontographica Canadana*, **2**, 1–105.
- Robison, R.A. 1964. Late Middle Cambrian faunas from Utah. *Journal of Paleontology*, **38**, 510–566.
- Rowell, A.J. 1965. Inarticulata. In: Moore, R.C. (Ed.), *Treatise on Invertebrate Paleontology. Part H, Brachiopoda*, pp. 260–296. The Geological Society of America and the University of Kansas Press; New York and Lawrence.
- Rožanov, A.Y., Missarzhevsky, V., Volkova, N., Voronova, L., Krylov, I., Keller, B., Koroluk, I., Lenzion, K., Michniak, R., Pyhova, N. and Sidorov, A. 1969. The Tommotian Stage and the Cambrian lower Boundary problem. *Trudy Ordena Trudovogo Krasnogo Znameni geologicheskogo instituta Akademii Nauk SSSR*, **206**, 1–379.
- Salter, J. W. 1866. On the fossils of North Wales. In: Ramsay, A.C., *The geology of North Wales. Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology*, **3**, 239–381.
- Sarmiento, G.N., Fernandez-Remolar, D. and Göncüoğlu, M.C. 2001. Cambrian small shelly fossils from the Çal Tepe formation, Taurus Mountains, Turkey. *Coloquios de Paleontologia*, **52**, 117–134.
- Schmidt, E.W. 1942. Die mittelkambrische Fauna von Doberlug. *Jahrbuch der Reichsstelle für Bodenforschung*, **62** (for 1941), 344–402.
- Sdzuy, K. 1957a. Revision der mittelkambrischen Trilobiten von Doberlug. *Senckenbergiana lethaea*, **38**, 7–28.
- Sdzuy, K. 1957b. Alter und tiergeographische Stellung des Mittelkambriums von Doberlug. *Geologie*, **6**, 465–475.
- Sdzuy, K. 1962. Neue kambrische Fossilien aus Bohrungen im Gebiet von Doberlug. *Geologie*, **11**, 1087–1101.
- Sdzuy, K. 1968. Trilobites del Cámbrico Medio de Asturias. *Trabajos de Geología, Universidad de Oviedo*, **1**, 77–133.
- Sdzuy, K. 1969. Unter- und mittelkambrische Porifera (Chancelloriida und Hexactinellida). *Paläontologische Zeitschrift*, **43**, 115–147.
- Sdzuy, K. 1970. Mittelkambrische Fossilien aus neuen Bohrungen bei Doberlug und bei Delitzsch. *Geologie*, **19**, 1066–1091.
- Sdzuy, K. 1972. Das Kambrium der acadobaltischen Faunenprovinz – Gegenwärtiger Kenntnisstand und Probleme. *Zentralblatt für Geologie und Paläontologie*, **2**, 1–91.
- Sdzuy, K. 1974. Mittelkambrische Graptolithen aus NW-Spanien. *Paläontologische Zeitschrift*, **48**, 110–139.
- Shinaq, R. and Elicki, O. 2007. The Cambrian sedimentary succession from the Wadi Zerqa Ma'in (northeastern Dead Sea area, Jordan): lithology and fossil content. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **243**, 255–271.
- Skovsted, C.B. 2004. The mollusc fauna of the Early Cambrian Bastion Formation of North-East Greenland. *Bulletin of the Geological Society of Denmark*, **51**, 11–37.
- Skovsted, C.B. 2006. Small shelly fauna from the upper Lower Cambrian Bastion and Ella Island formations, north-east Greenland. *Journal of Paleontology*, **80**, 1087–1112.
- Skovsted, C.B., Clausen, S., Álvaro, J.J. and Ponlevé, D. 2014. Tommotiids from the early Cambrian (Series 2, Stage 3) of Morocco and the evolution of the tannuolinid scleritome and setigerous shell structures in stem group brachiopods. *Palaeontology*, **57**, 171–192.
- Skovsted, C.B. and Holmer, L.E. 2005. Early Cambrian brachiopods from North-East Greenland. *Palaeontology*, **48**, 325–345.
- Skovsted, C.B., Pan, P., Topper, T.P., Betts, M.J., Li, G. and Brock, G.A. 2016. The operculum and mode of life of the lower Cambrian hyolith *Cupitheca* from South Australia and north China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **443**, 123–130.
- Skovsted, C.B. and Peel, J.S. 2007. Small shelly fossils from the argillaceous facies of the Lower Cambrian Forteau Formation of western Newfoundland. *Acta Palaeontologica Polonica*, **52**, 729–748.
- Skovsted, C.B. and Peel, J.S. 2010. Early Cambrian brachiopods and other shelly fossils from the basal Kinzers Formation of Pennsylvania. *Journal of Paleontology*, **84**, 754–762.
- Steiner, M., Li, G., Qian, Y. and Zhu, M. 2004. Lower Cambrian small shelly fossils of northern Sichuan and southern Shaanxi (China), and their biostratigraphic importance. *Geobios*, **37**, 259–275.
- Steiner, M., Li, G.X., Qian, Y., Zhu, M.Y. and Erdtmann, B.D. 2007. Neoproterozoic to Early Cambrian Small Shelly assemblages of the Yangtze Platform (China) and their potential for regional and international correlation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **254**, 67–99.
- Sysoev, V.A. 1957. On the morphology, systematics and affinity of hyoliths. *Doklady Akademii Nauk SSSR*, **116**, 304–307. [In Russian]
- Sysoev, V.A. 1968. Stratigraphy and hyoliths of the oldest Lower Cambrian beds of the Siberian platform, 67 p. Yakutskij filial Sibirskogo otdeleniya Instituta Geologii, Akademiya Nauk SSSR. [In Russian]
- Sysoev, V.A. 1972. Biostratigraphy and orthothecimorph hyoliths from the Lower Cambrian of the Siberian Platform, 152 p. Yakutskij filial Sibirskogo otdeleniya Instituta Geologii, Akademiya Nauk SSSR. [In Russian]
- Tate, R. 1892. The Cambrian fossils of South Australia. *Transactions of the Royal Society of South Australia*, **15**, 183–189.
- Torsvik, T.H. and Cocks, L.R. 2017. *Earth history and palaeogeography*, 332 p. Cambridge University Press; Cambridge.
- Ushatinskaya, G.T. and Korovnikov, I.V. 2014. Revision of the

- Early–Middle Cambrian Lingulida (Brachiopoda) from the Siberian Platform. *Journal of Paleontology*, **48**, 26–40.
- Ushatinskaya, G.T. and Korovnikov, I.V. 2016. Revision of the superfamily Acrotheloidea (Brachiopoda, class Linguliformea, order Lingulida) from the Lower and Middle Cambrian of the Siberian Platform. *Paleontological Journal*, **50**, 450–462.
- Valent, M., Fatka, O. and Marek, L. 2013. *Gracilitheca* and *Nepthrotheca* (Hyalolitha, Orthothecida) in the Cambrian of the Barrandian area, Czech Republic. *Alcheringa*, **37**, 115–124.
- Vasil'eva, N.I. and Sayutina, T.A. 1988. The morphological diversity of chancelloriid sclerites. *Trudy Instituta geologii i geofiziki (Novosibirsk)*, **720**, 190–198.
- Vasil'eva, N.I. and Sayutina, T.A. 1993. A new generic and specific name for the early Cambrian chancelloriid sclerites. *Paleontologicheskii Zhurnal*, **1993/1**, 113–114. [In Russian]
- Vendrasco, M.J., Checa, A.G. and Kouchinsky, A.V. 2011. Shell micro-structure of the early bivalve *Pojetaia* and the independent origin of nacre within the Mollusca. *Palaeontology*, **54**, 825–850.
- Vendrasco, M.J., Li, G., Porter, S.M. and Fernandez, C.Z. 2009. New data on the enigmatic *Ocruanus*–*Eohalobia* group of Early Cambrian small skeletal fossils. *Paleontology*, **52**, 1373–1396.
- Waagen, W.H. 1885. Salt Range fossils, Vol. I, Part 4, Productus Limestone fossils, Brachiopoda. *Palaeontologia Indica*, **13**, 729–770.
- Walcott, C.D. 1908. Cambrian Brachiopoda: Descriptions of new genera and species. *Smithsonian Miscellaneous Collections*, **53**, 53–137.
- Walcott, C.D. 1919. Cambrian geology and palaeontology IV, No. 5. Middle Cambrian Algae. *Smithsonian Miscellaneous Collections*, **67**, 217–260.
- Walcott, C.D. 1920. Middle Cambrian Spongiae. *Smithsonian Miscellaneous Collections*, **67**, 261–364.
- Westergård, A.H. 1936. *Paradoxides aeladicus* beds of Öland with the account of diamond boring through the Cambrian at Mössberga. *Sveriges Geologiska Undersökning Ser. C.* **394**, 1–66.
- Williams, A., Carlson, S., Brunton, C.H., Holmer, L.E. and Popov, L.E. 1996. A supraordinal classification of the Brachiopoda. *Philosophical Transactions of the Royal Society, London*, **351**, 1117–1193.
- Wotte, T. 2006. New Middle Cambrian molluscs from the Láncara Formation of the Cantabrian Mountains (north-western Spain). *Revista Española de Paleontología*, **21**, 145–158.
- Wotte, T. 2009. The youngest cambroclaves: *Cambroclavus absonus* from the Middle Cambrian of the Cantabrian zone (northwest Spain). *Journal of Paleontology*, **83**, 128–134.
- Wotte, T. and Mergl, M. 2007. Brachiopods from the Lower–Middle Cambrian Láncara Formation of the Cantabrian Mountains, northwest Spain. *Memoirs of the Association of Australasian Palaeontologists*, **33**, 101–122.
- Wotte, T. and Sundberg, F. 2017. Small shelly fossils from the Montezuman–Delamarian of the Great Basin in Nevada and California. *Journal of Paleontology*, **91**, 883–901.
- Wrona, R. 2003. Early Cambrian molluscs from glacial erratics of King George Island, West Antarctica. *Polish Polar Research*, **24**, 181–216.
- Wrona, R. 2009. Early Cambrian bradoriide and phosphatocopide arthropods from King George Island, West Antarctica; biogeographic implications. *Polish Polar Research*, **30**, 347–377.
- Xiao, L. and Zhou, B. 1984. Early Cambrian Hyolitha from Huainan and Huoqiu County in Anhui Province. *Professional Papers of Stratigraphy and Palaeontology*, **13**, 141–151.
- Xing, Y.S., Ding, Q.X., Luo, H.L., He, T.G. and Wang, Y.G. 1984. The Sinian–Cambrian boundary of China. *Bulletin of the Institute of Geology, Chinese Academy of Geological Sciences*, **10**, 1–262. [In Chinese]
- Yang, B. 2014. Cambrian small shelly fossils of South China and their application in biostratigraphy and palaeobiogeography, 182 p. Unpublished PhD Thesis, Freie Universität; Berlin.
- Zhao, Y., Zhu, M.Y., Babcock, L.E. and Peng, J. 2011. The Kaili Biota: Marine organisms from 508 million years ago, 251 p. Guizhou University Press; Guiyang. [In Chinese]

Manuscript submitted: 1st December 2017

Revised version accepted: 16th February 2018

PLATE 1

Molluscan fauna and other small shelly fossils from the Torgau-Doberlug Syncline.

1-6 – *Pelagiella* sp. 1 – FG 682-1209/01, 2 – FG 682-1209/02, 3 – FG 682-1209/03, 4 – FG 682-1209/04, 5 – FG 682-1209/05, 6 – FG 682-1209/06; lateral views. **7** – *Pojetaia runnegari* Jell, 1980. FG 682-1209/07. 7a – lateral view, 7b – apical view, 7c – details few showing close up of teeth (White square in 7b). **8** – *Cambroclavus* sp. FG 682-1209/08, upper view. **9** – *Eiffelia araniformis*. FG 682-1209/09. Scale bars 100 µm.

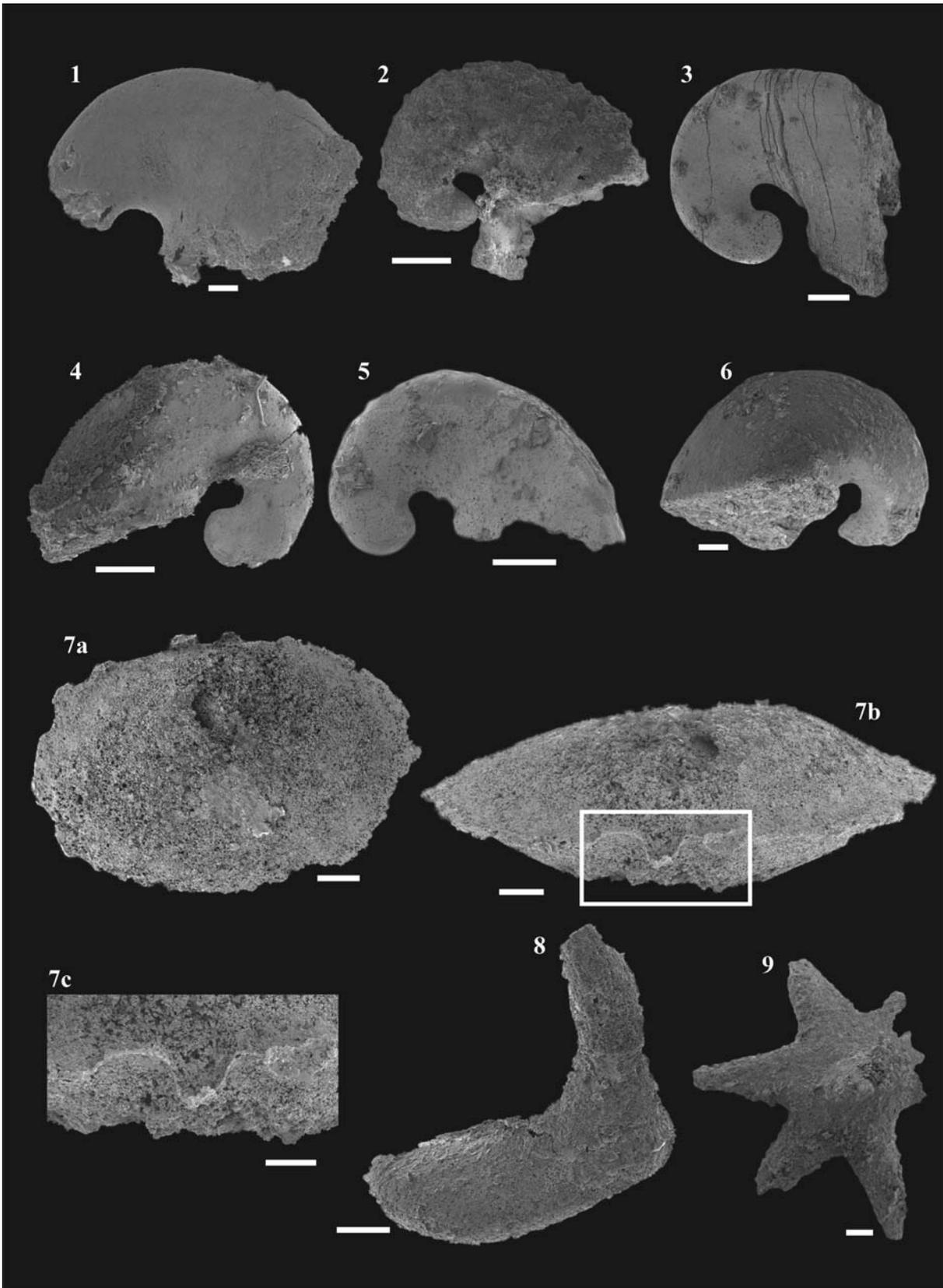


PLATE 2

Hyoliths and some problematic taxa from the Torgau-Doberlug Syncline.

1-4 – *Microcornus* sp. **1** – FG 682-1209/10, **2** – FG 682-1209/11, **3** – FG 682-1209/12, **4** – FG 682-1209/13. **1a-4a** – Cross-sections. **5** – Hyolithid indet. FG 682-1673A/01. Scale bar 500 µm. **6-8** – *Gracilitheca* sp. **6** – FG 682-1209/14, **7** – FG 682-1209/15, **8** – FG 682-1209/16. **9** – ?*Cupitheca* sp. FG 682-1209/17; **9a** – Lateral view; **9b** – Apical view showing the cross-section. **10** – *Conotheca* sp. FG 682-1209/18; **10a** – Lateral view; **10b** – Apical view showing the cross-section. **11** – Orthothecid conch indet. FG 682-1209/19. **12** – *Amphigeisina* sp. FG 682-1209/20. **13** – ?Siphogonuchitid indet. FG 682-1209/21. Scale bars 100 µm.



PLATE 3

Brachiopods and hemichordate from the Torgau-Doberlug Syncline.

1 – *?Eoobolus* sp. FG 682-1209/22, ventral view. Scale bar 100 μm . **2** – *?Lingulella* sp. FG 682-1691/01, dorsal view. Scale bar 200 μm . **3** – *?Acrothele* sp. FG 682-1673A/02, dorsal view. Scale bar 200 μm . **4** – *?Trematobolus* sp. FG 682-1209/78-23; 4a – Dorsal view, 4b – Interior view of dorsal valve. Scale bar 1 mm. **5** – *?Sphenoecium* sp. FG 682-1691/02. Scale bar 1 mm; 5a – Close-up of tubes, black arrow indicates fusellar banding. Scale bar 100 μm .

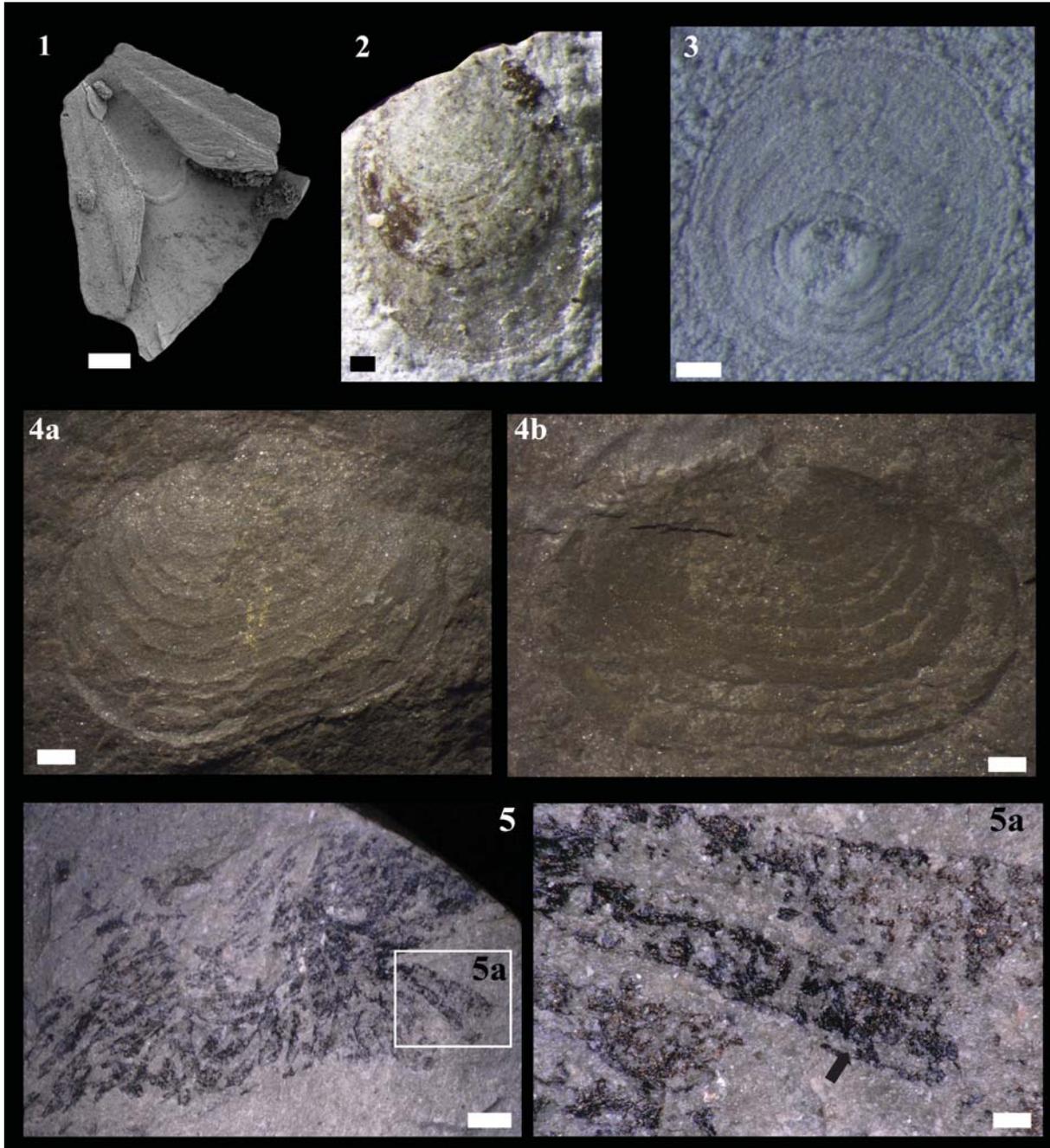


PLATE 4

Chancelloriid and indeterminate echinoderm ossicles from the Torgau-Doberlug Syncline.

1-4 – *Chancelloria* sp. 1 – FG682-1209/24, 2 – FG 682-1209/25, 3 – FG 682-1209/26, 4 – FG 682-1209/27. **5** – *Archiasterella* cf. *hirundo* (Bengtson in Bengtson *et al.*, 1990). FG 682-1209/28. **6-15** – Echinoderm ossicles indet. 6 – FG682-1209/29, 7 – FG 682-1209/30, 8 – FG 682-1209/31, 9 – FG 682-1209/32, 10 – FG 682-1209/33, 11 – FG 682-1209/34, 12 – FG 683-1209/35, 13 – FG 682-1209/36, 14 – FG 682-1209/37, 15 – FG 683-1209/38. Scale bars 100 μm .

