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Rediscovery of *Helicosphaera minima* in Oligocene deposits from the Albanian–Thessalian Basin (Albania)

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Abstract A distinctive, small helicolith species, which was observed during the study of Oligocene (Zone NP24) molasse sediments, was identified as *Helicosphaera minima* (Martini *in* Martini & Moisescu, 1974). Although almost never recorded since its original description, the species was common in some of our samples, which allowed the illustration of multiple specimens and the documentation of size variations. New information on the palaeoecology of *H. minima* indicates a preference for more eutrophic conditions and a shallow-marine palaeoenvironment.

Keywords calcareous nannofossils, measurements, *Helicosphaera*, Zone NP24, Oligocene

1. Introduction

A distinctive, small *Helicosphaera* species was observed during the analysis of Rupelian to Lower Chattian nannofossil samples from three sites (Mborja at 40˚35’47.52”N, 20˚48’50.89”E; Dardha Road 1 at 40˚32’3.93”N, 20˚47’28.36”E; Morava-5 at 40˚36’54.34”N, 20˚49’28.23”E) from the southern part of the Albanian–Thessalian Basin (ATHB, Korça Basin, Albania; Figure 1). This species was clearly unlike any other regularly-recorded Oligocene *Helicosphaera* species, but was very similar to a lesser-known species—*H. minima*—that was described by Martini *in* Martini & Moisescu (1974).

2. Material and methods

Samples from three sections near Korça, Albania were investigated as part of a calcareous nannofossil biostratigraphic study.

2.1 Mborja (Mb) section

Twenty-four calcareous nannofossil samples were collected from the marlstones and siltstones of the Mborja section (Figure 2) at intervals of 0.5–1 m. Of these, 14 came from the Drenova Formation (Figure 2A, B) and 10 were from the Drenica Formation (Figure 2C). Outcrops A and B are part of the same sedimentary succession and have a high molluscan content, with both bivalves and gastropods being present. Mollusc imprints and foraminifera are visible at some levels in Outcrop C.

2.2 Dardha Road 1 (RD-1) section

The Dardha Road 1 sediments (Figure 3) crop out on the left side of the road connecting Korça to the village of Dardha. The succession is monotonous and marly, with a broad horizontal extent and an ~28-m thickness (the sampled interval), containing molluscs and large foraminifera. Five indurated and compacted layers, up to 10–15 cm thick, of coarser-grained clastic and bioclastic material (shell fragments) were observed. The molluscs were visible all along the outcrop (although their collection was not always possible), while the foraminifer *Operculina complanata* occurred in almost every sample. A total of 56 samples were collected at intervals of 0.1, 0.2, 0.3, 0.4, 0.5 and a maximum of 1 m.

2.3 Morava-5 (Mo-5) section

A total of 54 samples were collected from the Morava-5 outcrop (Figure 4). The samples in Figure 4A belong to the Drenica Formation, those in Figure 4B and 4C to the ‘Chama’ Marls Formation, while the uppermost part of this section (Figure 4D) belongs to the Plasa Formation. The samples from Outcrops A and D were barren of nannofossils, whilst the rest of the samples (Outcrops B and C) had moderate to low calcareous nannofossil contents. Macrofaunas were present and quite abundant in Outcrop A, while in Outcrop C, some imprints and shell fragments were noted.

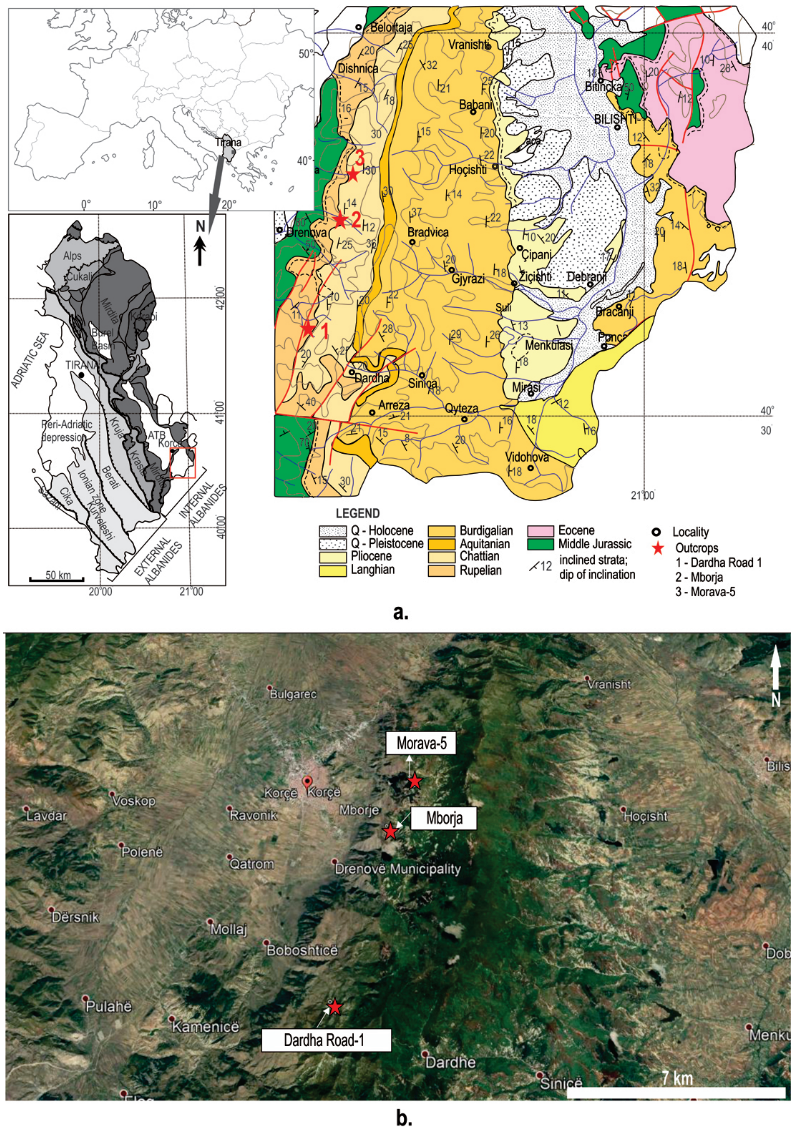

Figure 1: (**a**) Location map of the investigated sections, showing the geology of the area (1:200 000), redrawn and adapted after Xhomo et al. (2002). (**b**) Google Earth map showing the locations of the investigated sections

3. Investigation methods

The samples were prepared according to the standard smear-slide technique of Bown & Young (1998), and were analysed using cross-polarised light (XPL), bright-field (BF), phase-contrast (PC) and gypsum plate (GP), with an Optika light microscope (LM) at 1000x magnification.

Counts of at least 300 specimens per sample were performed on the most productive samples. For samples with less abundant assemblages, 50 to 100 specimens were counted. A qualitative investigation was performed on the least productive samples.

A total of 211 specimens from 10 samples from the Mborja section (Samples Mb-02, Mb-03, Mb-05, Mb-06, Mb-07, Mb-08, Mb-09, Mb-15, Mb-18 and Mb-19) and seven samples from the Dardha Road 1 site (RD-1/51, RD-1/53, RD-1/54, RD-1/57, RD-1/58, RD-1/59 and RD-2/60) were photographed in XPL with a Canon PC1201 digital camera. *Helicosphaera minima* was very rare in the Morava-5 section ('Chama' Marls Formation), and no images were taken from these samples. The length and width of each imaged helicolith was measured using ImageJ software, and the obtained data were plotted using Past software (Hammer et al., 2001). The frequencies of the measured parameters and the length/width ratios are plotted in Figure 5. Table 1 details the measurements of all specimens included in the investigation.

4. Biostratigraphy

The studied materials contained moderately-preserved calcareous nannofossil assemblages, dominated (28.67%) by *Reticulofenestra* sp. small (3–5 μm long), with a closed central area, *R. minuta* (23.44%), *Cyclicargolithus floridanus* (21.63%), *R. bisecta* + *R. stavensis* (5.68%), *Sphenolithus* spp. (4.25%), *H. minima* (3.82%) and *Coccolithus pelagicus* (3.12%). The biostratigraphically important species included *Sphenolithus ciperoensis*, *S. conicus*, *S. distentus*, *S. dissimilis*, *S. predistentus*, *Pontosphaera* cf. *P. enormis* and *Triquetrorhabdulus carinatus*.

5. Systematic palaeontology

Helicosphaera minima (Martini *in* Martini & Moisescu, 1974) Jafar & Martini, 1975 emend.

Plates 1, 2

Basionym: *Helicopontosphaera minima* Martini *in* Martini & Moisescu, 1974.

Diagnosis: A small *Helicosphaera* species with a type-III interference pattern (sensu Theodoridis, 1984), a closed to

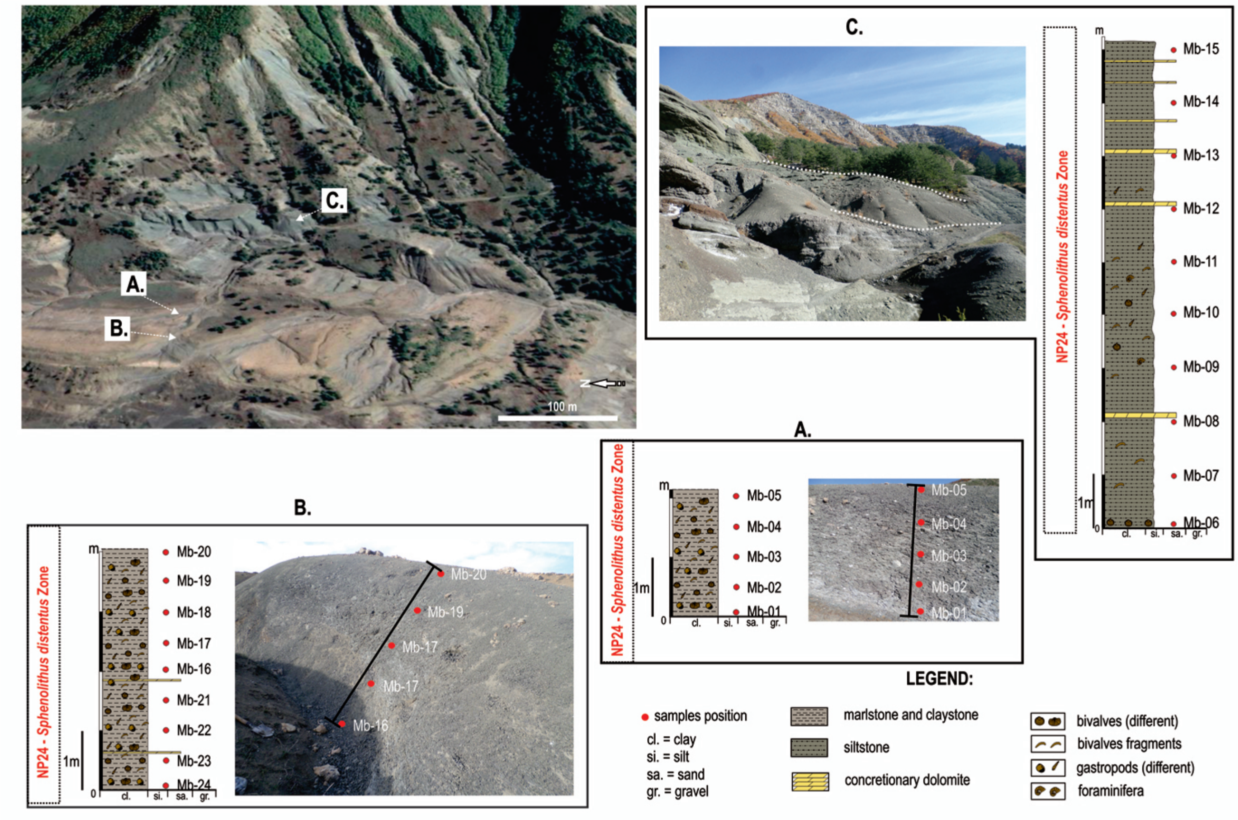

Figure 2: Mborja section—Google Earth map, location, lithology and sample positions

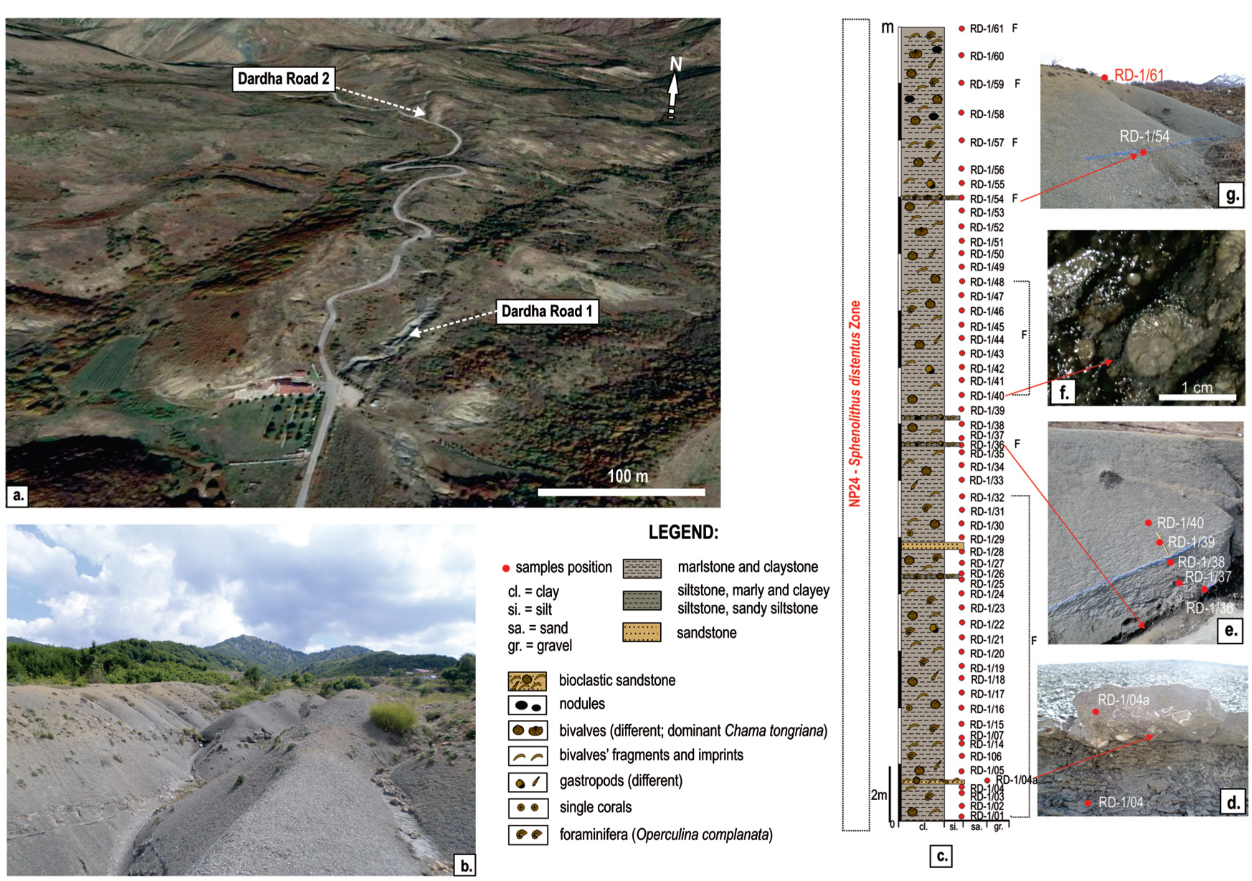

Figure 3: Dardha Road 1 section—Google Earth map, location, lithology and sample positions

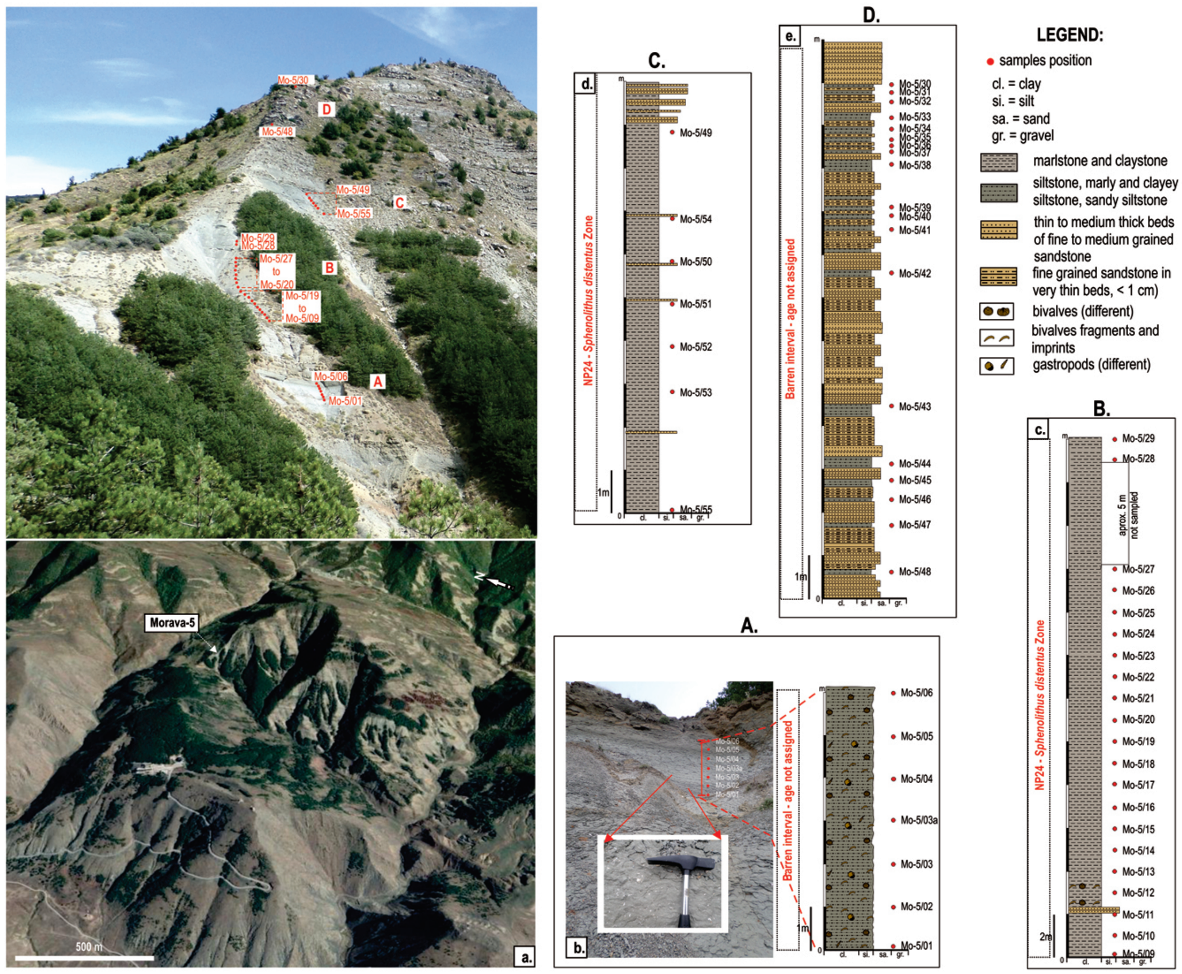

Figure 4: Morava-5 section—Location, lithology and sample positions

nearly-closed central-area, with a slit aligned with the major ellipse axis, and no visible wing. **Localities**: Mborja and Dardha Road 1 sections (ATHB, Albania). **Length**: 2.1–4.6 μm. **Width**: 1.5–3.6 μm. **Description**: A very small to small elliptical species, with a very narrow to closed central-area. The optical properties were investigated mainly in XPL, and diagnostic characteristics in two optical positions were identified. When a specimen is inclined at 30–45° to the polarisers, the general outline of the placolith is oblong, with near-parallel sides (Plate 1, figs 3, 6, 11, 14, 18; Plate 2, fig. 8). Cross-like pseudoextinction lines are present, comprising a thin line running along the length of the coccolith and two thicker, offset lines lying almost parallel to the short axis of the ellipse. When specimens are subparallel to the polarisers (Plate 1, figs 1, 2, 4, 5, 7–10, 12, 13, 15–17, 19, 20; Plate 2, figs 1–7, 9–14), they exhibit a narrowly- to broadly-elliptical outline, and display maximum birefringence. The centre appears to be closed, except for a narrow slit/elongated pore along the major axis. The best features for species identification are seen in the subparallel position, and all measurements were performed in this orientation. Minor etching was observed during the LM investigation.

As presented in Figure 5, the coccolith length ranges from 2.1 to ~4.6 μm, whilst the width ranges from 1.5–3.6 μm for longer specimens. The majority of the measured specimens range from 2.7–3.75 μm in length and 2.0–2.6 μm in width. The results from the two sites are virtually identical, and the populations are broadly unimodal, with a total relative size range that is similar to those of extant species (Young & Westbroek, 1991; Henderiks, 2008; Gibbs et al., 2013). **Identification**: The *H. minima* of Martini (1974) was described as a small (3–4 μm) species, without a wing and with an elongated central opening. The single holotype specimen that was illustrated falls well within the variability illustrated in our specimens. It was described from Romania, from the Lower Oligocene (Zone NP22). The NP22 age was determined based on the

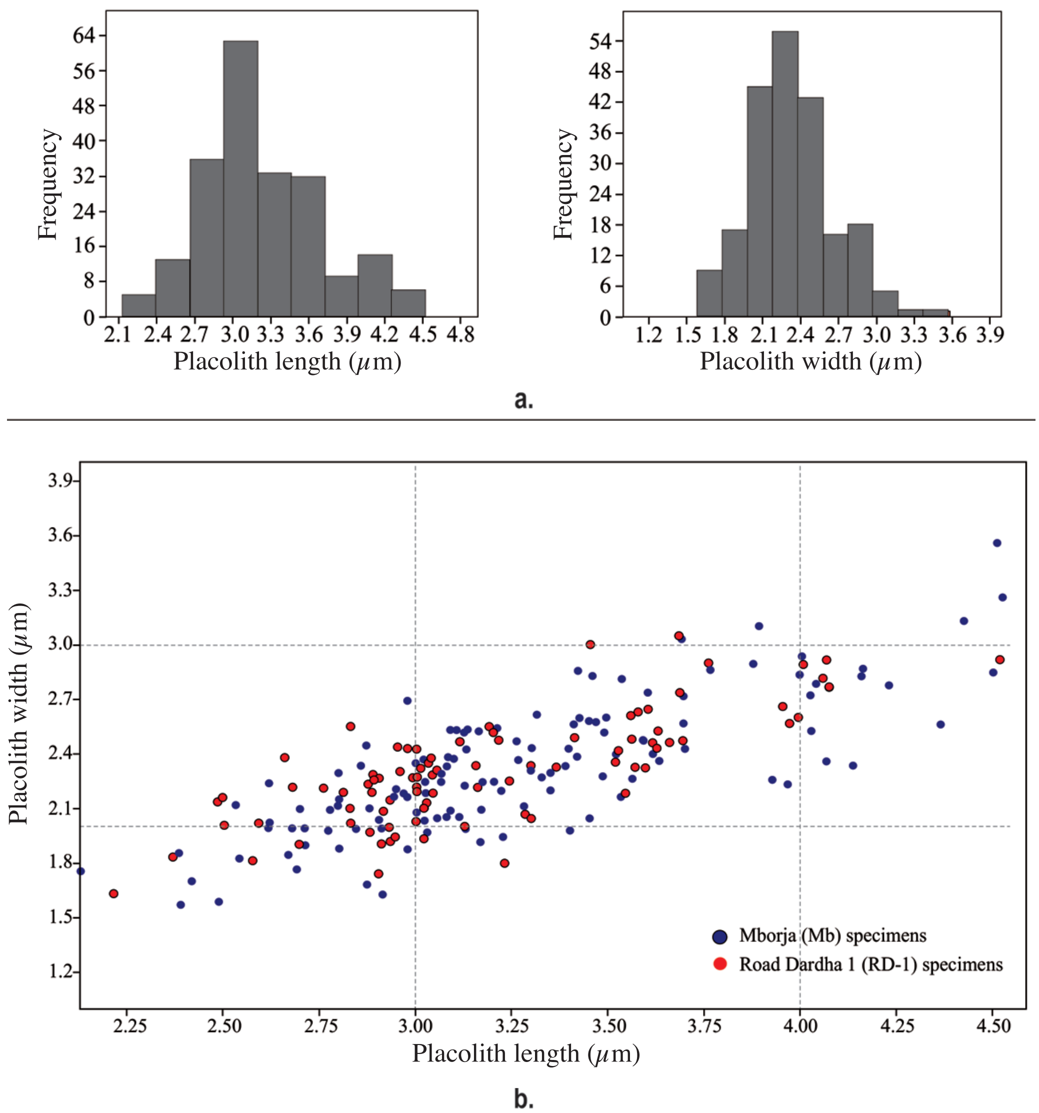

Figure 5: (**a**) Histograms showing length and width range frequencies in *H. minima*
(**b**) Length/width ratios of *H. minima*, showing the minimum and maximum sizes (μm)

co-occurrence of *Isthmolithus recurvus* and *S. predistentus* and the absence of *S. distentus* and *Coccolithus formosus*, thus providing robust time constraints. By comparison, our material from Albania, is somewhat younger, falling into Oligocene Zone NP24. Based on the original written description, it appears highly likely that this is the same species that we observed, and we are therefore using the name *H. minima*. **Differentiation**: There are no other Oligocene *Helicosphaera* species of similar size or shape. *Helicosphaera minima* is similar to another lesser-known species—*H. girgisii*—that Varol (1989) described from Zones NN1–NN10 in the Solomon Islands, but *H. minima* is much smaller than *H. girgisii,* and is only known from the Oligocene (our records, and those of Martini & Moisescu, 1974). As indicated by Varol (1989), the holotype of *H. girgisii* is 5.8 μm in length and 3.3 μm in width (Plate 2, fig. 15). **Remarks**: The type illustration of Martini (1974) is unsatisfactory, and we had hoped to re-examine the holotype material. However, the micropalaeontological collections at the Senckenberg Museum were unavailable due to a collections' move (A.R. Lord, pers. comm., 2018).

6. Discussion

The species *Helicopontosphaera minima* Martini *in* Martini & Moisescu, 1974 was recorded, in rare abundances, in NP22 (Lower Oligocene) in a total of six samples from several Romanian sections (Mera, Hoia-Berg and Tetişu). Comments on the palaeoenvironment of the sediments were not provided, but the presence of mollusc, foraminifera, echinoid and bryozoan faunas suggests a neritic environment. Subsequently, Jafar & Martini (1975) renamed the species as *Helicosphaera minima*. The species was also included in the reviews of Perch-Nielsen (1985) and Aubry (1990), but that information appears to be entirely based on the original description. There are no records of this species in the Neptune database (http://www.nsb-mfn-berlin.de/nannotax) and, after an extensive literature and online search, we found only one additional record. This was from Quaternary deposits in the Angola and Cape Basins (Atlantic Ocean; Sval'nov et al., 2014). The record is not illustrated and, given the Quaternary age of the sediments, it is unlikely to be the same taxon. A recent study of Oligocene nannofossils from the NW Transylvanian Basin (Fântânele Section, Romania; Kallanxhi et al., 2018) reported this species as *Helicosphaera* sp. In the Fântânele section, this species was found to be extremely rare, being present in only seven samples (M-EK, pers. obs., 2018) that were assigned to NP24–NP25. The only image available is from Sample FB43 (Plate 2, figs 18, 19). Excepting this latter paper, there do not appear to have been any published records of the species since the original description, even though the taxon is included in accessible standard reviews, and there have been extensive studies of Oligocene sediments. The absence of this small and inconspicuous species from previous investigations may be due to it having been overlooked, having a restricted occurrence or a combination of these factors. However, there have been several detailed taxonomic studies of well-preserved Oligocene assemblages, notably by Dunkley-Jones et al. (2009) and Bown & Dunkley Jones (2012). The absence of occurrences from these types of studies may suggest ecological or biogeographical restrictions.

In our study, we found *H. minima* in three Oligocene sites in the Korça area (ATHB, SE Albania). It was more abundant in samples from the Drenova (Mborja section) and Drenica (Mborja and Dardha Road 1 sections) Formations of Rupelian age, whilst being very scarce in the 'Chama' Marls Formation (Morava-5 section) of Early Chattian age. Both the Mborja and Dardha Road 1 sections contain abundant macrofaunas (bivalves, gastropods, corals, foraminifera and echinoids). The molluscan fauna of the Drenova Coal Formation (Pashko, 1977, 1981, 2018) is indicative of a lagoonal to shallow-marine basin setting, with normal- to slightly-brackish-salinity waters, as evidenced by predominantly euryhaline and much less abundant stenohaline forms. The assemblages from the Drenica Formation indicate a more marine, but still shallow, palaeoenvironment with normal salinity because stenohaline taxa were more abundant than euryhaline taxa in this formation. The assemblages from Dardha Road 1 are typical of the Tethyan mid-Oligocene interval, suggesting full marine conditions and shallow-water palaeoenvironments (Kallanxhi et al., 2015). The presence of *H. minima* has been associated with increased amounts of small reticulofenestrids, which are known to adapt to a wide range of environments, in terms of salinity and temperature, and to prefer mainly nearshore, eutrophic marine waters (Haq, 1980; Wade & Bown, 2006). The macrofossil evidence also suggests that *H. minima* preferred shallow, warm, tropical to subtropical, well-oxygenated marine waters, with sufficient nutrient loads to support abundant marine life. A preference for normal to lowered salinity for this species is also supported by the macrofauna. A lower abundance of *H. minima* in the 'Chama' Marls Formation (Morava-5) may be connected to a change in the basin towards increasingly marine conditions and increased water depth, as indicated by a decrease in the macrofaunal content (Pashko, 1977, 1981, 2018).

7. Conclusions

The known biostratigraphic range of *H. minima* was extended from NP22 only to NP22–NP24. Based on all known data, we conclude that this species is confined to the Oligocene. For the first time, LM measurements were performed on this species, and extended size ranges are documented. The data from this study suggest that *H. minima* preferred eutrophic conditions in shallow-/marginal-marine settings. Its sensitivity to these parameters (availability of nutrient supply, water depth) has probably been the reason for it rarely being recorded in previous studies.

Acknowledgments

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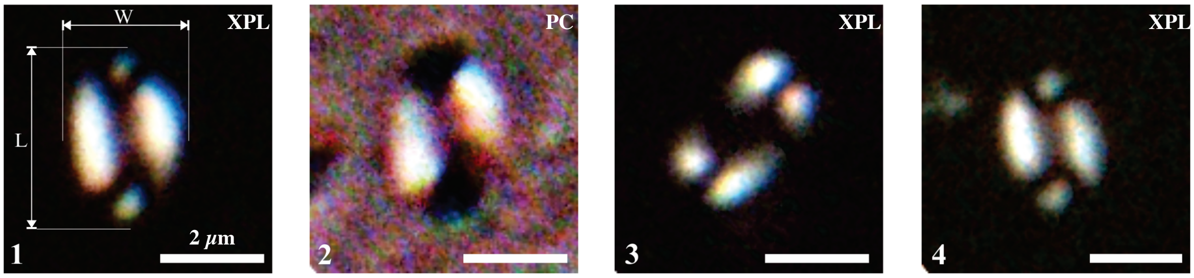
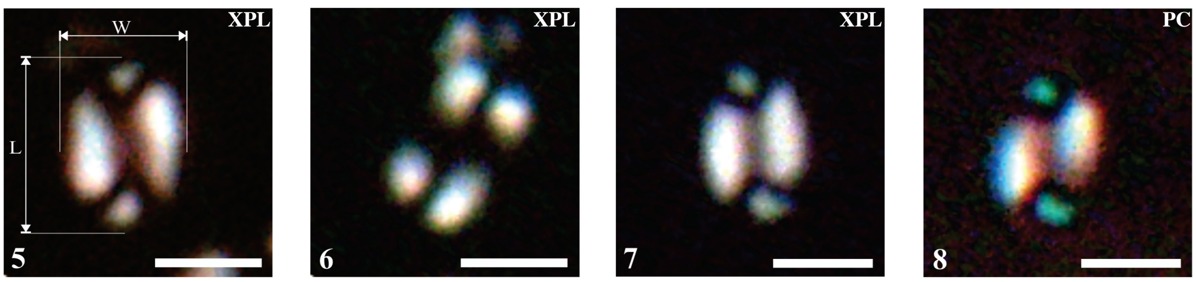
Plate 1

Helicosphaera minima



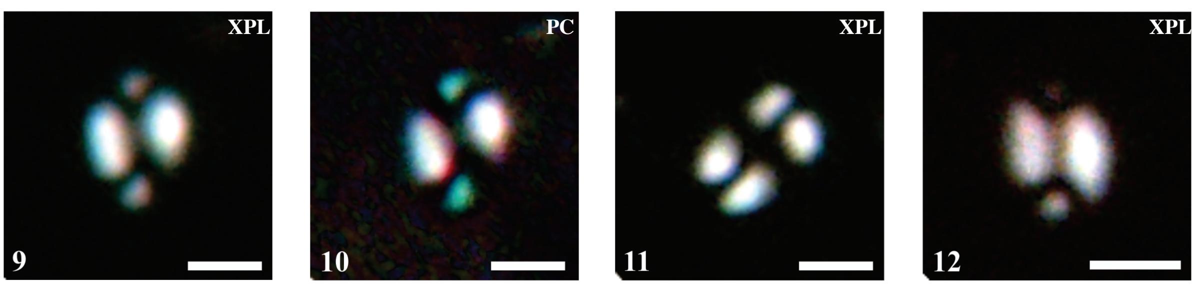
1–3: H-101, in sub-parallel and rotated positions
Sample Mb-07

H-048
Sample Mb-09



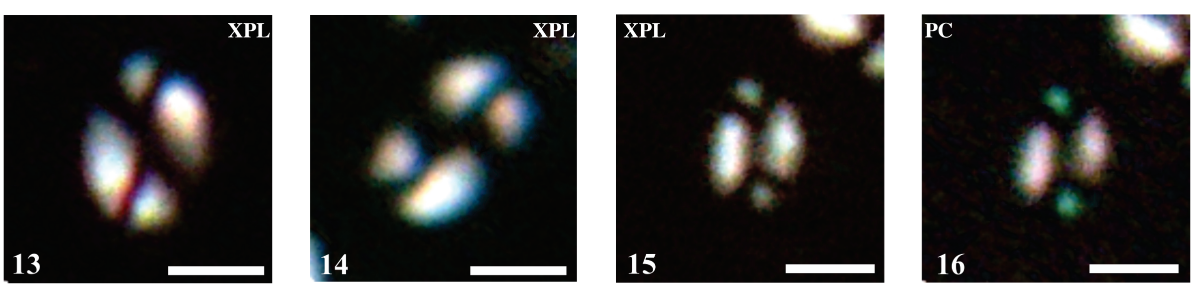
5, 6: H-107, in sub-parallel and rotated positions
Sample Mb-07

7, 8: H-111
Sample Mb-07



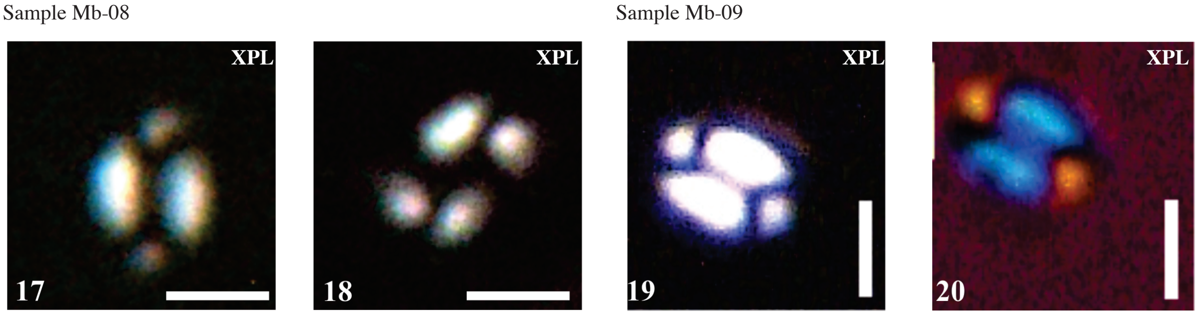
9–11: H-011, in sub-parallel and rotated positions
Sample Mb-08

H-041
Sample Mb-09



13, 14: H-020, in sub-parallel and rotated positions
Sample Mb-08

15, 16: H-025
Sample Mb-09

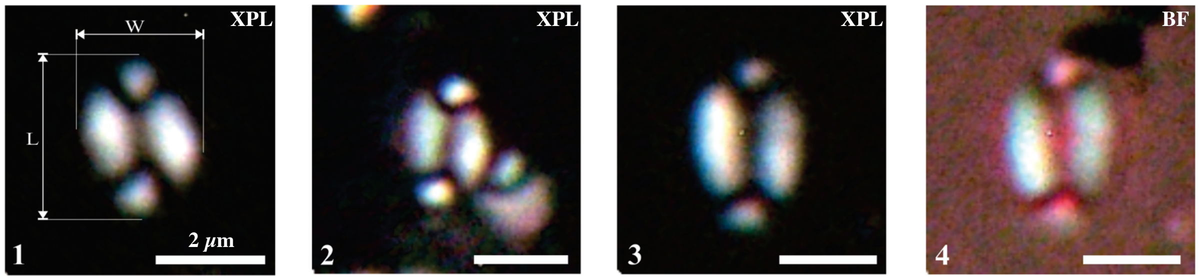


17, 18: H-029, in sub-parallel and rotated positions
Sample Mb-09

19, 20: H-211
Sample RD-1/53

Plate 2

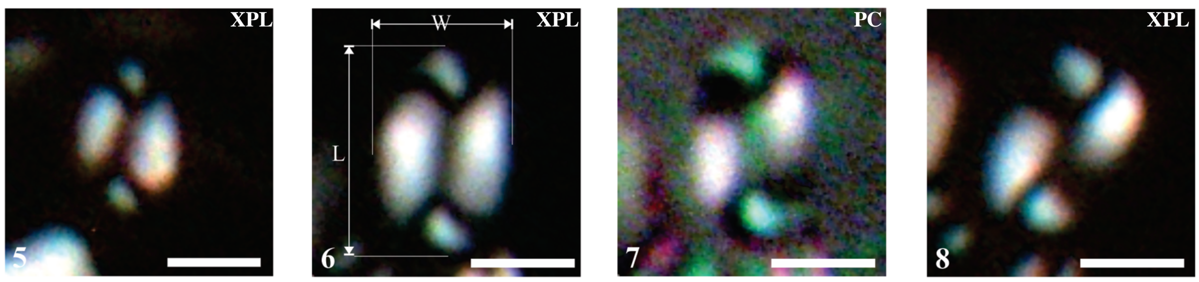
1–14: *H. minima*; 15–17: *H. girgisii*; 18, 19: *Helicosphaera* sp.



H-147
Sample RD-1/54

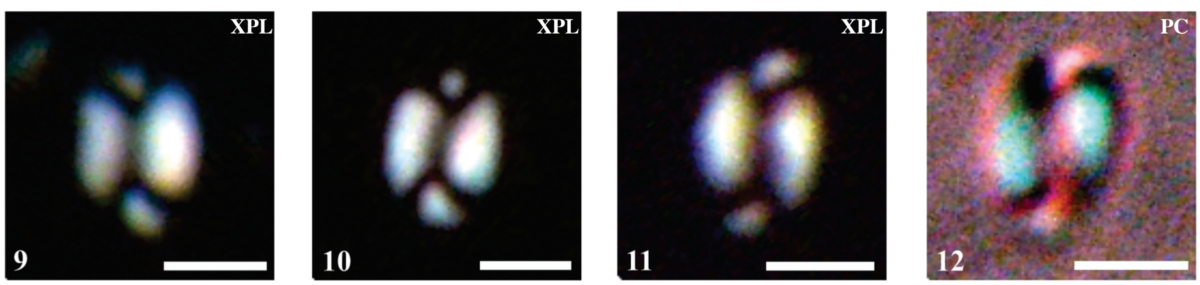
H-148
Sample RD-1/54

3, 4: H-161
Sample RD-1/54



H-164
Sample RD-1/54

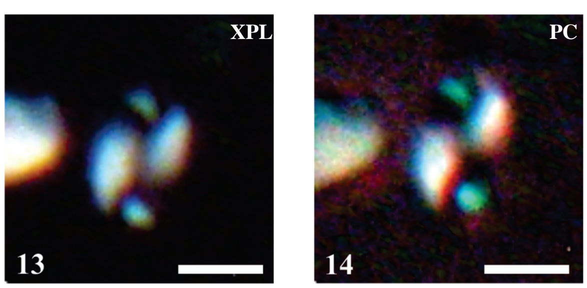
6–8: H-165, in sub-parallel and rotated positions
Sample RD-1/54



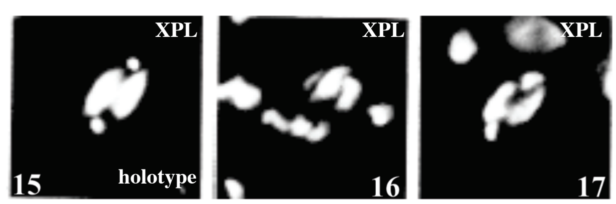
H-166
Sample RD-1/54

H-174
Sample RD-1/54

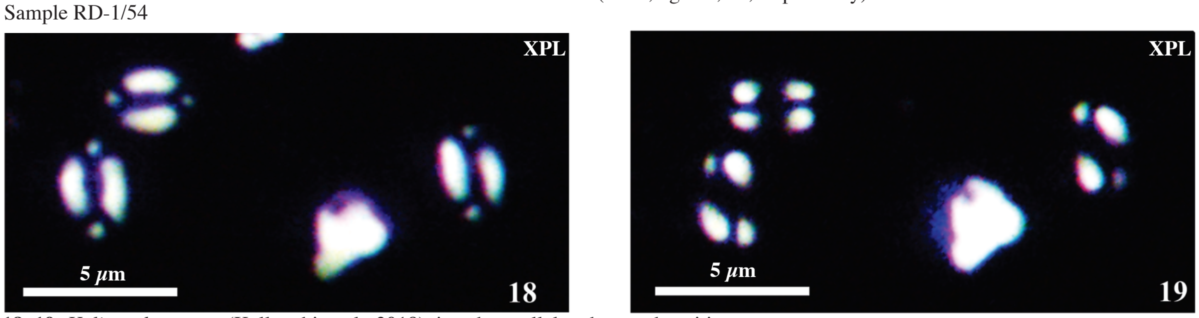
11, 12: H-177
Sample RD-1/54



13, 14: H-180
Sample RD-1/54



15–17: *H. girgisii*. Holotype reproduced from Varol (1989, fig. 11), length = 5.8 µm, width = 3.3 µm. **15, 16**: Reproduced from Varol (1989, figs 12, 13, respectively)



18, 19: *Helicosphaera* sp. (Kallanxhi et al., 2018), in sub-parallel and rotated positions
Sample FB43 (Transect C, Fântânele section, Transylvanian Basin, Romania; M-EK, pers. obs., 2018)

Specimen No.	Length µm	Width µm	Sample No.
H-001	3.000	2.038	
H-002	3.090	2.544	
H-003	3.494	2.612	
H-004	3.226	1.951	
H-005	2.869	2.458	Mb-19
H-006	3.077	2.341	
H-007	3.000	2.090	
H-008	2.974	2.703	
H-009	3.614	2.407	

Specimen No.	Length µm	Width µm	Sample No.
H-010	4.136	2.349	
H-011	4.157	2.841	
H-012	3.523	2.416	
H-013	3.000	2.218	
H-014	3.221	2.209	
H-015	3.163	2.534	
H-016	3.449	2.058	Mb-08
H-017	3.696	2.727	
H-018	2.843	2.004	
H-019	4.003	2.942	
H-020	4.024	2.735	
H-021	2.857	2.347	
H-022	4.231	2.787	

Specimen No.	Length µm	Width µm	Sample No.
H-023	3.131	2.542	
H-024	3.764	2.875	
H-025	2.902	2.055	
H-026	3.209	2.550	
H-027	2.698	2.109	
H-028	3.631	2.370	
H-029	3.200	2.260	
H-030	2.910	1.641	
H-031	3.113	2.062	
H-032	3.491	2.528	
H-033	3.457	2.843	
H-034	3.451	2.590	
H-035	3.965	2.241	
H-036	2.966	2.190	
H-037	3.349	2.210	
H-038	3.088	2.098	
H-039	3.298	2.446	
H-040	3.039	2.385	Mb-09
H-041	3.129	2.435	
H-042	4.041	2.795	
H-043	2.379	1.862	
H-044	3.562	2.271	
H-045	3.297	2.322	
H-046	3.281	2.119	
H-047	2.689	1.779	
H-048	3.266	2.377	
H-049	3.419	2.395	
H-050	3.127	2.005	
H-051	2.910	1.998	
H-052	3.054	2.059	
H-053	3.602	2.752	
H-054	2.879	2.112	
H-055	3.400	1.991	
H-056	4.503	2.859	
H-057	3.349	2.308	
H-058	3.125	2.532	

Specimen No.	Length µm	Width µm	Sample No.
H-059	3.891	3.114	
H-060	3.020	2.382	
H-061	3.410	2.572	Mb-15
H-062	3.533	2.175	
H-063	3.063	2.302	
H-064	3.696	2.579	

Specimen No.	Length µm	Width µm	Sample No.
H-128	2.831	2.029	
H-129	3.031	2.369	RD-1/58
H-130	3.525	2.425	

Specimen No.	Length µm	Width µm	Sample No.
H-143	2.500	2.021	
H-210	4.521	2.929	RD-1/53
H-211	3.595	2.333	

Specimen No.	Length µm	Width µm	Sample No.
H-065	2.800	2.310	
H-066	3.314	2.630	
H-067	3.029	1.974	
H-068	2.800	1.895	
H-069	2.666	1.854	
H-070	4.028	2.541	
H-071	2.706	1.908	
H-072	2.615	2.005	
H-073	2.800	2.159	
H-074	3.925	2.267	
H-075	2.776	2.108	
H-076	3.688	3.045	
H-077	4.069	2.368	
H-078	4.426	3.147	
H-079	3.261	2.480	
H-080	3.087	2.387	
H-081	3.485	2.284	
H-082	3.425	2.605	
H-083	4.162	2.876	
H-084	3.386	2.347	
H-085	2.486	1.603	
H-086	2.796	2.130	
H-087	3.064	2.255	Mb-07
H-088	2.940	2.172	
H-089	2.128	1.770	
H-090	2.414	1.711	
H-092	2.530	2.138	
H-093	2.873	1.695	
H-094	3.022	2.042	
H-095	3.000	2.362	
H-096	2.386	1.584	
H-097	2.676	2.003	
H-098	3.169	2.107	
H-099	3.079	2.062	
H-100	2.976	2.172	
H-101	3.700	2.435	
H-102	3.535	2.823	
H-103	3.394	2.442	
H-104	3.467	2.585	
H-105	3.093	2.385	
H-106	2.538	1.835	
H-107	3.590	2.486	
H-108	3.171	2.255	
H-109	3.167	1.923	
H-110	2.708	2.006	
H-111	3.325	2.282	

Specimen No.	Length µm	Width µm	Sample No.
H-112	3.000	2.036	
H-113	3.542	2.192	
H-114	2.877	2.244	
H-115	2.484	2.152	
H-116	2.758	2.227	
H-117	3.411	2.502	
H-118	2.212	1.640	
H-119	2.879	1.986	RD-1/57
H-120	3.042	2.196	
H-121	2.491	2.167	
H-122	2.951	2.449	
H-123	3.954	2.672	
H-124	3.993	2.612	
H-125	3.020	1.946	
H-126	2.957	2.315	
H-127	3.626	2.440	

Specimen No.	Length µm	Width µm	Sample No.
H-131	3.298	2.057	
H-132	3.682	3.060	
H-133	3.037	2.385	
H-134	3.214	2.490	
H-135	3.053	2.321	
H-136	2.809	2.199	RD-1/59
H-137	2.978	2.440	
H-138	3.569	2.335	
H-139	3.298	2.343	
H-140	2.914	2.094	
H-141	3.012	2.334	
H-142	3.041	2.294	

Specimen No.	Length µm	Width µm	Sample No.
H-144	2.889	2.299	
H-145	2.831	2.560	
H-146	4.074	2.780	
H-147	3.000	2.282	
H-148	2.933	1.928	
H-149	2.366	1.843	
H-150	3.001	2.224	
H-151	2.574	1.827	
H-152	2.885	2.200	
H-153	4.009	2.903	
H-154	4.067	2.931	
H-155	3.364	2.341	
H-156	3.000	2.437	
H-157	2.901	1.748	
H-158	2.676	2.232	
H-159	2.928	2.005	
H-160	3.658	2.475	
H-161	3.970	2.580	
H-162	3.575	2.640	RD-1/54
H-163	3.760	2.912	
H-164	3.615	2.470	
H-165	4.058	2.829	
H-166	3.603	2.654	
H-167	3.200	2.531	
H-168	3.000	2.203	
H-169	3.126	2.015	
H-170	3.155	2.344	
H-171	2.588	2.028	
H-172	3.284	2.079	
H-173	3.229	1.808	
H-174	3.689	2.743	
H-175	3.240	2.261	
H-176	3.520	2.366	
H-177	3.694	2.486	
H-178	3.021	2.113	
H-179	3.025	2.142	
H-180	3.559	2.490	

Specimen No.	Length µm	Width µm	Sample No.
H-181	2.658	2.396	
H-182	3.629	2.538	
H-183	2.931	2.158	
H-184	2.909	1.917	
H-185	2.696	1.918	
H-186	2.943	1.953	
H-187	3.453	3.013	RD-1/60
H-188	3.190	2.560	
H-189	2.891	2.271	
H-190	2.899	2.276	
H-191	3.558	2.622	
H-192	3.159	2.223	
H-193	2.830	2.114	
H-194	2.992	2.283	

Specimen No.	Length µm	Width µm	Sample No.
H-195	2.948	2.216	
H-196	3.024	2.258	
H-197	2.770	1.987	Mb-05
H-198	3.024	2.195	
H-199	2.977	1.883	
H-200	2.618	2.036	

Specimen No.	Length µm	Width µm	Sample No.
H-201	4.365	2.578	
H-202	3.877	2.904	Mb-02
H-203	3.420	2.867	

Specimen No.	Length µm	Width µm	Sample No.
H-204	3.126	2.238	
H-205	4.528	3.278	Mb-03
H-206	3.998	2.847	

Specimen No.	Length µm	Width µm	Sample No.
H-207	2.619	2.251	
H-208	3.103	2.543	Mb-06
H-209	4.513	3.576	

Specimen No.	Length µm	Width µm	Sample No.
H-091	3.117	2.481	RD-1/51

Table 1: Raw measurements of all investigated specimens. 'H-' corresponds to specimens illustrated in the plates