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A new calcareous nannofossil species of the genus *Helicolithus* from the Santonian and its biostratigraphic significance in the Cretaceous Western Interior Seaway

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Abstract A high-resolution biostratigraphic study of Santonian calcareous nannofossils from the type area of the Smoky Hill Member of the Niobrara Formation in western Kansas identified a new nannofossil species, *Helicolithus blairiae* sp. nov. This species has a lozenge-shaped longitudinal bar which separates two very short, but diagnostic, disjunct segments along the minor axis of the ellipse. The longitudinal bar has a distinct 's'-shaped extinction pattern. The range and distribution of *H. blairiae* is limited to the Late Santonian in the Smoky Hill type area and is verified in sections from South Dakota and Texas. *Helicolithus blairiae* may have been limited in its paleogeographic range, as it is present in the Western Interior Seaway but it was not observed in Santonian sediments from the Gulf of Mexico or the western coast of Africa. *Helicolithus blairiae* could prove to be a useful biostratigraphic marker in the Niobrara Formation because of the absence of holococcolith marker species.

Keywords Calcareous nannofossils, biostratigraphy, *Helicolithus*, Santonian, taxonomy, Niobrara Formation

1. Introduction

A new species of calcareous nannofossil, *Helicolithus blairiae* sp. nov., was identified during a high-resolution biostratigraphic study of Santonian and Campanian sediments from the Cretaceous Western Interior Seaway in western Kansas, USA. *Helicolithus blairiae* exhibits a unique morphology, is moderately abundant over its short stratigraphic range, and has potential use as an alternate marker for nannofossil Zone CC17 (Perch-Nielsen, 1985). This utility is particularly enhanced in the Niobrara Formation where the holococcolith species (e.g., *Calculites obscurus*, *Lucianorhabdus cayeuxii*), which serve as biostratigraphic markers in the CC and UC zonation schemes, are extremely rare or absent.

2. Materials and methods

The primary locality examined in this study is the type area of the Smoky Hill Member of the Niobrara Formation in western Kansas (Figure 1; Localities 20 and 23 of Hattin, 1982). The Niobrara Formation consists of cyclic intervals of chalk and calcareous shale and contains rich calcareous nannofossil assemblages, which exhibit moderate to good preservation. Secondary localities include outcrop samples of the Austin Chalk from Lake Waxahachie in Texas (Eby & Clarke, 1983; section 13 of Jiang, 1989); the Dessau Member stratotype in Texas (Young, 1985; section 7 of Jiang, 1989); the Burditt Member reference section in Texas (Young, 1985; section 8 of Jiang, 1989); and a South Dakota Geological Survey core of the Smoky Hill Member of the Niobrara Formation from Miner County, South Dakota (Figure 1).

Smear-slide preparation for the Smoky Hill type area and the Miner County core samples followed the double slurry technique detailed by Watkins & Bergen (2003). Smear slides from the Austin Chalk in Texas were prepared using a modified settling technique by Jiang (1989). Calcareous nannofossils were observed using an Olympus BX 51 light microscope at total magnification of 1250x using cross-polarized light, plane polarized light, phase contrast, and a 1/4 λ gypsum plate. Photomicrographs were taken using an Olympus DP71 camera. Univariate analysis of key morphological characteristics was conducted using PAST (Hammer *et al*., 2001). Figured specimens, type species, and slides have been deposited in the Micropaleontology Collection at the University of Nebraska-Lincoln.

3. Abundance and distribution

The abundance of *Helicolithus blairiae* was documented throughout its observed range in the Smoky Hill Member type area in Kansas. The species never became common during its range, with a maximum abundance of approximately 2% of the assemblage in sample Loc 23B –4.0m. The first appearance datum (FAD) of *H. blairiae* is located approximately 15m above the FAD of *Ahmuellerella regularis* (Table 1), which has been documented in the Santonian (Bergen & Sikora, 1999), and 16m above the FAD of the ammonite *Clioscaphites choteauensis* (Table 1), placed in the Middle Santonian by Walaszczyk & Cobban

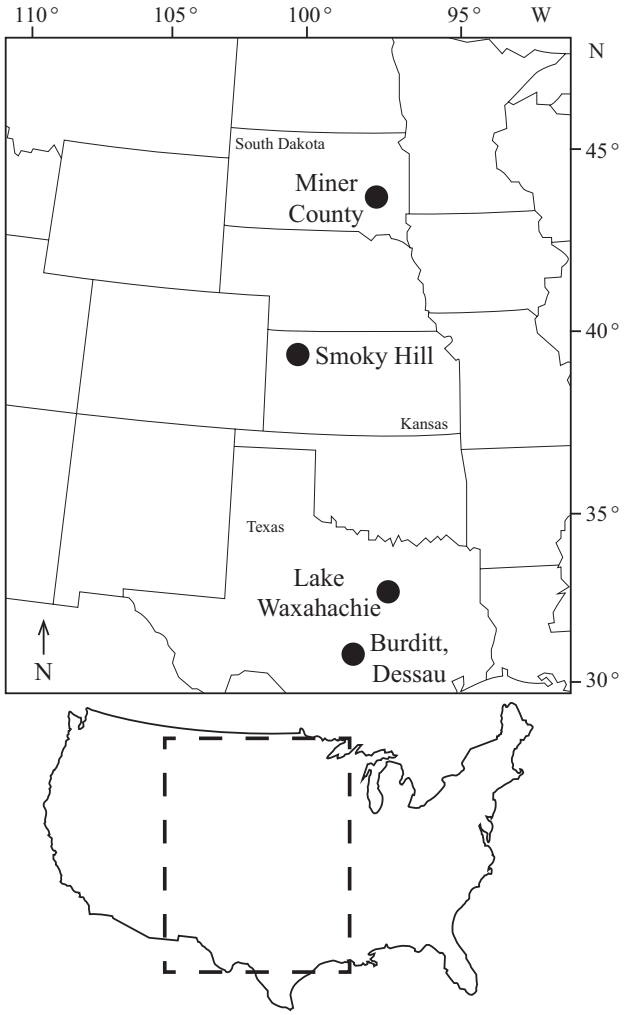

Figure 1: Geographical distribution of the five sites examined for *Helicolithus blairiae*

(2007) in the Western Interior Seaway. The last appearance datum (LAD) of *H. blairiae* is located approximately 16m below the FAD of *Aspidolithus parcus parcus* (Table 1), the marker for the base of nannofossil Zone CC18.

The new species was subsequently observed nine meters above the FAD of *A. regularis* in a South Dakota Geological Survey core of the Niobrara Formation from Miner County, SD (Table 2). Following initial identification in the Niobrara Formation, *H. blairiae* was also observed in the Dessau Member stratotype (Table 3), the Burditt Member reference section (Table 4) and the Lake Waxahachie section of the Austin Chalk and Taylor Marl (Table 5) (Figure 1). The geographic distribution of *H. blairiae* appears to be limited to the Western Interior Seaway. It was not observed in the Santonian of the nearby Gulf of Mexico (Deep Sea Drilling Program Leg 10) or in sediments from along the Ivory Coast and Ghana (Ocean Drilling Program Leg 159) based on examination of samples from these sections.

Several holococcolith marker species (e.g., *Calculites obscurus*, *Lucianorhabdus cayeuxii*) were not present in

Smoky Hill Type Area

Sample #	Height (m)	Height (ft)	CC Zone	*H. blairiae* vs. Bioevents
Loc 24 6.0m	166.30	545.6	18a	FAD *A. parcus parcus*
Loc 24 5.0m	165.30	542.3	16–17	
Loc 24 4.0m	164.30	539.0	16–17	
Loc 24 3.0m	163.30	535.8	16–17	
Loc 24 2.0m	162.30	532.5	16–17	
Loc 24 1.0m	161.30	529.2	16–17	
Loc 24 0.1m	160.40	526.2	16–17	
Loc 20 6.0m	159.00	521.7	16–17	
Loc 20 5.0m	158.00	518.4	16–17	
Loc 20 4.0m	157.00	515.1	16–17	
Loc 20 3.0m	156.00	511.8	16–17	
Loc 20 2.0m	155.00	508.5	16–17	
Loc 20 1.0m	154.00	505.2	16–17	
Loc 20 0.0m	153.00	502.0	16–17	
Loc 20 –1.0m	152.00	498.7	16–17	
Loc 20 –2.0m	151.00	495.4	16–17	
Loc 20 –3.0m	150.00	492.1	16–17	X
Loc 20 –4.0m	149.00	488.8	16–17	
Loc 20 –5.0m	148.00	485.6	16–17	X
Loc 23B 2.0m	147.88	485.2	16–17	
Loc 20 –6.0m	147.00	482.3	16–17	X
Loc 23B 1.0m	146.88	481.9	16–17	X
Loc 20 –7.0m	146.00	479.0	16–17	
Loc 23B –1.0m	144.88	475.3	16–17	
Loc 23B –2.0m	143.88	472.0	16–17	X
Loc 23B –3.0m	142.88	468.8	16–17	X
Loc 23B –4.0m	141.88	465.5	16–17	X
Loc 23B –5.0m	140.88	462.2	16–17	X
Loc 23B –6.0m	139.88	458.9	16–17	X
Loc 23B –7.0m	138.88	455.6	16–17	X
Loc 23B –8.0m	137.88	452.4	16–17	
Loc 23A 8.0m	136.68	448.4	16–17	X
Loc 23A 7.0m	135.68	445.1	16–17	
Loc 23A 6.0m	134.68	441.9	16–17	
Loc 23A 5.0m	133.68	438.6	16–17	X
Loc 23A 4.0m	132.68	435.3	16–17	X
Loc 23A 3.0m	131.68	432.0	16–17	
Loc 23A 2.0m	130.68	428.7	16–17	
Loc 18 7.0m	129.98	426.4	16–17	
Loc 23A 1.0m	129.68	425.5	16–17	
Loc 18 6.0m	128.98	423.2	16–17	
Loc 23A 0.0m	128.68	422.2	16–17	
Loc 18 5.0m	127.98	419.9	16–17	
Loc 18 4.0m	126.98	416.6	16–17	
Loc 18 3.0m	125.98	413.3	16–17	
Loc 18 2.0m	124.98	410.0	16–17	
Loc 18 1.0m	123.98	406.8	16–17	
Loc 18 –0.1m	122.88	403.1	16–17	
Loc 18 –1.0m	121.98	400.2	16–17	
Loc 18 –2.0m	120.98	396.9	16–17	
Loc 18 –3.0m	119.98	393.6	16–17	
Loc 18 –4.0m	118.98	390.4	16–17	
Loc 18 –5.0m	117.98	387.1	16–17	
Loc 18 –6.0m	116.98	383.8	16–17	FAD *A. regularis*

Table 1: Stratigraphic distribution of *Helicolithus blairiae* in the Smoky Hill Member type area, Kansas. All samples are from the Smoky Hill Member of the Niobrara Formation

Miner County Core				
Sample #	Depth (m)	Depth (ft)	CC Zone	*H. blairiae* vs. Bioevents
28-1	139.20	456.7	18a	
28-2	139.80	458.7	18a	FAD *A. parcus parcus*
28-3	140.40	460.6	16–17	
28-4	141.00	462.6	16–17	
28-5	141.70	464.9	16–17	
29-1	142.30	466.9	16–17	
29-2	142.90	468.8	16–17	
29-3	143.50	470.8	16–17	
29-4	144.10	472.8	16–17	
29-5	144.70	474.7	16–17	
30-1	145.30	476.7	16–17	
30-2	145.90	478.7	16–17	
30-3	146.50	480.6	16–17	
30-4	147.10	482.6	16–17	
30-5	147.80	484.9	16–17	
31-1	148.40	486.9	16–17	
31-2	149.00	488.8	16–17	
31-3	149.60	490.8	16–17	
31-4	150.20	492.8	16–17	
31-5	150.70	494.4	16–17	
32-2	151.90	498.4	16–17	
32-3	152.50	500.3	16–17	
32-4	153.10	502.3	16–17	
32-5	153.70	504.3	16–17	
33-1	154.30	506.2	16–17	
33-2	154.90	508.2	16–17	X
33-3	155.50	510.2	16–17	X
33-4	156.10	512.1	16–17	X
33-5	156.50	513.5	16–17	X
34-1	157.10	515.4	16–17	
34-2	157.70	517.4	16–17	
34-3	158.40	519.7	16–17	
34-4	159.10	522.0	16–17	
34-5	159.70	524.0	16–17	
35-2	161.00	528.2	16–17	
35-3	161.60	530.2	16–17	
35-4	162.20	532.2	16–17	
35-5	162.80	534.1	16–17	
36-1	163.40	536.1	16–17	
36-2	164.00	538.1	16–17	
36-3	164.60	540.0	16–17	
36-4	165.20	542.0	16–17	FAD *A. regularis*

Table 2: Stratigraphic distribution of *Helicolithus blairiae* in the Miner County, SD core. All samples are from the Smoky Hill Member of the Niobrara Formation

Dessau Member Stratotype				
Sample #	Height (m)	Height (ft)	CC Zone	*H. blairiae*
S07-01	37.19	122.0	17	X
S07-02	35.05	115.0	17	
S07-03	33.53	110.0	17	X
S07-04	33.22	109.0	17	X
S07-05	32.92	108.0	17	X; FAD *C. obsc*
S07-06	31.70	104.0	16	X
S07-07	30.18	99.0	16	
S07-08	28.04	92.0	16	
S07-09	25.60	84.0	16	
S07-10	23.32	76.5	16	
S07-11	21.64	71.0	16	

Table 3: Stratigraphic distribution of *Helicolithus blairiae* in the Dessau Member stratotype, Taxas. All samples are from the Dessau Member of the Austin Chalk

Burditt Member Reerence Section				
Sample #	Height (m)	Height (ft)	CC Zone	*H. blairiae*
S08-36	7.01	23.0	18a	
S08-37	7.16	23.5	17	
S08-38	7.47	24.5	17	
S08-39	7.77	25.5	17	
S08-40	8.08	26.5	17	
S08-41	8.23	27.0	17	
S08-42	8.53	28.0	17	
S08-43	8.84	29.0	17	
S08-44	9.14	30.0	17	
S08-45	9.45	31.0	17	
S08-46	9.60	31.5	17	
S08-47	9.91	32.5	17	
S08-48	10.13	33.3	17	
S08-49	10.36	34.0	17	
S08-50	10.67	35.0	17	
S08-51	10.97	36.0	17	
S08-52	11.13	36.5	17	
S08-53	11.28	37.0	17	
S08-54	12.04	39.5	17	
S08-55	12.95	42.5	17	
S08-56	13.56	44.5	17	
S08-57	14.17	46.5	17	
S08-58	14.78	48.5	17	
S08-59	15.39	50.5	17	X

Table 4: Stratigraphic distribution of *Helicolithus blairiae* in the Burditt Member reference section, Texas. All samples are from the Burditt Member of the Austin Chalk

the Kansas or South Dakota sections, but were abundant in the Texas sections. The relative abundance of holococcolith marker species in the Texas sections allowed for comparison of the observed range of *H. blairiae* with those of the holococcolith marker species which were absent in the Kansas and South Dakota material. By placing *H. blairiae* in a biostratigraphic framework along with the full suite of nannofossil marker species, including holococcoliths, the FAD of this species was reliably placed only 4ft (1.22m) below the FAD of the holococcolith *C. obscurus*, the marker for Zone CC17, in the Dessau Member stratotype section (Table 3). The close proximity of the FAD of *H. blairiae* to the FAD of the commonly-used nannofossil marker *C. obscurus* suggests that the FAD of *H. blairiae* may serve as an alternate marker for the base of nannofossil Zone CC17, particularly when holococcoliths are absent as has been observed in the Niobrara Formation.

Lake Waxahachie Section				
Sample #	Height (m)	Height (ft)	CC Zone	*H. blairiae*
S13-04	–0.15	–0.5	18b	
S13-05	0.00	0.0	17	
S13-06	0.15	0.5	17	X
S13-07	0.61	2.0	17	X
S13-08	0.76	2.5	17	
S13-09	1.68	5.5	17	
S13-10	2.74	9.0	17	
S13-11	3.35	11.0	17	X
S13-12	4.27	14.0	17	
S13-13	5.49	18.0	17	X
S13-14	6.71	22.0	17	X
S13-15	7.92	26.0	17	X
S13-16	9.60	31.5	17	
S13-17	10.97	36.0	17	X
S13-18	11.13	36.5	17	
S13-19	11.66	38.3	17	X
S13-20	11.81	38.8	17	X
S13-21	12.34	40.5	17	X

Table 5: Stratigraphic distribution of *Helicolithus blairiae* in the Austin Chalk of the Lake Waxahachie section, Texas. Sample S13-04 is from the Taylor Marl. Samples S13-05 through S13-21 are from the Austin Chalk

4. Morphology and evolutionary lineage

Helicolithus blairiae possesses an axial cross similar to *H. varolii*, but has a lozenge-shaped bar along the major axis, whereas *H. varolii* has triangle-shaped crossbar elements. Under cross-polarized light, *H. blairiae* displays a distinct 's'-shaped extinction pattern on the longitudinal bar in well-preserved specimens (Figure 2). This species may be a part of the *Helicolithus compactus* lineage, as *H. compactus* has a near axial cross and is of similar size (See Varol & Girgis, 1994; Pl.1, fig. 7). Seemingly related forms were observed below the FAD of *H. blairiae*, possessing a lozenge-shaped longitudinal bar as seen in *H. blairiae*, except with a very dull crossbar in cross-polarized light. These forms are somewhat similar to *H. compactus*, except with an axial, rather than diagonal, cross and are referred to as *Helicolithus* sp. cf. *H. blairiae* (Pl.1, fig. 6) in the current study, as they are considered to be transitional forms with an unknown range. *Helicolithus* sp. cf. *H. blairiae* has an axial cross similar to *Helicolithus turonicus* but is smaller in size, as *H. turonicus* is >6μm (Varol & Girgis, 1994) and went extinct in the Coniacian (Burnett, 1998).

5. Biostratigraphic Significance

Currently, the base of nannofossil Zone CC17 is marked by the FAD of the holococcolith *Calculites obscurus*. In much of the Smoky Hill Member of the Niobrara Formation *C. obscurus* is rare to absent, impeding its application as a biostratigraphic marker. The LAD of *Eprolithus floralis* was suggested as an alternate marker by Perch-Nielsen (1979, 1985). This species was then reported within the basal five meters of the Smoky Hill Chalk by Covington (1986), indicating that it becomes locally extinct in the Coniacian and cannot be used as an alternate marker for the base of Zone CC17 in the Western Interior Basin.

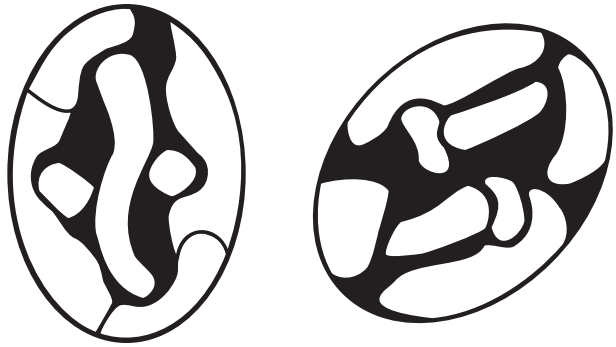

Figure 2: Stylized drawing showing birefringence and extinction patterns of *Helicolithus blairiae* aligned at 0° and 45° to the polarizers

Where traditional holococcolith zonal markers are rare or absent, *H. blairiae* may prove to be a useful substitute. The FAD of *H. blairiae* closely approximates the base of Zone CC17, as it is only 4ft (1.22m) below the FAD of *C. obscurus* in the Dessau stratotype area in central Texas (Table 3). Further studies globally and in the Western Interior Seaway will ultimately determine the robustness of this species as a biostratigraphic marker and continue to ascertain its geographic distribution.

6. Systematic paleontology

Taxonomic concepts follow those of Perch-Nielsen (1985), Bown (1998), or nannotax, unless otherwise noted. Only taxonomic references not included in these references are included in the reference list.

Family ***Eiffellithaceae*** Reinhardt, 1965

Genus *Helicolithus* Noël, 1970
Type Species: *Discolithus anceps* Górka, 1957

Helicolithus blairiae sp. nov.
Pl.1, figs 1–5

Derivation of name: Named after Dr. Stacie Blair, nannofossil paleontologist, friend, and mentor.

Diagnosis: A small to medium-sized species of *Helicolithus* having an axial cross structure nearly filling the central area. A lozenge-shaped longitudinal bar separates two very short, but diagnostic, disjunct segments along the minor axis of the ellipse.

Description: This species is a small to medium-sized (4.3–5.3μm), normally elliptical murolith. The broad inner rim cycle displays pronounced birefringence while the narrow outer rim cycle is dull in cross-polarized light. A broad, lozenge-shaped bar aligned with the major axis nearly fills

the central area and is constructed of numerous lath-shaped elements. When aligned with the polarizers, this bar exhibits a distinct 's'-shaped extinction pattern as the two sets of elements that form the bar on each side do not exhibit simultaneous extinction. When aligned at 45° to the polarizers, the opposite elements appear birefringent. This longitudinal bar bisects two short, disjunct bar segments aligned with the minor axis which, in cross-polarized light, resemble two bright, birefringent dots when aligned with the polarizers. These disjunct segments are not orthogonal to the longitudinal bar. The central area elements display birefringence equal to the broad inner rim cycle.

Differentiation: *Helicolithus blairiae* differs from most *Helicolithus* species by having an axial cross instead of a diagonal cross. *Helicolithus compactus* contains a near-axial cross that is offset from both the major and minor axis. *Helicolithus blairiae* differs from *H. turonicus* by being smaller in size and having a lozenge-shaped bar along the major axis. In less well-preserved specimens, the central area of *H. blairiae* can resemble that of *Broinsonia signata*, but with a very different rim structure. *Helicolithus blairiae* differs from *H. varolii* by being smaller in size (*H. varolii* averages 6.24μm) and by not having triangular-shaped crossbar elements with medial sutures in the central area (Blair & Watkins, 2009).

Dimensions: N = 15; Length = 4.3–5.3μm, 4.9μm (mean), 0.08 (std. error), 0.10 (var.). Width = 3.1–3.8μm, 3.4μm (mean), 0.06 (std. error), 0.05 (var.).

Holotype: Pl.1, fig. 1

Holotype size: L = 5.1μm; W = 3.6μm

Paratype: Pl.1, fig. 2

Type level: 4 meters below marker unit 14 in Locality 23B of the Smoky Hill Member type area described in Hattin (1982).

Type locality: Smoky Hill Member type area of the Niobrara Formation, Gove County, Kansas.

Observed range: Upper Santonian

Depository: Micropaleontology Collection at the University of Nebraska-Lincoln

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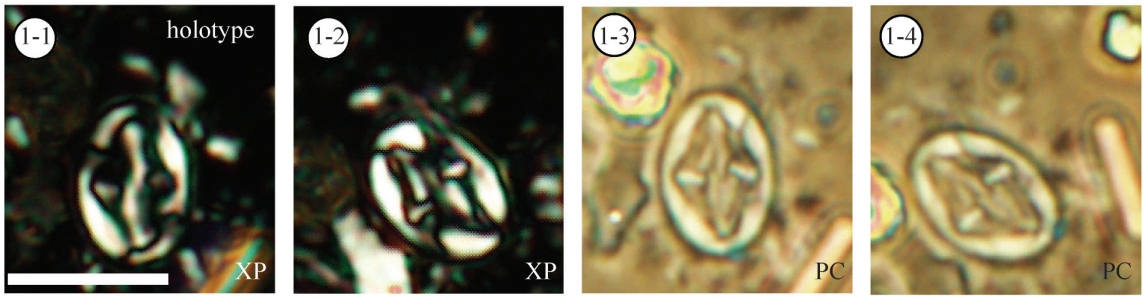
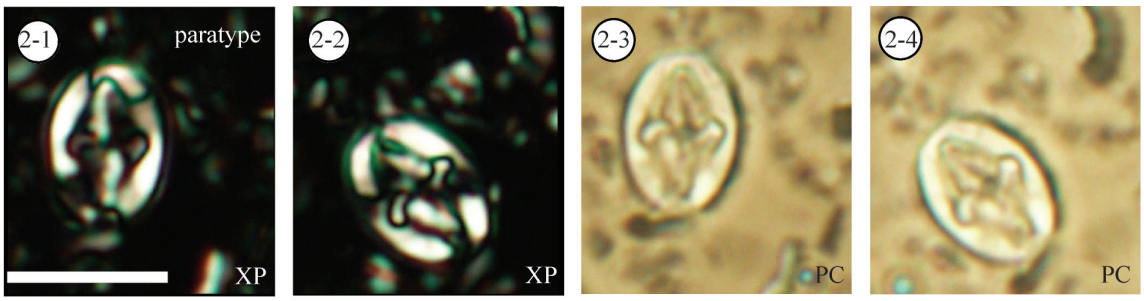
Plate 1

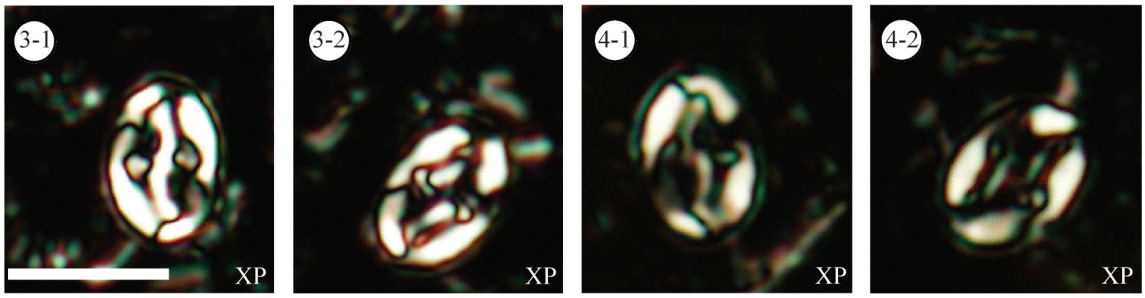
Scale-bars = 5 μm
For each specimen, odd numbers - specimens aligned with polarizers,
even numbers - 45° to polarizers. (XP) cross-polarized light (PC) phase contrast



H. blairiae Smoky Hill type area Loc 23B -4.0m

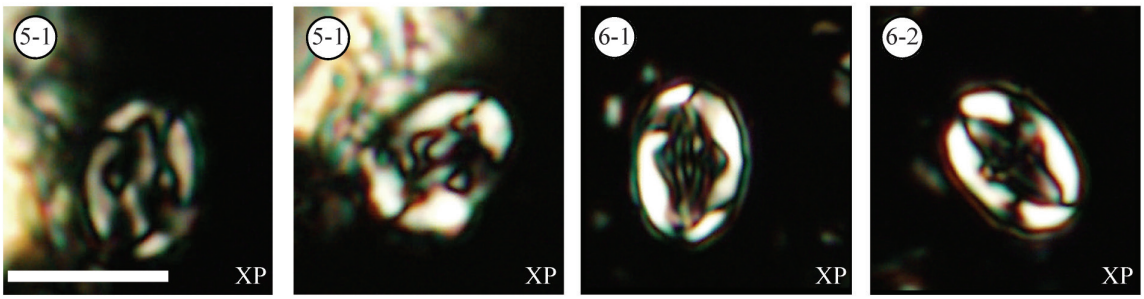


H. blairiae Smoky Hill type area Loc 23B -4.0m



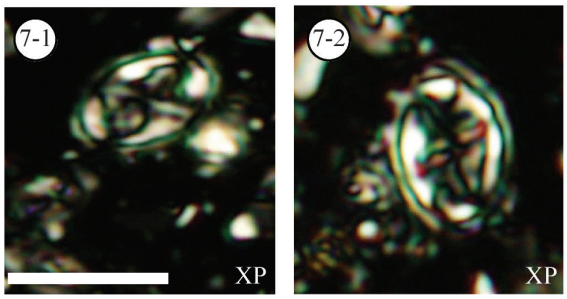
H. blairiae Sample Miner County 33-4, 156.1m

H. blairiae Lake Waxahachie S13-14, 22 ft from top



H. blairiae Lake Waxahachie S13-21, 41ft from top

Helicolithus sp. cf. *H. blairiae*
Smoky Hill type area Loc 18B -7.0m



Helicolithus compactus
Smoky Hill type area Loc 18b -7.0m