

Rarely seen coleoid phragmacone steinkerns from the Eocene Castle Hayne Limestone of southeastern North Carolina

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With one plate and one text figure.

**Zusammenfassung**

Eozän coleoiden Phragmocon Steinkerne vom Castle Hayne Kalk, im südösten North Carolina, werden beschreiben und diskutiert. Es wird in Erwägung gezogen, dass die Exemplare den Belopteridae und den Belosaepiidae angehören. Mögliche generische Angliederungen *Beloptera?* und *Anomalosaepia* werden vorgeschlagen. Des weiteren werden Auswirkungen auf auf die phylogenetische Rekonstruktion von Spiruliden und Sepiiden diskutiert.

Schlüsselwörter: Coleoiden -- Phragmocon -- Eozän -- *Beloptera* -- *Anomalosaepia*

**Summary**

Eocene coleoid phragmacone steinkerns from the Castle Hayne Limestone of southeastern North Carolina are described and discussed. Specimens are considered to belong to Belopteridae and to Belosaepiidae. Possible generic affiliations *Beloptera?* and *Anomalosaepia* are proposed.

Implications for phylogenetic reconstruction of spirulids and sepiids are discussed.

Key words: Coleoid -- phragmacone -- Eocene -- *Beloptera* -- *Anomalosaepia*

**Contents**

Introduction.....	2	Repository .....	9
Geologic setting .....	3	Acknowledgments.....	9
Previous works.....	4	References.....	10
Systematic Paleontology .....	6	Explanation of plate .....	14
Discussion.....	9		

**Introduction**

World-wide, Tertiary coleoids have been known since the 1800s (Deshayes, 1824; DeBlainville, 1827 and Voltz, 1830). Early work focused on descriptions diagrammatic representations of whole organisms and phylogenetic relationships (Naef, 1922). Workers have since focused on taxonomic descriptions based on guard-like sheaths (Palmer, 1937; Allen, 1968; Garvie, 1996 and Weaver and Ciampaglio, 2003), studied microstructures within the guard-like sheaths (Jeletzky, 1966 and Dauphin, 1984 and 1985), or attempted phylogenetic reconstruction

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of coleoid lineages (Jeletzky, 1969; Donovan, 1977; Engeser, 1990; Doyle *et al.*, 1994; Young *et al.*, 1998 and Haas, 1997 and 2003). While guard-like sheaths of Tertiary coleoids are widely represented, phragmacones of these organisms are virtually unknown and knowledge of phragmaconal elements is necessary for understanding coleoid lineages.

Coleoid phragmacone steinkerns have been found in spoil piles at Martin Marietta Quarry, near Castle Hayne, New Hanover County, North Carolina. UNC 1416, previously figured as *Belemnosella?* sp. (Carter *et al.*, 1988, fig. 26), is considered *Beloptera?* sp., as is NCSM 7714, while NCSM 7713 and NCSM 9262 are considered to be *Anomalosaepia* sp.

### Geological setting

Near-surface deposits of the middle Eocene Castle Hayne Limestone extend as a 16-32 km wide zone from Brunswick County and New Hanover County north through east-central Pender County, through western portions of Onslow, Jones and Craven Counties, and into southeastern Pitt County in southeastern North Carolina (Otte, 1986). Bounded by unconformities above and below, the formation is typically overlain by Oligocene and younger rocks and underlain by Paleocene and Cretaceous rocks. The Castle Hayne Limestone is thought to range in age from mid-Lutetian to Priabonian (Harris and Laws, 1997).

Baum *et al.*, 1978; Ward *et al.*, 1978; Kier, 1980, Zullo and Harris, 1986 and 1987; and Harris and Zullo, 1987, have interpreted the lithostratigraphic subdivisions of the Castle Hayne Limestone. Ward *et al.* (1978) named three lithosomes within the Formation (New Hanover, Comfort and Spring Garden Members). The lowest unit (New Hanover Member) is a slightly arenitic, micritic and phosphatic lithocalrudite; the middle unit (Comfort Member) is a gray to cream colored bryozoan-echinoid calcirudite, grading to a fine calcarenite; and the uppermost unit (Spring Garden Member) is a tan to gray arenaceous molluscan-mold biocalcirudite. All units typically represent differing time sequences at different exposures.

Applying a sequence approach, Harris and Zullo (1987) divided the Castle Hayne Limestone into five depositional sequences (0-4). These sequences, divided by regional unconformities, reflect sea-level and depositional environmental change. A complete lithologic section consists of a phosphate pebble biomicrudite base overlain by biosparudite, in turn overlain by biomicrudite grading into biosparudite. A complete lithostratigraphic section is rarely represented at a single locality and sequences are typically represented by different lithologies at various exposures.

Using an echinoid-based biostratigraphic approach, Kier (1980) divided the Castle Hayne Limestone into three informal biozones (early, middle, late). These temporal biozones overlap somewhat with the depositional sequences defined by Harris and Zullo (1987) and provide a reasonable biostratigraphic interpretation. Correlation between sequence stratigraphy (Harris and Zullo, 1987), biostratigraphy (Kier, 1980) and lithostratigraphy (Ward *et al.*, 1978) is provided in Text-figure 1.

Stratigraphic location within the Castle Hayne Limestone is not precisely known, but based on where in the quarry the specimens were collected, coupled with the presence of *Periarchus lyelli* and the lithologic composition of the phragmacone steinkerns, it is likely that these specimens were contained within sequences 3 or 4 (Zullo and Harris, 1987).

		Ward, et al, 1978 Lithology		
Harris & Zullo, 1987 Sequence Stratigraphy	Kier, 1980 Biostratigraphy	New Hanover Member	Comfort Member	Spring Garden Member
Sequence 4	Late Biozone			
Sequence 3	Middle Biozone			
Sequence 2				
Sequence 1	Early Biozone			
Sequence 0				

**Text-Figure 1**--Correlation between sequence stratigraphy (Harris and Zullo, 1987), lithostratigraphy (Ward *et al.*, 1978) and biostratigraphy (Kier, 1980) of the Castle Hayne Limestone. Ward *et al.*'s (1978) New Hanover, Comfort, and Spring Garden Members are time transgressive and not found in all depositional sequences. They form a "fining upwards" lithology in each depositional sequence in which they are found.

### Previous works

Reconstruction of phylogenetic relationships using microstructures preserved within coleoid guard-like sheaths, (Jeletzky, 1966; Donovan, 1977 and Doyle *et al.*, 1994), and comparison with extant taxa (Engeser, 1990; Young *et al.*, 1998, and Haas, 1997 and 2003) have been attempted. Deshayes (1824) originally thought *Beloptera* to be a transitional genus between *Belemnites*, *Belosaepia* and recent *Sepia* but many authors have since offered various interpretations of belopterid phylogeny. Pichtet (1854) thought *Beloptera* was a spirulid. Zittel (1887) proposed *Beloptera* as Phragmophora of the family Belemnitidae. Naef (1922) considered *Beloptera* to be an extinct collateral branch of the sepioids. Orlov (1976) agreed with Naef (1922), but derived *Beloptera* from the Belemnitidae through the Belemnoselidae. Jeletzky (1969) argued that *Beloptera* was an independent, aberrant form having the same sepiid root-stock as the Belemnosellidae. Donovan (1977) does not elaborate on systematic position, but thought that *Beloptera* must be excluded from the Sepiida. Müller (1981) placed *Beloptera* into the Neobelemnitidae and Doyle *et al.* (1994) placed the beloptrids in the order Spirulida. Most recently, Engeser (1990) and Haas (1997 and 2003) compared *Beloptera* to extant coleoids and used cladistics to place *Beloptera* in the spirulid lineage.

Though there appears to be little consensus on where *Beloptera* will ultimately reside, all workers agree that their guard-like sheaths have transitional morphologic characters (Dauphin, 1985). Dauphin (1985) also points out that some authors (Jeletzky, 1966 and Donovan, 1977) based interpretation on phragmacones and protoconchs that are either nonexistent or poorly preserved. After close inspection of images of the specimen identified as *Belemnosella?* sp. (Carter *et al.*, 1988, fig. 26) and of specimen NCSM 7714 we consider these specimens to be partial phragmacone steinkerns of *Beloptera?* sp. and trust that our descriptions of these specimens will be useful in determining belopterid phylogeny.

Belosaepiid phylogeny is somewhat less controversial than that of the belopterids, but unresolved issues remain. Most studies have concentrated on microstructures found within the guard-like sheaths and phragmacones are not well known. Voltz (1830) separated *Belosaepia* from *Sepia*, and proposed that *Belosaepia* had certain affinities with the sepioids, but was probably intermediary between the two. Buckland (1836) and Riefstahl (1886) proposed that belosaepiids represented a transitional form between belemnites and sepiids. Edwards (1849) considered belosaepiids to be transitional between true sepiids and spirulids. Naef (1922) placed *Belosaepia* in an evolutionary lineage beginning with the belemnites and terminating with the true sepiids: *Diploconus-Belemnosella-Spirulirostra-Spirulirostrina-Belosaepia-Sepia*.

More recently, Jeletzky (1966) based on mineral composition of the guard-like sheaths, proposed that the rostral elements of belemnites and sepiids are not homologous. He also proposed that the ancestor of the sepiids could be the phragmaoteuthiids. Dauphin (1984), studying microstructures within the guard-like sheaths, concluded that guard-like sheaths alone are not sufficient to reconstruct phylogenetic lineages. Doyle *et al.* (1994) placed the belosaepiids within the group containing the sepiids, and both Engeser (1990) and Haas (1997 and 2003), using a cladistic model, placed the genus in the stem-lineage of the Sepiida.

Recently, Weaver and Ciampaglio (2003) described a new genus of fossil sepiid *Anomalousaepia* and placed it in the family Belosaepidae. New phragmacone steinkerns with strongly oblique septa from the Castle Hayne Limestone are considered here to be *Anomalousaepia* sp. These steinkerns, coupled with the calcitic nature of the guard-like sheath of *Anomalousaepia*, lead us to consider *Anomalousaepia* as perhaps a direct ancestor of *Sepia*.

### Systematic paleontology

Order SPIRULIDA Stolley, 1919

Family BELOPTERIIDAE Naef, 1922

BELOPTERA? sp.

1988 *Belemnosella?* sp.-CARTER, GALLAGHER, VALONE, AND ROSSBACH, WITH GENSEL, WHEELER AND WHITMAN, p.77, Pl.18, Fig. 26.

(Plate 1.1-1.5)

Description.--Two partial phragmacone steinkerns. Both orthoconic. Septa parallel but becoming slightly oblique towards apical end. Camera regularly spaced but becoming slightly oblique towards the apical end indicating recurvature. UNC 1416 siphuncular ridge bisecting the camera on ventral side, extending the length of the phragmacone. This feature not apparent on NCSM 7714. UNC 1416 weak medial ring bisecting the camera. This feature not apparent on NCSM 7714.

Materials examined.--Images of UNC 1416 and NCSM 7714

Measurements.--UNC 1416 length 34.44mm, apical angle 20 degrees. NCSM 7714 length 64.03mm, apical angle 20 degrees.

Occurrence.--Middle Eocene Castle Hayne Limestone, Sequence 3 or 4, Martin Marietta Quarry near Castle Hayne, New Hanover Co., North Carolina.

Discussion.--UNC 1416 and NCSM 7714 differ slightly in that UNC 1416 shows a siphuncular ridge on the ventral side and has a faint medial ring bisecting its camera. These features are not evident on NCSM 7714 but we are convinced that this is a preservational, not a generic, difference.

Specimen UNC 1416 was formerly figured as *Belemnosella?* sp. (Carter *et al.*, 1988); no systematic description was given. Though no guard-like sheaths of *Beloptera* have yet been recovered from the Castle Hayne Limestone, this specimen, along with NCSM 7714, is considered to be *Beloptera?* sp. No other phragmacone steinkerns of either *Belemnosella* or *Beloptera* have been found. Descriptions of phragmacones of *Belemnosella* (Jeletzky, 1969) were based on structures observed by looking down into the guard-like sheath. UNC 1416 and NCSM 7714 differ from *Belemnosella* in being somewhat more cylindrical in outline, possessing a ventral siphuncular ridge, and lacking a well defined protoconch. The orthoconic shape of the phragmacone, the slight recurvature of the apical end and the siphuncular ridge accurately mirror Naef's (1922) line drawings (particularly his figure 18G) for *Beloptera*.

Order SEPIIDA Gray, 1849  
Suborder SEPIINA Gray, 1849  
Family BELOSAEPIIDAE Nyst, 1843  
ANOMALOSAEPIDAE sp.

(Plate 1.6-1.11)

Description.--Partial phragmacone steinkerns: slightly recurved apically, pyramidal in shape with dorsal surface convex but lateral and ventral surfaces flattened. Wide apical angle. Strongly oblique septa. On ventral surface plane of initial seven septa of specimen NCSM 7713 interrupted by capitulum. On specimen NCSM 9262 initial seven septa uninterrupted. High camera.

Materials examined.--NCSM 7713 and NCSM 9262

Measurements.--NCSM 7713: length 52.16 mm, apical angle 28 degrees. NCSM 9262: length 27.03 mm, apical angle 34 degrees.

Occurrence.--Middle Eocene Castle Hayne Limestone, Sequence 3 or 4, Martin Marietta Quarry near Castle Hayne, New Hanover Co., North Carolina.

Discussion.--Though no phragmacones have been found with their guard-like sheaths still attached, we consider these specimens to be *Anomalosaepia* for the following reasons: many guard-like sheaths of *Anomalosaepia* have been found at the same locality, and the curvature of the septa is much too strong for them to be *Belosaepia*. Specimens NCSM 7713 and NCSM 9262 differ in that NCSM 9262 has a much broader apical angle and is somewhat flattened dorsally. This could be a specific difference or a preservational difference. Also NCSM 7713 has an interruption of the septal plane in its first seven septa and this could represent a specific difference, a preservational difference or sexual dimorphism. No attempt is made to assign these specimens to a species, as they were found without guard-like sheaths attached. These specimens differ from those extrapolated for *Belosaepia* (Engesser, 1990 and Haas, 1997 and 2003) by having a much wider apical angle, more strongly oblique septa, and higher cameral angles. The apical curve between the two genera is somewhat similar. Due to the strongly oblique septa we postulate that *Anomalosaepia* may be a direct ancestor of *Sepia*.

## Discussion

New coleoid phragmacone steinkerns of *Beloptera?* sp. and *Anomalosaepia* sp. from the Castle Hayne Limestone of southeastern North Carolina may aid in understanding coleoid phylogenetic lineages. Recent cladistic models of Engeser (1990), Young *et al.* (1998) and Haas (1997 and 2003) have been based primarily on morphologic characters of soft tissue seen in extant coleoid taxa. In fossil coleoids, information about soft tissue is extrapolated from features within guard-like sheaths and is added to their models to produce the cladograms. New coleoid phragmacone steinkerns of *Beloptera?* sp. and *Anomalosaepia* sp. will add much needed data to the fossil portion of these cladograms. Though producing new cladograms is beyond the scope of this paper it is likely that *Beloptera* will turn out to be part of the stem lineage of the spirulids. *Anomalosaepia*, due to the highly oblique angle of its septa will most likely turn out to be a direct ancestor to *Sepia* or an offshoot from the same stem lineage.

## Repository

The specimen of *Beloptera?* sp. (UNC 1416) is housed at The University of North Carolina, Chapel Hill. All other illustrated specimens are housed in the collections of the North Carolina State Museum of Natural Sciences, Raleigh (NSCM).

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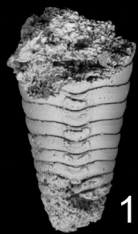
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#### Explanation of Plate

Plate 1.--1, 2, ?*Beloptera* sp. UNC 1416 ventral view and dorsolateral view. 3, 4, 5, *Beloptera* sp. NCSM 7714 lateral, ventral and dorsal views. 6, 7, 8 *Anomalosaepia* sp. NCSM 7713 lateral, ventral and dorsal views. 9, 10, 11 *Anomalosaepia* sp. NCSM 9262 lateral, ventral and dorsal views. Scale bar equals 1 cm.

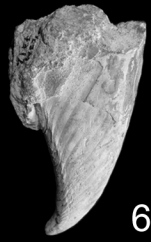




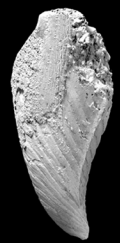
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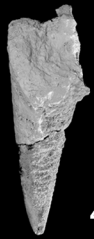
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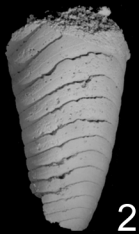
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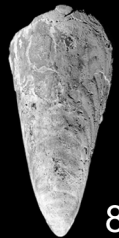
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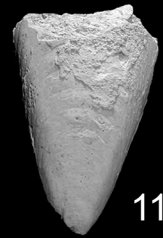
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