FIRST RECORD OF PHRAGMOCONE AND ALVEOLAR CAVITY OF THE CHALK BELEMNITE *GONIOTEUTHIS*

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ABSTRACT

Two variably complete belemnite guards preserving the alveolar cavity (alveolus) and phragmocone believed to belong to the Chalk belemnite **Gonioteuthis** *Bayle, 1879 were discovered in Chalk-derived flint cobbles collected from glacial sediments at Whitlingham gravel pits, near Norwich, Norfolk. These specimens provide the first data on the alveolus and phragmocone of this belemnite genus and contradict some earlier speculations on their possible composition.*

INTRODUCTION

In recent decades, several very large pits in glacial deposits at Whitlingham in the Yare valley to the east of Norwich have been worked for gravel. Once extraction ceased, the workings, which were very close to the river Yare, were allowed to flood and have become popular recreational lakes or broads. Around the southern perimeter of each broad is a flint pebble beach 1-3m wide. This has provided a rich source of flint preserved Chalk fossils; some of the taxa being extremely rare (Whittlesea 2005a, 2005b). Some of the fossils in these flint pebbles are stratigraphically restricted to rocks of Turonian, or possibly older age, outcrop and subcrop of which is in the west and central part of Norfolk. This implies glacial transport with a westerly component. However, the glacier must subsequently have travelled into the area that is now the Yare valley creating several major and minor Chalk erratics that show easterly overthrusts (Woodward, 1887).

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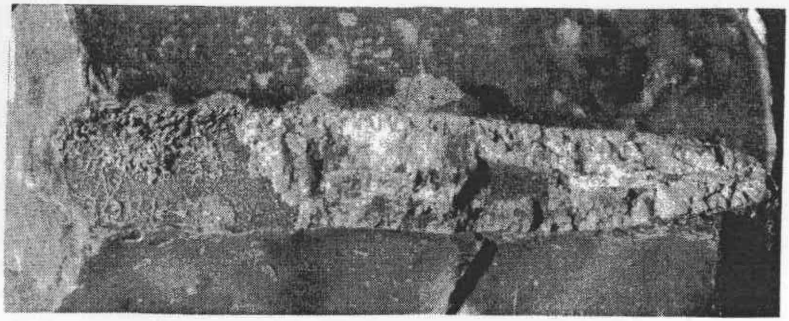

Fig. 1. Photograph of specimen WMP(GB)34/2. The anterior is toward the right. Specimen is 53 mm long.

MATERIAL

The material consists of two belemnite specimens of the genus *Gonioteuthis* Bayle, 1879, enclosed in flint cobbles (Fig. 1). Both specimens are preserved as partial silica replacements of the original calcite guard and/or as external moulds in flint. Traces of either original or diagenetic phosphate are present. One specimen is rather incomplete, but best preserves the phragmocone, excluding that part in the vicinity of the protoconch. The part of the guard hosting the phragmocone shows traces of what may be the boring ichnogenus *Nygmites* within the alveolar wall. None of the guard posterior to the protoconch is present. The second specimen is more complete, but more worn with about 45% of the guard preserved. However, in this specimen it is possible to determine the location of the protoconch and thereby measure the minimum depth of the alveolus containing the phragmocone. Much of the posterior has been dissolved but shows many flint infilled fungal and algal borings attributable to the ichnogenera *Calcideletrix* and *Dendrina*.

DETAILED DESCRIPTIONS

WMP(LB)34/1 (author's collection catalogue number) from the beach surrounding Whitlingham Little Broad [NGR TG 255079].

The fossil is exposed on a broken flint surface 13 mm long by 5 mm wide; within this, the phragmocone is 2 mm wide adorally and 0.6 mm wide adapically. Septa are visible most clearly along a 7 mm interval (Fig. 2) although recrystallisation obscures detail elsewhere and very locally within this interval. 19 septa are clearly present and 25 may be inferred by interpolation. An unusually well-exposed individual septum has a partial length of 0.5 mm, across-which it narrows from 1.1 mm to 1.0 mm. (Damage to the succeeding adoral septum enabled these observations.) The septa are strongly concave

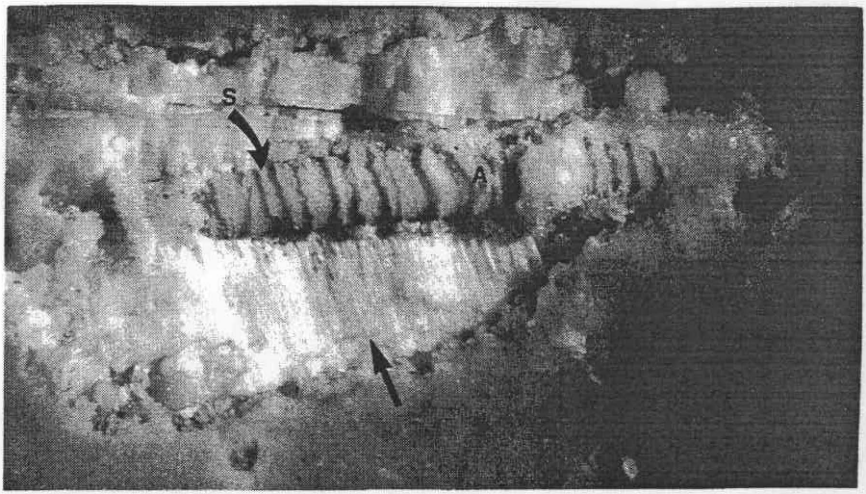

Fig. 2. Photomicrograph of alveolus (A) and septa (S) of WMP(LB)34/1. Growth lines intercept the alveolar wall at 20-25°. Radiating crystallites (arrow) of the guard are clearly visible. The anterior is towards the right. Field of view is 12 mm wide.

adapically (Fig. 2) and are unlikely to have attained a length in excess of ~0.7 mm. No siphuncle components are visible, hence the length separating individual septa along this structure cannot be ascertained. Several relatively well-exposed septa show numerous (~10 >0.5 mm) very-fine, concentric growth-lines. Normally, each septum almost totally encloses the succeeding one leaving just an additional 0.15 mm exposed adapically around the perimeter of each septum. The angle of the phragmocone appears to be very close to 6 degrees.

The composition of the alveolus is clearly a continuation of the guard: it shows radiating crystallites (Fig. 2) traversed by growth lines. Lining the alveolus there is a layer of microcrystalline quartz. Adapically and especially in the vicinity of the inferred position of the protoconch, (not visible in this specimen), the guard contains a boring occupied by a sponge (*Cliona*?) and several sections of gently curving tubular borings (*Nygmites*?) now infilled by silica. In the vicinity of the protoconch some of the radiating crystallites appear to be more densely packed; this could represent either a taphonomic artefact or the possible location of the junction of the alveolus with the pseudo-alveolus. There is no trace of the guard posterior to the protoconch.

WMP(GB)34/2 (author's collection and catalogue number) from the beach surrounding Whitlingham Great Broad [NGR TG 257079].

The specimen occupies an area 53 mm x 8 mm on a broken flint cobble. The phragmocone extends 15 mm into the guard (Fig. 1). The most posterior section of the guard is 17 mm long and largely represented by a flint external mould with silica internal moulds of the boring algae and fungi *Dendrina* and *Calcideletrix* (Fig. 3). About 45% of the guard is present between this section and the alveolar cavity. From the guard that is preserved it is inferred that its overall shape was slender and gently tapering. However, the preserved guard is obliquely and unevenly fractured and thus does not preserve or exhibit most of the central region; the surface is also very worn in places. The relationship between the alveolus to the guard is readily interpreted in this specimen because a substantial section of the latter is preserved. Radial crystallites of silica-replaced calcite form the guard and are traversed by growth lines. Anterior of the protoconch, growth lines, certainly "major" lines (and many finer ones) curve in so as to

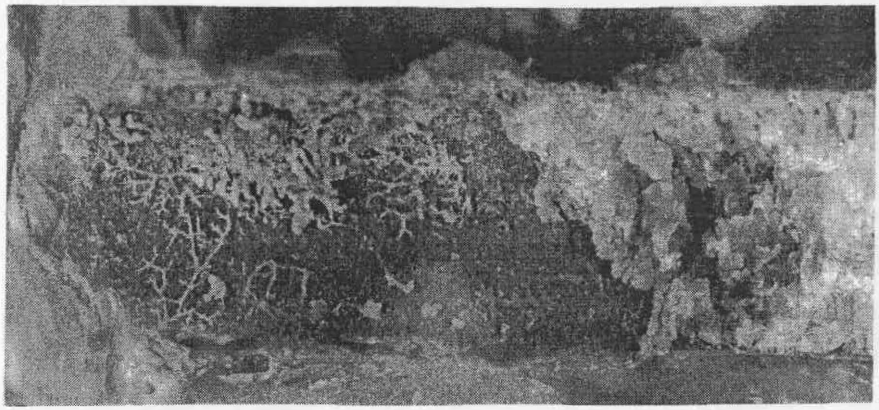

Fig. 3. Posterior of WMP(GB)34/2 showing silica internal moulds of the boring algae and fungi *Dendrina* and *Calcideletrix*. Field of view is 25 mm wide.

intercept the alveolar wall at an angle of 20-25°. Because the ventral fissure cannot be identified with confidence, it is not possible to place the guard in a standard orientation, (i.e. identify the ventral-dorsal plane). The guard is fractured for short lengths along internal growth lines to reveal sections of concave growth surfaces. In the body of the preserved section of the guard, posterior to the protoconch, there are a series of sub-parallel "growth lines" that curve sharply into the centre of the guard (Fig. 4). These are too numerous and consistent to be dismissed simply as taphonomic artefacts. If they are growth lines then they imply that the belemnite did not develop a phragmocone at the anterior end of the guard until late in ontogeny, which is very surprising.

The length of the phragmocone may be seen in its entirety; anteriorly it is largely covered with microcrystalline quartz crystals, but the posterior exposes the protoconch (Fig. 5) and first few septa reasonably well. The protoconch is 0.5 mm in diameter and little more than a shallow concavity 0.2 mm deep, quite unlike the more capacious flask or tulip-shaped protoconch in *Belemnitella*. It is also the only structure in the phragmocone that is convex adapically, although this may be an artefact due to wear. No trace of siphuncle components are discernable.

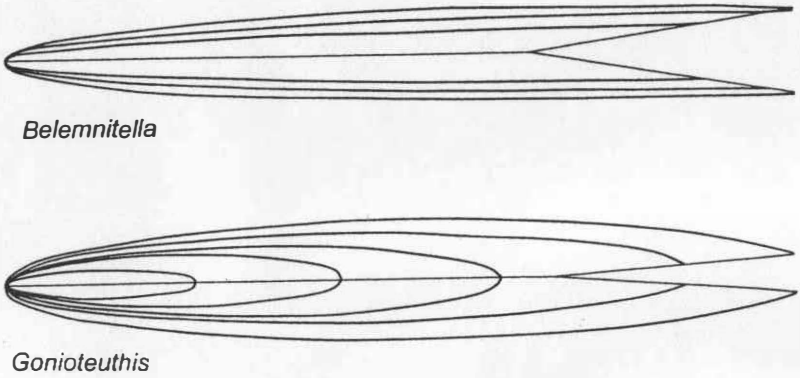

Fig. 4. Illustration of growth lines in belemnite guards. Note how those in *Belemnitella* are concentric about the protoconch, i.e. the base of the alveolus (v-notch), while those in *Gonioteuthis* progressively 'encroach' around the protoconch.

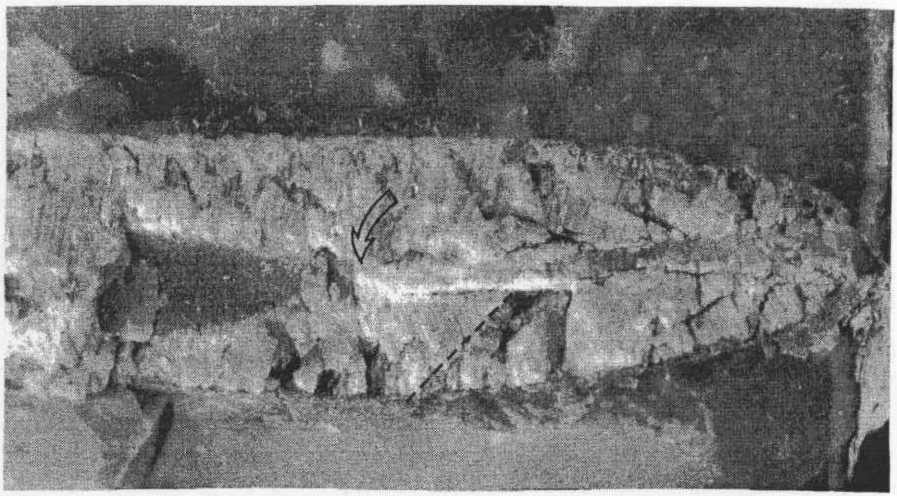

Fig. 5. Detail of alveolus and septa of WMP(GB)34/2. Protoconch (arrow) at the base of the (largely missing) alveolar cavity. Frequent, well spaced, consistently orientated fractures (highlighted by pecked line) in the anterior of the guard meet the phragmocone at a significantly higher angle (60-70°) than the genuine growth lines. Anterior is towards the right. Specimen is 26 mm wide.

DIAGNOSTIC FEATURES OF *GONIOTEUTHIS*

In contrast to younger genera belonging to the family Belemnitellidae Pavlov, 1914 (all of which are differentiated on characters of the guard), the diagnosis of *Gonioteuthis* includes reference to a pseudo-alveolus rather than an alveolus. The pseudo-alveolus is a hollow of variable shape and depth in the anterior end of the guard. It is believed to have been in immediate juxtaposition or otherwise partially enclosed the alveolus proper containing the phragmocone with its septa and siphuncle. It was speculated by Christensen (1975, p. 30) that the alveolus proper might have been organic. The ratio of the depth of the pseudo-alveolus to the length of the guard is a critical factor in species determination and is known as the "Riedel Quotient". However, the horizon from which any specimens are collected must be accurately known and delimited and there must be sufficient of them to undertake a valid statistical analysis. The two incomplete guards described here, collected *ex-situ* in a glacial deposit do not satisfy either of these criteria. *Gonioteuthis* guards may show a short ventral fissure and traces of vascular impressions but again, these cannot be detected in these specimens.

The material described here shows the guard extended sufficiently anterior of the pseudo-alveolus to produce an actual alveolus that housed a deep, narrow phragmocone. It consisted of radiating calcite crystals otherwise identical to the main body of the guard and certainly shows clear traces of growth lines. The specimens figured by Christensen (1975) had been split ventro-dorsally and exhibited the "bottom of the ventral fissure" and the "splitting surface" in the anterior end of the guard occupied by the pseudo-alveolus; two taxonomically important features. A random plane of fissure might well have missed these features, so their absence in the material described here is not crucial. A Riedel Quotient is only valid if a "separation point" exists between the alveolus and pseudo-alveolus at a constant position (statistically significant) within a population at a given stratigraphic horizon. It is of some concern that no trace of such a junction with or between the pseudo-alveolus and alveolus could be seen.

Comparing details of the phragmocone of *Gonioteuthis* with *Belemnitella* cf. *langei* Jeletzky, as described by Whittlesea (1991), the alveolar angle is much smaller (6 degrees versus 19 degrees) and the septa very crowded. Their more even spacing is probably a consequence of the small alveolar angle. Indeed, the septa are so closely overlapping (in "cone-in-cone" fashion) that it was only possible to see the details reported above because some septa were damaged, allowing a view of more axial areas. In *Gonioteuthis*, septa are thick, relatively evenly spaced, and are concave posteriorly.

By contrast, *Belemnitella* septa are very much thinner, rapidly increase in spacing as the phragmocone widens and are convex posteriorly; it is also possible to get a good view of the siphuncle and its components. (The author has collected many more specimens since that described in Whittlesea, 1991).

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GLOSSARY

Adapical: towards the apex (posterior) of the guard and the rear of the animal.

Adoral: towards the oral (mouth, anterior) end of the animal (front, head, tentacles, etc.).

Alveolus: (synonym: **alveolar cavity**): the conical cavity in the adoral end of the guard that houses the conical chambered phragmocone.

Ontogeny: the series of stages that an organism passes through during life, often associated with significant changes in size or shape, and / or the acquisition or loss of organs.

Phragmocone: the conical chambered shell of the belemnite animal, analogous to the

shell of an ammonite.

Protoconch: the initial shell of the belemnite animal located at the base of the phragmocone.

Septum (plural: **septa**): one of the curved walls of the phragmocone that partition it into separate chambers.

Siphuncle: a tube, located on the ventral interior margin of the phragmocone, passing adorally from just in front of the protoconch through each successive septum as it forms.

Ventral fissure: a fissure or slit that commences on the interior of the alveolus a short distance from the protoconch before connecting with the exterior of the ventral surface of the guard. It continues adapically from that point.

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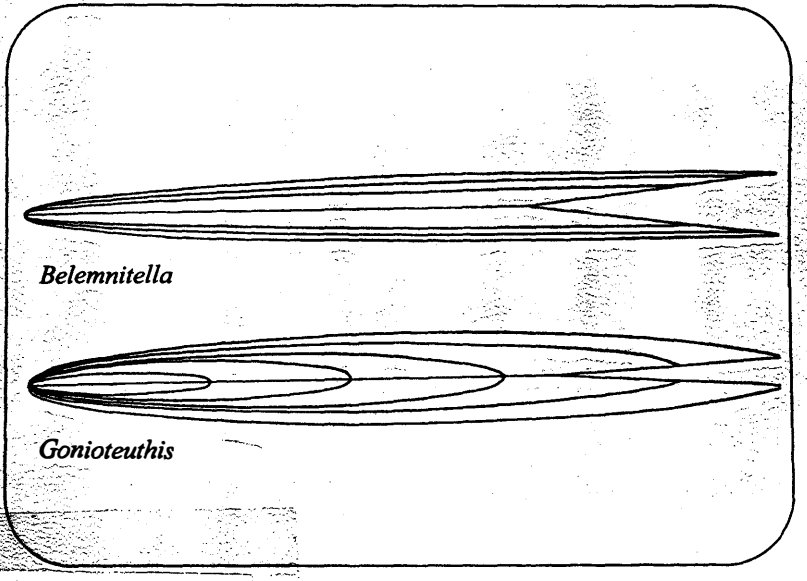

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