Siphuncle Structures in Barremian (Lower Cretaceous) Ammonites from Austria

by Alexander LUKENEDER[1]

(With 5 text figures, 1 table and 2 plates)

Abstract

Siphuncle structures of *Barremites* cf. *difficilis* from the Schrambach Formation (Lower Cretaceous, Northern Calcareous Alps, Upper Austria) are recorded for the first time. The extraordinary preservation allows the observation of siphuncle structures in these Barremian ammonites.

Zusammenfassung

Aus der Schrambach-Formation (Unterkreide; Nördliche Kalkalpen, Oberösterreich) liegen erstmals Siphonalstrukturen von *Barremites* cf. *difficilis* vor. Besondere Erhaltungsbedingungen von Ammoniten aus dem Barremium der Kalkmergellagen gestatten die Untersuchung ihres Siphonalstranges.

Schlüsselwörter: Kreide, Ammoniten, Sipho-Strukturen

Introduction

Barremites cf. *difficilis* occurs in laminated dark grey to black *Karsteniceras*-bearing beds of the Schrambach Formation (text-fig.1).

In most extant and fossil chambered cephalopods, the siphuncular system consists of a tube-like organ that extends from the protoconch to the base of the living chamber (TANABE & LANDMAN 1998). The siphuncular tube (=siphonal tube of MUTVEI 1967) extends from the adoral side of one septal neck to the adapical side of the next. Because this tube spans between two subsequent septa, it is also termed a connecting ring (MILLER et al. 1957; BIRKELUND 1981). It consists of multilayered concentric membranes of conchiolin. Siphuncular tubes in ammonoids, as opposed to that in *Nautilus*, are only constructed of organic matter (KULICKI 1998). The siphuncle and the bulb-like beginning of the siphuncle (cecum) are replaced in most fossil ammonoids, but were originally organic (LANDMAN et al. 1998).

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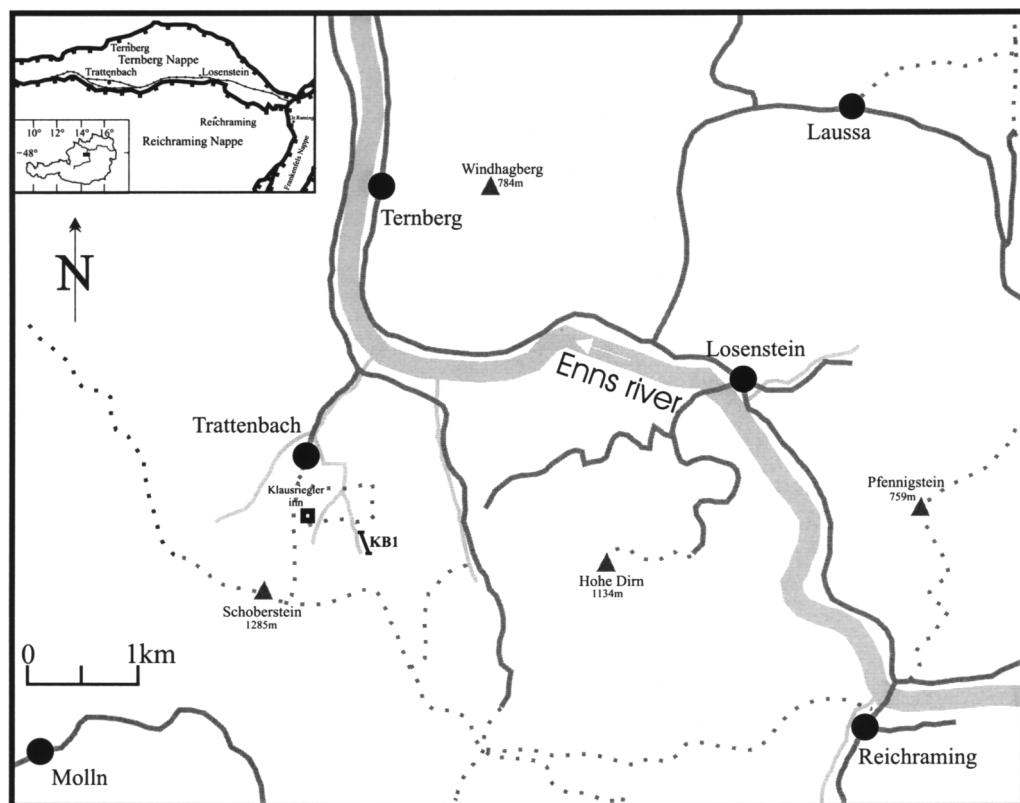
Fig. 1: Geographic and tectonic position of the investigated section KB1 (modified after LUKENEDER 1999).

Geography, Lithostratigraphy and Environmental Conditions

According to LUKENEDER (1997, 1998) the investigated section lies 7 km west of Losenstein, 1 km south of Kienberg in the Ternberg Nappe (Upper Austria) (see text-fig. 1).

The Schrambach Formation is intercalated with platy and laminated grey to black *Karsteniceras*-bearing beds (text-fig. 2). The fabric is laminated, partly destroyed by bioturbation (mostly small *Chondrites*-type burrows, rare *Planolites*-tubes; intrafaunal biofacies level 3 to 4 after ARTHUR & SAGEMAN 1994; taphofacies type 7 after BRETT & BAIRD 1986). BRETT and BAIRD (1986) have coined the term *taphofacies* for sedimentary rocks characterized by particular, sometimes unique, combinations of preservational features, which are the result of similar taphonomic pathways. As observed by WAGREICH & SACHSENHOFER (1999) pyrite is finely disseminated throughout such organic-rich marlstones and calcareous shales.
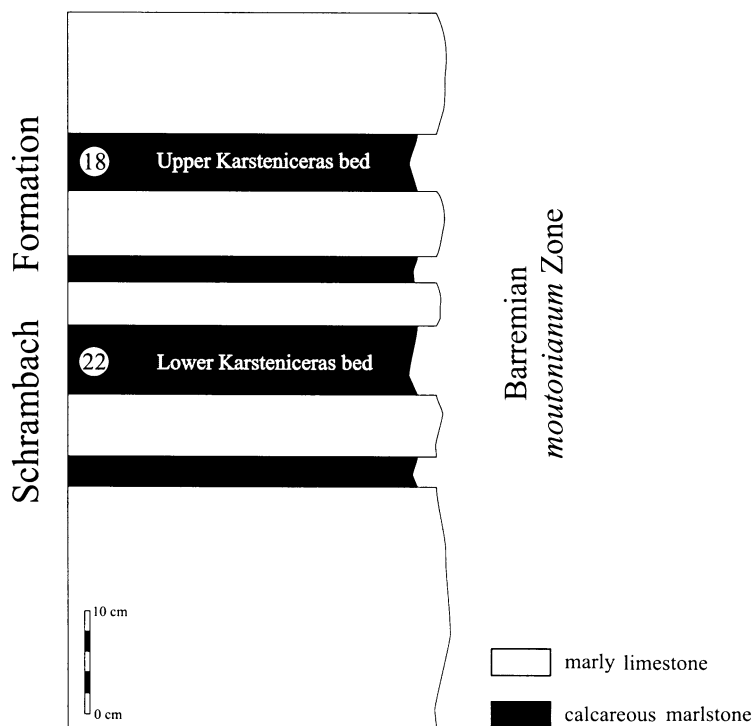
Fig. 2: Detailed stratigraphic column of the Barremian *Karsteniceras*-bearing beds (18 and 22).

The calcium carbonate contents ($CaCO_3$ equivalents calculated from total inorganic carbon) vary between 66 and 80 % and show a negative correlation within the Karsteniceras-bearing beds to the TOC-values if all samples were regarded.

The weight % TOC values vary between 1.6 and 4.6 %. The total sulphur content shows an extremely positive correlation to the TOC values. The maximum amount of 4.6 % TOC corresponds to the maximum sulphur content of 18.0 mg/g.

The amounts in the strata below and above the Karsteniceras-bearing beds vary between 78 to 90 % $CaCO_3$, 0.01 to 0.7 % TOC and 3.3 to 1.0 mg/g sulphur.

Systematic Paleontology

Conventions: The standard dimensions for normally coiled ammonites are given in millimetres and as percentages of the diameter. The following abbreviations have been used: D = shell diameter, Wh = whorl height, U= umbilicus width, U % = U percentage of D; NHMW Museum of Natural History Vienna. The author follows the classification of the Cretaceous Ammonoidea by WRIGHT et al. (1996).

Order Ammonoidea ZITTEL, 1884

Superfamily Desmocerataceae ZITTEL, 1895

Family Desmoceratidae ZITTEL, 1895

Subfamily Barremitinae BRESKOVSKI, 1977

Genus *Barremites* KILIAN, 1913

Subgenus *Barremites (Barremites)* KILIAN, 1913

T y p e   s p e c i e s : *Ammonites difficilis* d'ORBIGNY, 1841. Barremian, France.

Barremites (Barremites) cf. *difficilis* (d'ORBIGNY, 1841)
(Plates 1-2)

1841   *Ammonites difficilis* (d'ORBIGNY) – d'ORBIGNY: 135, pl. 41, figs 1-2
1967   *Barremites (Barremites) difficilis difficilis* (d'ORBIGNY) – DIMITROVA: 129, pls. 60, figs. 1-2
1976   *Barremites (Barremites) difficilis* (d'ORBIGNY) – AVRAM: 44; pl.4, fig.4 (cum syn.)
1987   *Barremites (Barremites) difficilis* (d'ORBIGNY) – IMMEL: 83; pl.8, fig.1

M a t e r i a l : Six flattened and compressed, imperfectly preserved specimens: NHMW 2000z0183/0001, NHMW 2000z0183/0002, NHMW 2000z0183/0003, NHMW 2000z0183/0004, NHMW 2000z0183/0005, NHMW 2000z0183/0006. The phragmocones are damaged, compressed and flattened. The siphuncle is preserved within the phragmocone in all specimens found. All specimens are stored at the Museum of Natural History (NHMW, Vienna, Austria).

L o c a l i t y : All specimens are from KB1 (SSE Trattenbach). According LUKENEDER (1997, 1998) the section lies 7 km west of Losenstein, 1 km south of Kienberg in the Ternberg Nappe (Upper Austria) (47°55'N and 44°21'E; see text-fig. 1).

D e s c r i p t i o n : NHMW 2000z0183/0001 (pl. 1, fig. 1): The phragmocone is extremely flattened. The body chamber is compressed (3 mm). The whorls are moderately involute with flat flanks, sharp umbilical margins and a narrow umbilicus. Three S-shaped, comparatively broad constrictions, sharply defined anteriorly and passing the outer side prosiradiately, can be observed on the internal moulds of the incomplete body chamber. Ornamentation and suture line cannot be observed on the internal moulds. Single and dislocated white siphuncle tubes (0.5 mm to 1 mm) are present on the phragmocone. The length of the single tubes shows the distance from one septum to the next before dissolution of the aragonitic shell and septa. They are completely crushed and compressed (0,1 mm). The crushed tubes are preserved as rectangles with more or less lungitudinal fractures (text-fig.3).

R e m a r k s : *Barremites (Barremites) difficilis* (d'ORBIGNY) is clearly distinguished by showing more constrictions (5 to 7) on the body chamber and no ribs from other species of the genus *Barremites*. *Barremites strettostoma* (UHLIG) has strongly S-shaped ribs, *Barremites psilotatus* (UHLIG) has relatively broad and less constrictions (1 to 2) on the body chamber and more rounded flanks.

M e a s u r e m e n t s : table 1

Tab. 1: Dimensions of the ammonites studied.

	D	Wh	U	U %
NHMW 2000z0183/0001	63	31	10	15,5 %
NHMW 2000z0183/0002	16	7	——	——
NHMW 2000z0183/0003	23,5	12	3,2	13,6 %
NHMW 2000z0183/0004	14	8	——	——
NHMW 2000z0183/0005	35	17,5	——	——
NHMW 2000z0183/0006	26	14,5	3,5	13,4 %

O c c u r r e n c e : *Barremites (Barremites) difficilis* (d'ORBIGNY) is known from the Barremian of SE-France, Bulgaria, Romania, Czech Republic, Switzerland, S-Russia and Austria.

S t r a t i g r a p h y : The ammonite-bearing section at Trattenbach (KB1) yield the stratigraphic important taxa *Barremites (Barremites)* cf. *difficilis*, *Pulchellia* sp., *Holcodiscus* sp. and *Karsteniceras* sp.. Due to the occurrence of *Moutoniceras moutonianum* (d'ORBIGNY, 1850) the *Karsteniceras*-bearing beds, and with them this part of the Schrambach Formation, belong to the *moutonianum* ammonite Zone of the uppermost Lower Barremian (COMPANY et al. 1995).

Discussion

To some degree the chronological sequence and interrelationship of diagenetical processes can be reconstructed from preservational features. Because of their generally aragonitic composition, fossil cephalopod shells are commonly altered by various diagenetic processes. Calcitic and β-Chitin shell structures are rarely restricted to some aptychi and belemnite guards. They have a better potential for preservation of their original structural pattern and crystal orientation (BANDEL 1990). Shape, structure and composition of fossils are intrinsic variables that relate to the chemical and compactional changes in sediments, which largely follow completion of strationomic processes and precede later diagenetic change associated with tectonic history. Chemical dissolution and compactional deformation of the aragonitic shell are the two main processes, whose interplay determines ammonite preservation in pelitic to marly sediments (except concretions) which would undergo compaction (SEILACHER et al. 1976).

The case presented in this paper chiefly reflect the varying interplay of shell dissolution during diagenesis and shell deformation by compaction. The preservation of *Barremites* (plates 1 - 2; see text-fig. 3) discussed here is interpreted by sediment infilling of body chambers within anaerobic/euxinic substrate collapse of phragmocone, shell and septa dissolution (text-fig. 4). This situation is described by GOLDRING (1999: fig. 3.19) as a preservation mode in mudrocks (e.g. bituminous shales): high organic content, ammonite shells completely flattened, aragonite dissolved, pyrite disseminated in the sediment.
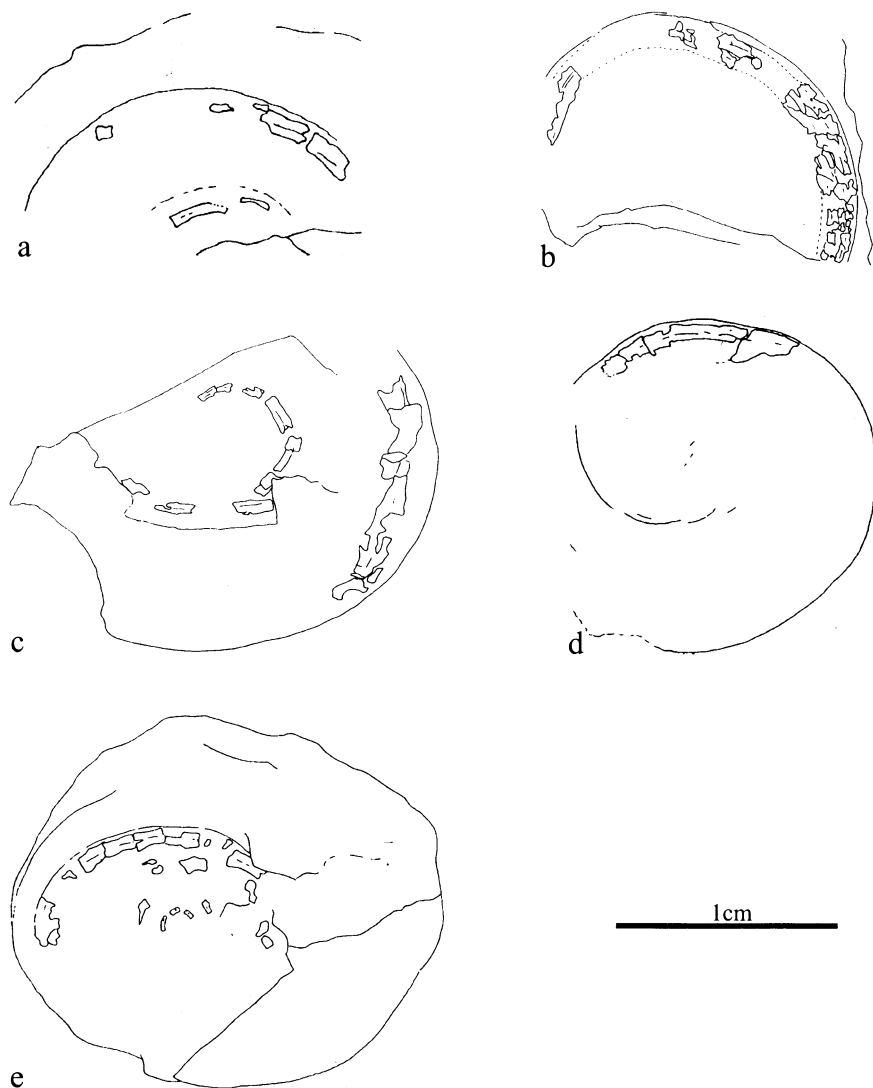
Fig. 3: Siphuncle tube preservation in *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY 1841) from KB1.

(a) NHMW 2000z0183/0002, (b) NHMW 2000z0183/0004, (c) NHMW 2000z0183/0003, (d) NHMW 2000 z0183/0005, (e) NHMW 2000z0183/000/6.

In all specimens described, the siphuncle is phosphatic. UV-light renders the phosphatic siphonal structure visible due to its fluorescence.

WEITSCHAT (1986) described the phosphatization of an extraordinary well preserved ammonoid-fauna from the Boreal Triassic province of Centaral-Spitzbergen. The original calciumcarbonate of the ammonoid-shell, the septa and organic structures (e.g.
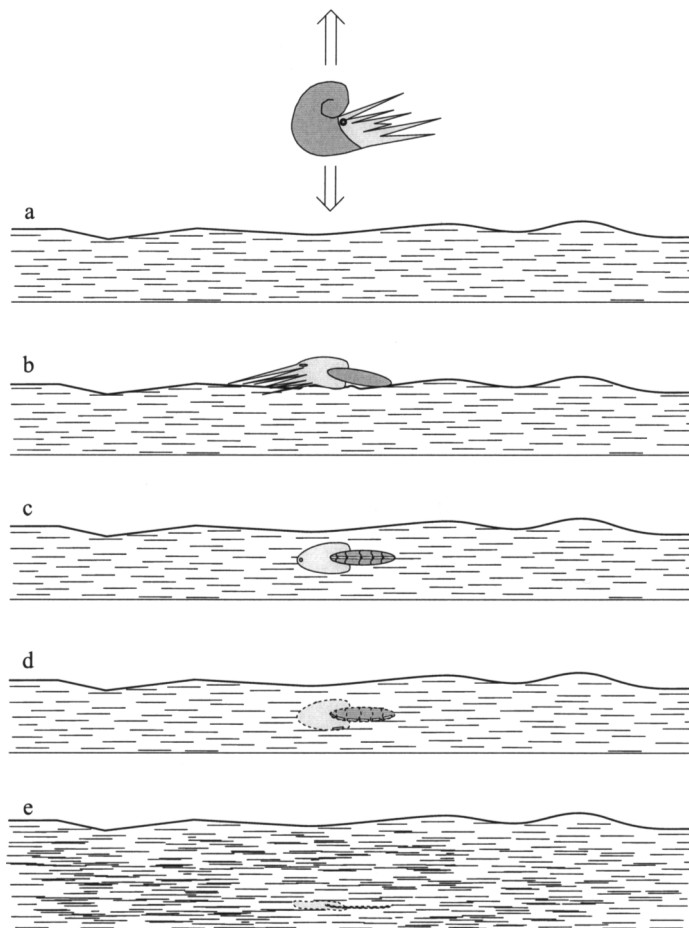
Fig. 4: Sketch showing the preservational history of ammonite shells in the *Karsteniceras*-bearing beds. (**a**) living conditions; (**b**) death of ammonite; sinking to bottom; (**c**) embedding of shell; infilling of body chamber; entire siphuncle; (**d**) solution of the shell and septa; phragmocone remains empty; shifting and dislocation of siphuncle tubes; (**e**) compaction of sediment, collapse of phragmocone.

siphuncle) was replaced by apatite at a very early stage of diagenesis. He established that an encreasing pH-value (higher than 7) and anaerobic conditions are the most important factors for phosphatization.

For GOLDRING (1999) replacement of the tissue by minerals (clay, pyrite, silica, carbonate, phosphate) where precipitation was induced by bacterial action, is one of five modes of preservation. Microbal mats are now recognized as perhaps the main influence on soft tissue preservation (WILBY et al. 1996; WILBY & BRIGGS, 1997) by inhibiting diffusion of phosphorus from the sediment/organism into the water column. After BRIGGS & WILBY (1996) the phosphatization of soft tissue is generally associated with low burial rate and high organic input as it is discussed above for the *Karsteniceras*-bearing beds.

In general, increasing depth of burial (GOLDRING 1999: Fig. 3.14) leads to desoxygenation and then to anaerobic decay associated with manganese, nitrate, iron and sulphate reduction, methanogenesis and decarboxylation, which can promote formation of pyrite, carbonate or phosphate.

The investigation of KEAR et al. (1995) on coleoid cephalopods demonstrates the range of tissues that may be preserved with ultrastructural detail in phosphatized fossil coleoids. Their study emphasizes that this kind of preservation is not confined to a small number of Konservat-Lagerstätten, but is more widespread.

Several cases of exceptional preservation are reported from the ammonite fauna of the Solnhofen Formation (Lower Tithonian) and the Nusplingen Formation (Late Jurassic, SW-Germany) (text-fig. 5). A few specimens from these localities show the same siphonal structures as these are described here (see text-fig. 3).

In the micritic limestones of the Solnhofen Formation (Upper Jurassic), ammonite preservation resembles that of bituminous shales compaction took place as the shell dissolved (GOLDRING 1999). GOLDRING described the different modes of ammonite preservation caused by different chemical reactions during embedding and the various modes the shells are filled with sediment (p. 47 - 48; figs. 3.17 - 3.18).

The phosphatic siphuncle apparatus has proved to be particularly stable. It is always preserved, whereby single sections of the siphuncle are often dislocated along the boundaries to the septa. After the aragonite shell was dissolved, but before the final compaction, a cavity must have been left in the phragmocone because the tubes of the siphuncles are often shifted, often having drifted into the body chamber (SCHWEIGERT 1998).

Low water energy and preservation of the phosphatic siphuncle (ANDALIB 1972) reduced draught filling, thus the phragmocones remained largely empty except in damaged shells.

Streblites cf. *zlatarskii* (SAPUNOV) (SCHWEIGERT & DIETL 1998: pl. 3, fig. 2; pl. 6, fig. 1), *Lithacoceras fasciferum* (NEUMAYR) (SCHWEIGERT & DIETL 1998: pl. 7, fig. 1 and SCHWEIGERT 1999: pl. 9, fig. 1) and *Lithacoceras ulmense* (OPPEL) (SCHWEIGERT 1999: pl. 1, fig. 2) show the same phenomenon of siphuncle preservation in the compressed and flattened phragmocones.

The same preservation is reported from the Posidonienschiefer Formation (Lower Jurassic, Lower Toarcian, Holzmaden, Germany). The ammonites, namely *Harpoceras*, are mainly flattened and the shells have also been completely dissolved without being replaced, leaving behind a brownish periostracal film only (SEILACHER et al. 1976). The connecting tubes of the siphuncles seem to have been highly phosphatic and often appear disarticulated due to the solution of the aragonitic linkages (ANDALIB 1972).

Posidonienschiefer specimens with siphuncle structures are shown in RIEGRAF et al. (1984). He figured *Hildoceras (Hildaites) levisoni* (SIMPSON) (p. 55, fig. 13c - d), *Hildoceras (Hildaites) serpentinum* (REINECKE) (p. 55, fig.13, e; pl. 1, fig. 7), and a specimen of *Harpoceras (Tiltoniceras) antiquum* (WRIGHT). A specimen of *Physodoceras* sp. from the Nusplingen Formation (Late Jurassic, SW-Germany) (p. 58, fig. 14a) shows the siphuncle still attached to the soft body.
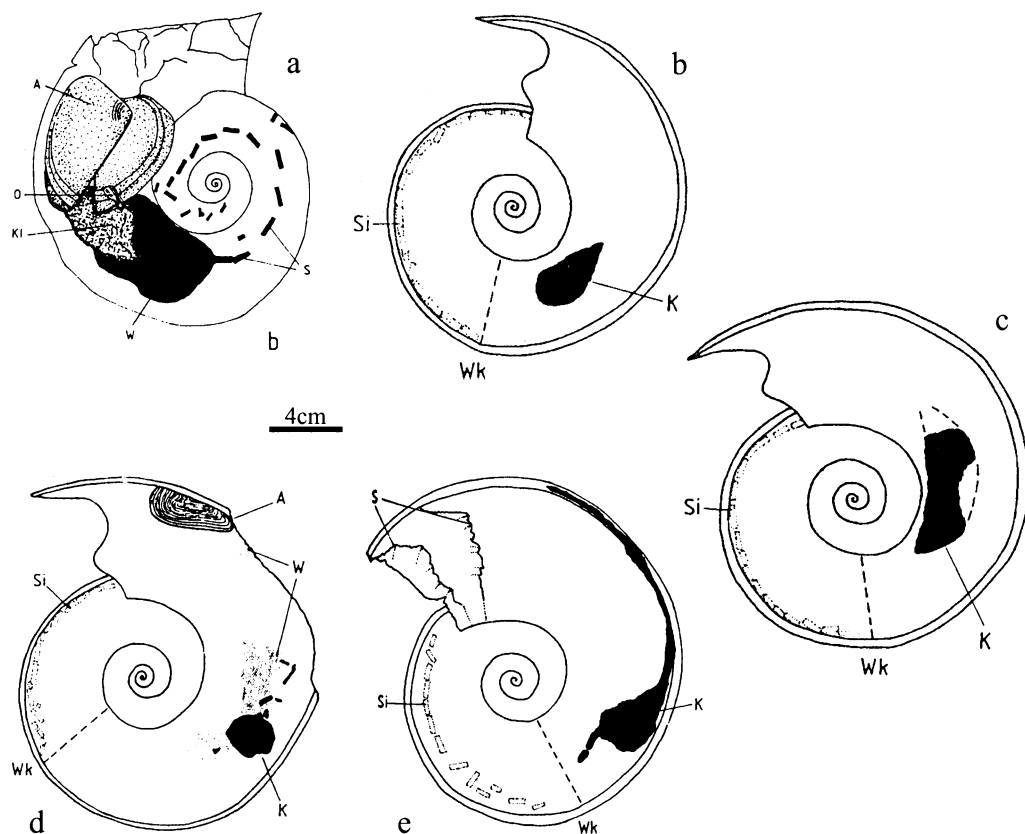
Fig. 5: The preservational mode of siphuncle tubes compared from three different localities and ages.

a   *Physodoceras* sp. (from LEHMANN 1972: pl. 10, fig. 2); Upper Kimmeridgian, Nusplingen Formation, Southwest Germany.

b - c *Hildoceras (Hildaites) levisoni* (from RIEGRAF et al. 1984: fig. 13, c-d); Lower Toarcian, Posidonienschiefer Formation, Southwest Germany.

d   *Hildoceras (Hildaites) serpentinum* (from RIEGRAF et.al. 1984: fig. 13, e); Lower Toarcian, Posidoninschiefer Formation, Southwest Germany.

e   *Harpoceras (Tiltoniceras) antiqum* (from RIEGRAF et.al. 1984: fig. 13, g); Lower Toarcian, Posidonienschiefer Formation, Southwest Germany.

Si,S: siphuncle; A: aptychi; K: crop (filling); O: upper jaw; W: soft body; Wk: beginning of body chamber.

Because of the better preservation, the material studied by REYMENT (1959) is not as ideal in terms of preservational mode linked to diagenetic processes; the shells are not flattened and compressed and that in most cases the siphuncle is in the original position in the shell, i.e. attached to the septal walls.

Preservational features express the varying time relationships between shell solution, compaction and cementation during early diagenesis. In many cases they better correlate with the depositional environments than with the actual lithologies of the matrix (SEILACHER et al. 1976).

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Plate 1

Fig. 1: Typical *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY, 1841) with constrictions, NHMW 2000z0183/0001, x 1.

Fig. 2: Part of *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY, 1841) with siphuncle structure, NHMW 2000z0183/0002, x 2.

Fig. 3: *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY, 1841) with siphuncle structure, NHMW 2000z0183/0003, x 4.

Fig. 4: *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY, 1841) with siphuncle structure, NHMW 2000z0183/0004, x 5.

All specimens were collected at KB1 which is situated SSE of Trattenbach, 7 km W of Losenstein, Upper Austria.
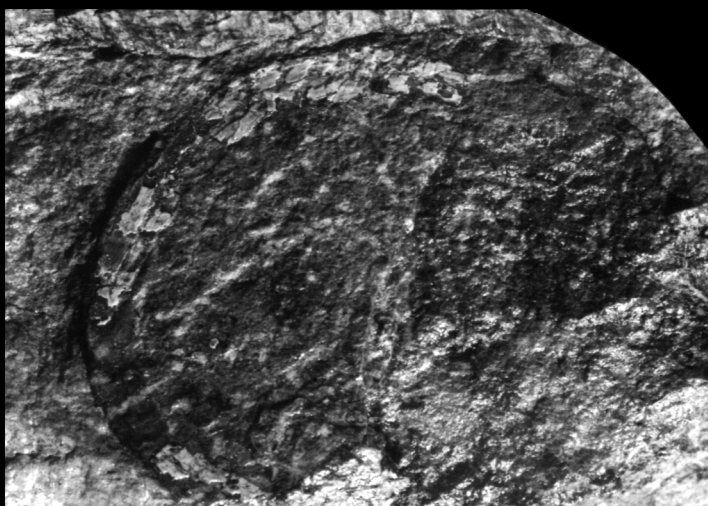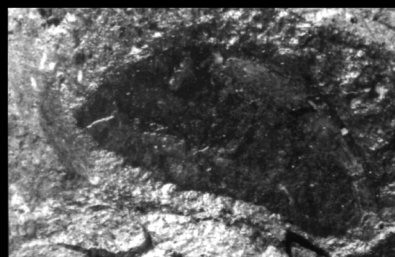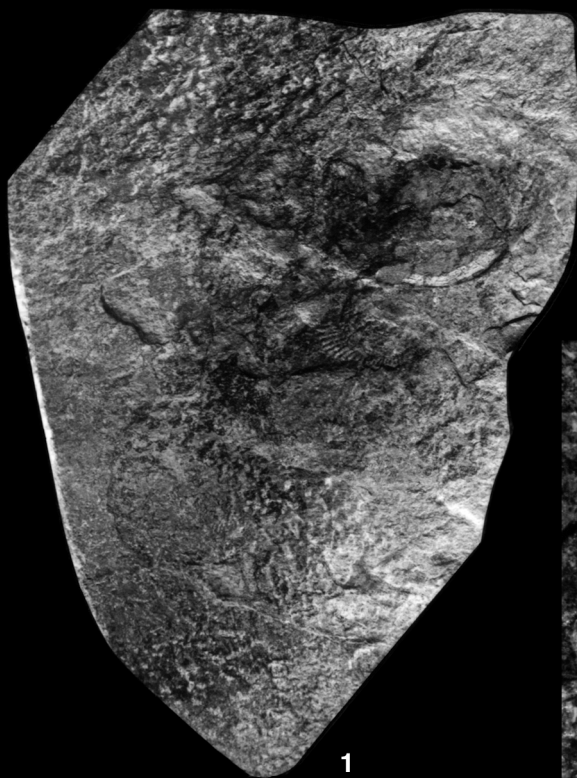
Plate 2

Fig. 1: *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY, 1841) with siphuncle structure, together with accumulation of *Karsteniceras*, NHMW 2000z0183/0005, x 1.

Fig. 2: Detail of siphuncle structure of Fig. 1, NHMW 2000z0183/0005, x 4.

Fig. 3: *Barremites (Barremites)* cf. *difficilis* (d'ORBIGNY, 1841) with siphuncle structure, NHMW 2000z0183/0006, x 4.

All specimens were collected at KB1 which is situated SSE of Trattenbach, 7 km W of Losenstein, Upper Austria.

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