PRESERVATIONAL HISTORY OF CERATITE SHELLS

by A. SEILACHER

ABSTRACT. In the Germanic Muschelkalk basin, only sediment-filled shells survived diagenetic destruction. Their steinkerns reveal a surprising variety of case-histories indicative of particular environmental conditions.

THE mid-Triassic ceratites remained restricted to the Germanic Muschelkalk basin throughout most of the evolutionary history of the group (Wenger 1957). In this basin the sedimentational and diagenetic environments were fairly uniform so that the preservational conditions here described apply to all species in the stratigraphic sequence. Compared to other ammonoid occurrences, the Muschelkalk ceratites are extraordinary in that they have left: (*a*) no external molds or sculpture steinkerns, (*b*) no shell fragments, (*c*) no flattened shells, (*d*) no drusy calcite or pyrite fillings, (*e*) no juvenile shells, neither isolated nor as early stages inside later whorls. This lack, which applies to the limestones as well as to the clay beds, explains why we know so little about the shape of growth lines and apertural margin (Sun 1928), and even less about the early ontogeny of the ceratites. What is found are internal casts of body chamber and outer phragmocone, the latter with clear suture lines.

To explain this unusual bias in the ceratite record, we have to postulate an early diagenetic solution of aragonite shell and conchiolin periostracum, whereby all external casts have been wiped out. Only sedimentary fillings that had been subject to previous

EXPLANATION OF PLATE 6

Ceratite steinkerns from the Upper Muschelkalk, Germany.

Fig. 1. 'Double suture line' (Kumm 1927); pressure solution has imposed the relief of the suture line onto a plane in which sections of septal surfaces are much smoother (Vellberg; Tübg. cat. nr. 1391/2; ×1·8).

Figs. 2, 3. Projecting sutures and solution edges are another effect of pressure solution on flat-lying ceratite steinkerns (evolutus Zone, Neudenau; specimen collected by R. Mundlos, Tübg. cat. nr. 1391/3; ×0·8). 3, Same specimen, showing sickle marks on the upper surface of the sediment that partly filled the body chamber; these marks are considered as traces of draught currents in case 6 (Mundlos 1970).

Fig. 4. Sinus channel formed in the final stage of phragmocone draught filling of case 6; the lower bends of the channel pass through the septal necks (Seilacher 1968; Tübg. cat. nr. 1338/4; ×0·6).

Fig. 5. Case 3 with lobe voids formed by draught filling; later compaction of the spiral steinkern effected mainly by differential movement of the chamber fillings along septal contacts (Bayrische Staatssammlung f. Paläontol., Munich; ×0·4).

Fig. 6. Case 7 with calcite-filled lobe voids of case 3 protruding due to pressure solution that followed reworking of the pre-fossilized shell into horizontal position (from Seilacher 1966, pl. 43, fig. 2, nat. size).

Fig. 7. Case 9. Reworking of upright shells at a stage when the filling was absent or not yet hardened has left characteristic cappings (marked by arrows) that are inconsistent with the present orientation and fill structure (Seilacher 1963); detail of large slab from Bruchsal; Tübg. Inv. nr. 24620a, ×0·17.

[Palaeontology, Vol. 14, Part 1, 1971, pp. 16–21, pl. 6.]

concretionary petrification, have survived in the fossil record. This rule applies also to associated aragonitic bivalves and gastropods, while calcitic shells of gervilliid, limid, pectinid, and oyster-like bivalves remained unharmed. Therefore the calcitic epizoans (*Placunopsis*, oysters, *Spirorbis*), as well as the phosphatic ones (*Discinisca*), appear now directly superimposed on ceratite steinkerns. Only certain bioclastic 'Kornstein'-beds with non-micritic matrix present a somewhat different mode of preservation. In this sediment the early lithification, instead of being restricted to steinkerns, seems to have affected the whole bed. Subsequent aragonite solution has left open crevices which eventually became lined with a drusy calcite crust.

At a later stage, but still rather early in diagenesis, hardened limestone beds as well as concretionary steinkerns have often suffered from pressure solution at their contact with a more clayey sediment. Obvious traces of this process left on ceratite steinkerns are 'double suture lines' (Pl. 6, fig. 1), and sharp solution edges (Pl. 6, fig. 2). Stylolites, on the other hand, are the product of a much later stage of pressure solution and are most clearly developed in bioclastic horizons.

In general, we may say that micritic Muschelkalk beds were subject to the following sequence of diagenetic events that have also controlled the preservation of enclosed fossils:

1. Periostracum disintegration;
2. Concretionary lithification of sedimentary infills in shells and interstices of bioclastic beds;
3. Aragonite solution;
4. Lithification of the micritic matrix;
5. Pressure solution.

SEDIMENTARY FILLING

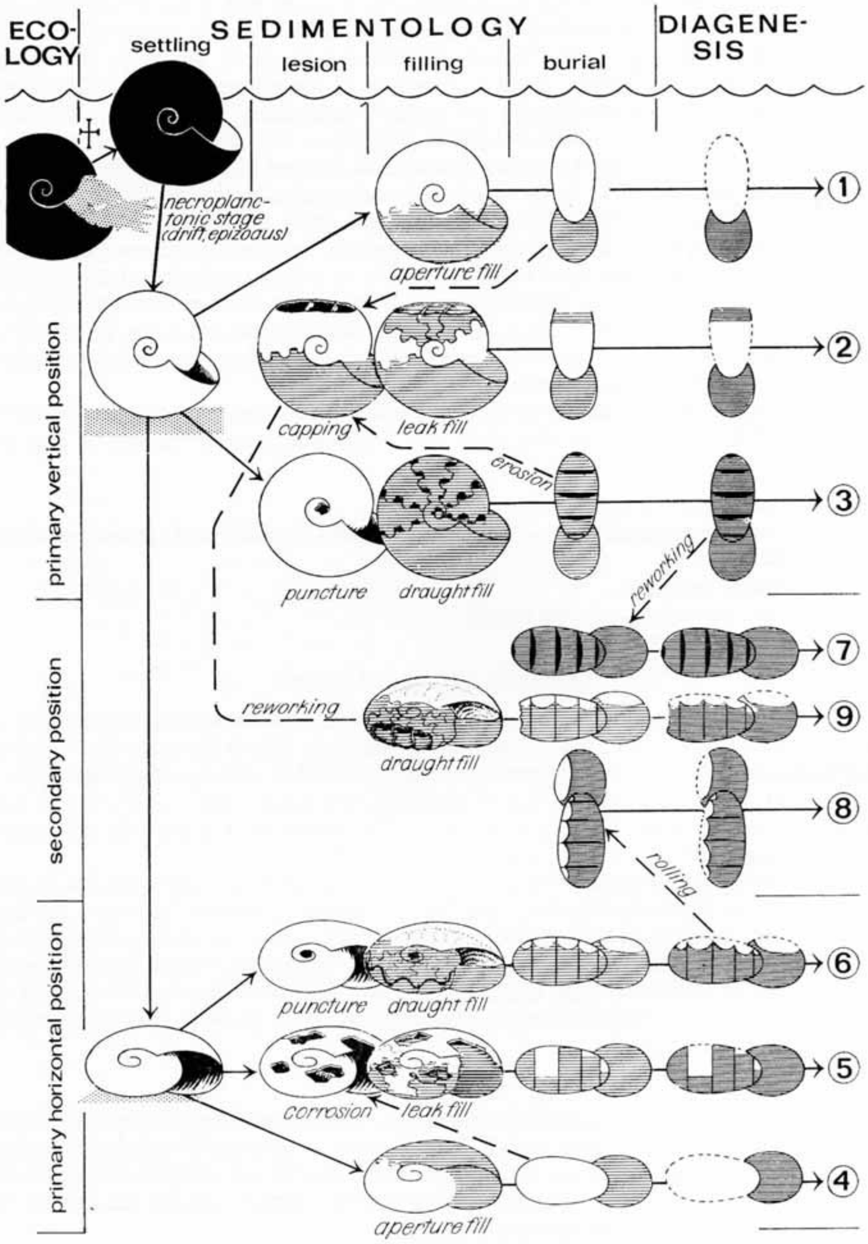
The particular diagenetic history of the ceratites has wiped out many of the preservational details that can be observed in other ammonites. But at the same time it brings out more clearly the sedimentational processes involved in ammonoid preservation.

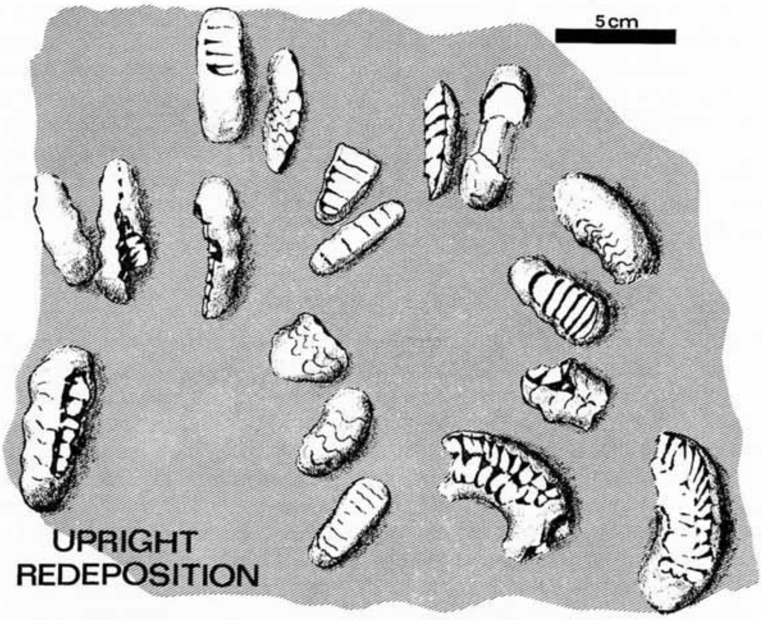
Significant case-histories are diagrammatically shown in text-fig. 1. They result from different combinations of shell attitude and fill mechanism, and sometimes from the resedimentation of pre-buried and pre-fossilized shells.

Naturally not all cases occur with the same frequency. But it is surprising that draught filling (intra-cameral draught stream created by external turbulence through constricted siphuncular openings; Seilacher 1968), which would appear to be the most unlikely process, is in fact the most common. This may also be the explanation for the juvenile gap. In a given sediment there will be a minimum fill-hole diameter, below which the draught fill does not work any more; the siphuncle of the juvenile shell was probably below this critical diameter.

REWORKING

One would expect that most shells would have been tipped into a horizontal position before they became filled and buried. In fact, many more ceratites are found in horizontal than in upright position. This can be deduced even for museum specimens that were not orientated when collected, because vertical pressure solution has marked the final orientation on most specimens.


ECO-
LOGY
SEDIMENTOLOGY
settling
lesion
filling
burial
DIAGENE-
SIS
necroplanc-
tonic stage
(drift, epizoaus)
aperture fill
capping
leak fill
erosion
puncture
draught fill
reworking
reworking
draught fill
rolling
puncture
draught fill
corrosion
leak fill
aperture fill
primary vertical position
secondary position
primary horizontal position
1
2
3
7
9
8
6
5
4



TEXT-FIG. 2. The upright positions on a slab collected by R. Mundlos (case 8) must be secondary because the fillings correspond to case 6. Wheeling of pre-fossilized shells into sticky mud may explain this phenomenon (Upper Muschelkalk, Neudenau; Tübg. cat. nr. 1391/1).

TEXT-FIG. 1. Case-histories of ceratite preservation. While having a similar diagenetic background (concretionary hardening of steinkern, solution of aragonitic shell, pressure solution of steinkern), preserved specimens were involved in diverse sedimentational processes:

(1) Due to rapid burial of the upright shell the phragmocone remains unfilled and disappears during shell solution. The surviving body chamber steinkern is easily overlooked by collectors.
(2) Upright shells become re-exposed and capped by erosion so that sediment could fill into some of the chambers; collectional bias as in case 1.
(3) A puncture allows the phragmocone to draught fill before it becomes completely buried, retaining the upright position and lobe voids recording the filling mechanism (see Pl. 6, fig. 5).
(4) Like case 1, but after the shell had been tipped into horizontal position.
(5) Like case 2, but leaks situated on flank.
(6) Like case 3, but without lobe voids; instead, draught filling often leaves a sinus-shaped fill channel above the mid-line of the phragmocone (Pl. 6, fig. 4) and/or sickle marks on the infill of the body chamber (Pl. 6, fig. 3).
(7) Reworking has brought pre-fossilized specimens of case 3 into horizontal position, but they preserve the lobe voids from their primary upright position (Pl. 6, fig. 6).
(8) Reworking of pre-fossilized case 6 shells from horizontal into upright position (text-fig. 2).
(9) Case 2 shells, reworked before their sedimentary filling had become hardened, can be distinguished from case 6 by cappings inconsistent with their present position (Pl. 6, fig. 6).

Explanation: Light hatching = filled with soft sediment; dark hatching = fill sediment diagenetically hardened.

But if other criteria (lesions, fill structures) are also considered, it turns out that most of these shells have previously been deposited in an upright position and assumed their present orientation only through later reworking. This conclusion can be drawn from the fact that most of the specimens with capping and with lobe voids, two features related to upright positions, were found in horizontal attitude (Seilacher 1963, 1966). These are not exceptional, as becomes clear from large slabs in which among hundreds of now horizontal specimens more than 50% have cappings (Pl. 6, fig. 7). Since not all specimens would have had this lesion originally, it is likely that practically all suffered the same displacement (Seilacher 1963).

FACIES CONTROL

The ceratite example, though surprisingly complex, presents only a selection of all the case histories possible in ammonoid preservation. This selection is controlled by environmental conditions or, more precisely, by facies. In the case of the ceratites, indications are for a high energy level causing draught fill, rapid burial, and frequent reworking, and for carbonate diagenesis fast enough to interfere with these sedimentational processes. This fits in with the general picture of the Muschelkalk Basin as a shallow marginal sea with increased salinity. It also confirms the idea that the limestone and clay beds have largely altered their carbonate content during diagenesis and may be derived from sediments that were originally not so different.

Another preservational situation has recently been described from the Oxford Clay of Woodham (Hudson and Palframan 1969), where the juvenile gap seems to be reversed. Here the empty inner chambers, instead of being destroyed, survived aragonite solution and compaction because they had already been reinforced by a thick pyrite lining. The sediment-filled outer whorls, however, lacking concretionary cementation, became so flattened that they are usually overlooked by collectors. Fairly quiet water conditions, but with enough oxygen to support benthonic life, and with bacteria reducing sea water sulphate to sulphide in the upper few centimetres of the sediment are postulated by the authors.

The Woodham model is still comparable to the Muschelkalk situation in its burial part and differs mainly in the diagenetic aftermath. It will probably fit many of the dark clays of the German Lias and elsewhere. It does not apply, however, to the fossiliferous *Posidonia Shales* of Holzmaden, where truly stagnant conditions seem to have excluded benthonic life, draught filling, and the bacterial action responsible for void-pyritization. As a result, all ammonites are now completely flattened without showing any suture line.

Similarly diagnostic sets of preservational histories can probably be found in many other types of sedimentary facies. Some additional examples, as well as other kinds of fossils, are presently being studied by a Tübingen group of earth scientists in a special research programme ('Fossil-Diagenese'). It is hoped that the results will help to improve understanding of the incompleteness of the fossil record and at the same time provide an additional tool in facies analysis.

Acknowledgements. This article has developed from a presentation at the Birmingham Symposium of the Palaeontological Association on the Preservation of Fossils (December 1969). It is largely based on material supplied by the private collector Rudolf Mundlos (Bad Friedrichshall). Photographs were made by Werner Wetzel (Tübingen). Mr. F. Springer helped in the preparation of text-fig. 1.

REFERENCES

HUDSON, J. D. and PALFRAMAN, D. F. B. 1969. The ecology and preservation of the Oxford clay fauna at Woodham, Buckinghamshire. *Quart. Jl. geol. Soc. Lond.* **124,** 388–418, pl. 19–20.

KUMM, A. 1927. Diagenetische und metagenetische Veränderungen an Ceratiten. *J. Ber. Nieders. Geol. Ver.*, Hannover, **20,** 1–40, 1 pl.

MUNDLOS, R. 1970. Wohnkammerfüllung bei Ceratitengehäusen. *N. Jb. Geol. Pal., Mh.*, Stuttgart, **1,** 18–27.

SEILACHER, A. 1963. Umlagerung und Rolltransport von Cephalopoden-Gehäusen. Ibid. 593–615.

—— 1966. Lobenlibellen und Füllstruktur bei Ceratiten. Ibid. 125 (Festband Schindewolf), 480–8, 2 pls.

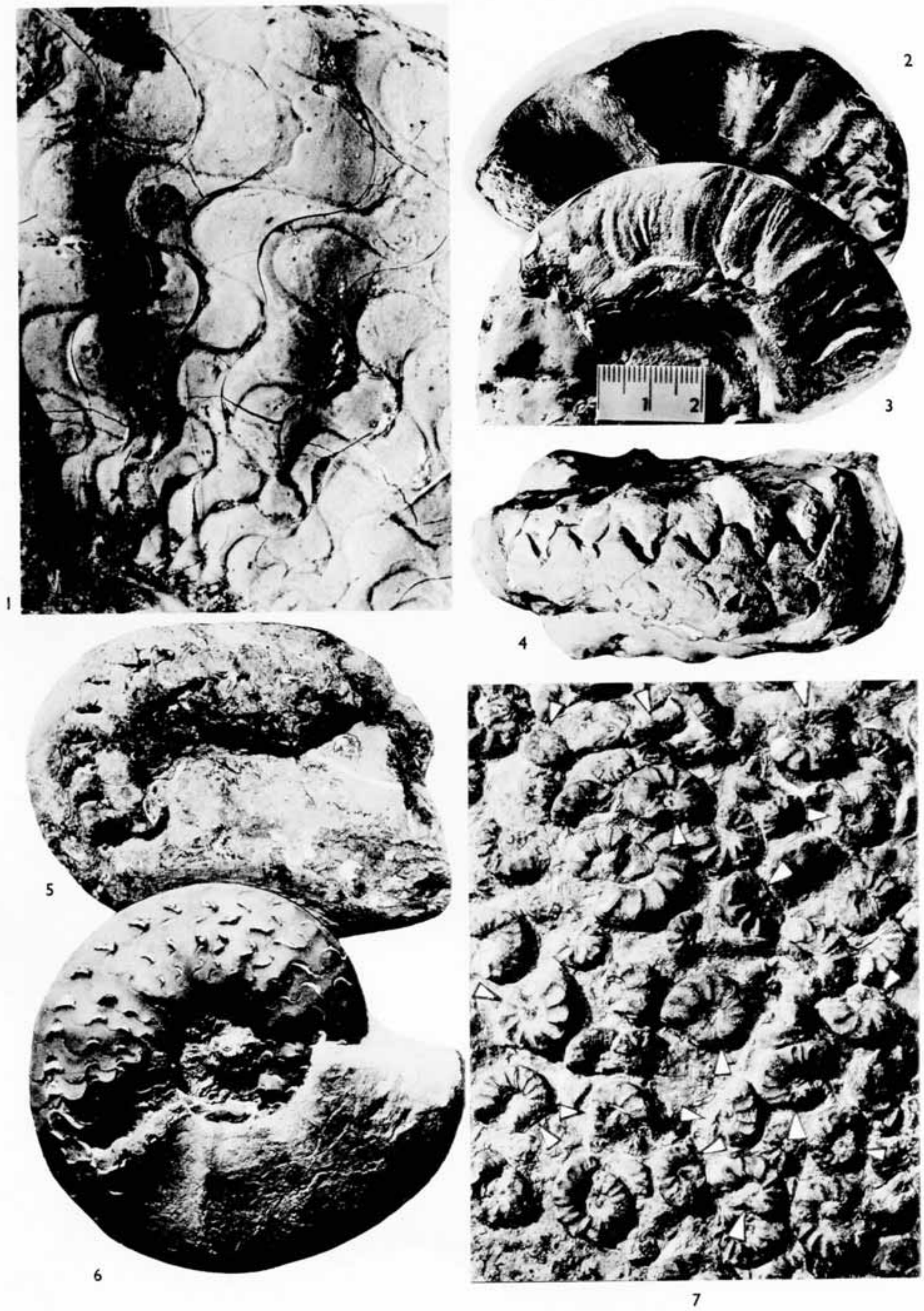
—— 1968. Sedimentationsprozesse in Ammonitengehäusen. *Akad. Wiss. u. Lit., Abh. d. Math.-Naturw. Kl.*, 1967, Mainz, **9,** 191–203, 1 pl.

SUN, Y. C. 1928. *Mundsaum und Wohnkammer der Ceratiten des Oberen deutschen Muschelkalks.* Max Weg, Leipzig, pp. 1–23, 2 pls.

WENGER, R. 1957. Die germanischen Ceratiten. *Palaeontographica*, Stuttgart, **108A,** 57–129, 13 pls.

ADOLF SEILACHER
Geologisches Institut der Universität
74 Tübingen, Germany
Sigwartstr. 10

Typescript received 7 May 1970



SEILACHER, Preservation of Triassic ceratites