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Suture ontogenies of *Zelandites* MARSHALL and *Saghalinites* WRIGHT & MATSUMOTO (Ammonoidea, Cretaceous)

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With 3 figures in the text

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Abstract: The ontogenies of the lytoceratid genera *Zelandites* MARSHALL and *Saghalinites* WRIGHT & MATSUMOTO from the Upper Cretaceous of Far East Russia indicate a typical gaudryceratid development of the former species. The genus *Saghalinites,* however, exhibits a specific type of suture ontogeny with the exceptional formation of an additional umbilical lobe U_4. Separation of a new subfamily might be necessary, if the sutural features of *Saghalinites* will appear also in other taxa.

Zusammenfassung: Ontogenetische Untersuchungen an den Lytoceraten-Gattungen *Zelandites* MARSHALL and *Saghalinites* WRIGHT & MATSUMOTO aus der Oberen Kreide Fernost-Rußlands lassen eine typisch gaudryceratide Entwicklung bei *Zelandites* erkennen. Die Gattung *Saghalinites* zeigt allerdings als Sonderentwicklung der Lobenontogenie die Bildung eines zusätzlichen Umbilikallobus U_4. Dies könnte zur Definition einer eigenen Subfamilie führen, wenn sich dieses Merkmal auch noch bei anderen Taxa finden sollte.

1. Introduction

The genera *Zelandites* MARSHALL and *Saghalinites* WRIGHT & MATSUMOTO are typical taxa of lytoceratids which are especially numerous in the Upper Cretaceous of the Pacific region.

KRIVOSHAPKINA (1976) was the first who studied the suture ontogeny (starting from the fifth suture line) of *Zelandites,* i.e. *Z. japonicus* MATSUMOTO, from the Maastrichtian of Sakhalin. According to KRIVOSHAPKINA, the genus *Zelandites* is attributed to the subfamily *Gaudryceratinae,* family *Tetragonitidae,* having a sixlobate suture line, from the fifth line to the middle of the third whorl; all following suture lines have five lobes only. KRIVOSHAPKINA does not give any information on prosuture, primary suture and the following three suture lines.

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MIKHAILOVA (1983) investigated a series of lytoceratids including *Saghalinites cala* (FORBES) from the Santonian of Sakhalin. She described general features of the suture ontogeny for all tetragonitids and gaudryceratids and the similarity of the individual development of *Saghalinites* with *Epigoniceras* SPATH and of *Zelandites* with *Gaudryceras* GROSSOUVRE and *Anagaudryceras* SHIMIZU. According to MIKHAILOVA (1983, figs. 49, 126), the main suture features of *Saghalinites* are the sixlobate suture line from the beginning (primary suture), development of the lobe U_1 (*I* of the Russian terminology) without subdivision, the absence of a sutural lobe and the possibility to generate two more lobes by subdivision of saddles (not of lobes) during ontogeny.

In order to become acquainted with the prosuture, primary suture, and the ontogenetic appearance of new lobes in *Zelandites*, as well as the origin and differentiation of new sutural elements of *Saghalinites*, well-preserved specimens of *Zelandites japonicus* MATSUMOTO and *Saghalinites teshioensis* MATSUMOTO were investigated. The *Zelandites* specimens were collected in the Maastrichtian of Southern Sakhalin, *Saghalinites* in the Upper Santonian/Lower Campanian of northwestern Kamchatka, Far East Russia, and are deposited in the Geologisch-Paläontologisches Institut Tübingen (GPIT) and in the North-Eastern Interdisciplinary Scientific Research Institute Magadan (NEIM).

2. Suture ontogeny of *Zelandites japonicus* MATSUMOTO

Seven specimens from a single Maastrichtian locality of the Naiba area, Sakhalin Island, were investigated. General features of the suture ontogeny of *Z. japonicus* (Fig. 1) are the following: prosuture LU_2U_1 (Text-fig. 1 A), primary suture ELU_2U_1I (Fig. 1 B), reduction of U_3 in the 6th or 7th line, early opening of the ventral lobe *E* (Fig. 1 C). The entire following sutural development is based on five lobes: ELU_2U_1I. Additional elements are now formed by the umbilical lobe U_1, developing a sutural lobe (Fig. 1 G). The main differences of our interpretation of the suture ontogeny of *Zelandites japonicus* MATSUMOTO compared with the opinion of KRIVOSHAPKINA (1976) are as follows:

1. The third umbilical lobe U_3 disappears before the primary constriction.

2. All consecutive suture incisions are connected with the formation of a sutural lobe in U_1, and not with the development of U_3 or U_2.

3. The umbilical lobe U_1 moves from the dorsal side to the umbilical margin after 2,5 whorls (Fig. 1 F). In KRIVOSHAPKINA (1976, p. 77), this element remains in a dorsal position, although the text is not compatible with the figure.

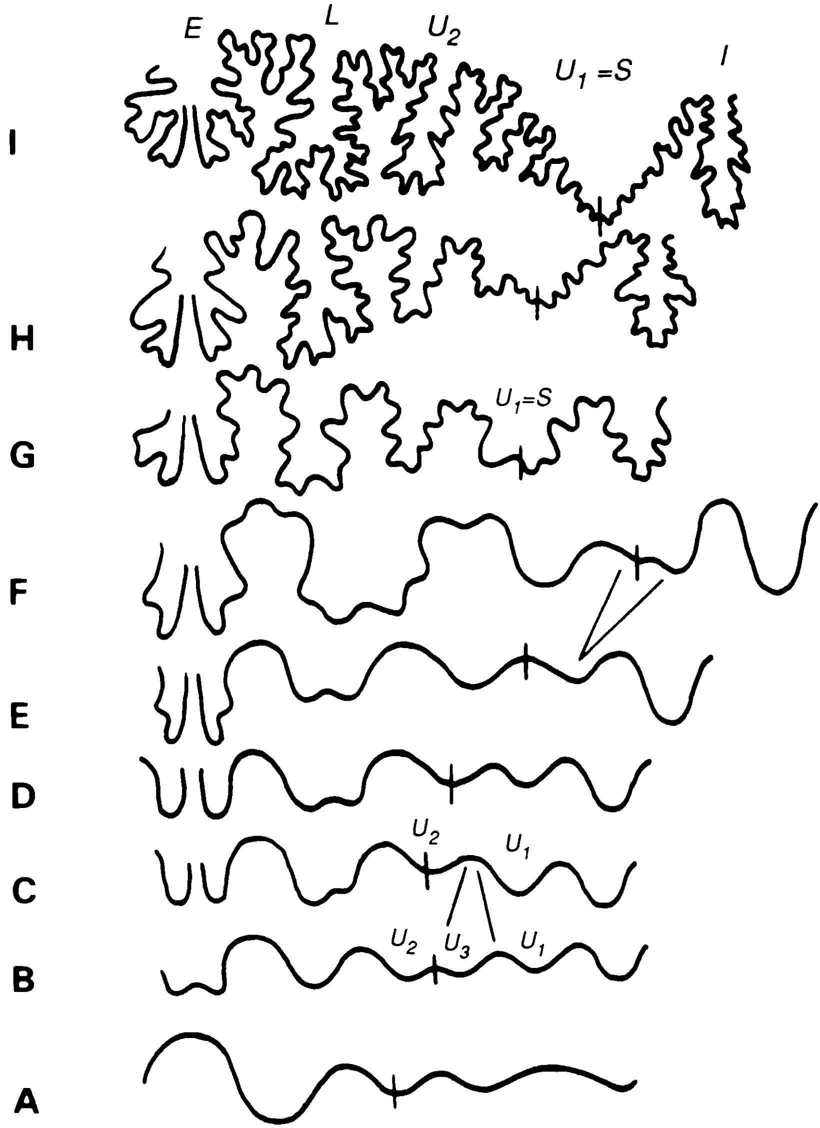


Fig. 1. Suture line ontogeny of *Zelandites japonicus* MATSUMOTO, specimen NEIM 22s/5-1. Maastrichtian, Naiba River, southern Sakhalin. A - prosuture, ×50; B - primary suture, ×50; C–E - 9th (primary constriction), 17th (1,5 whorls), 21st (2,0 whorls) suture lines, ×50; F - 28th suture line (2,5 whorls), ×30; G - 35th suture line (3,0 whorls), ×25; H - 42nd suture line (3,5 whorls), ×20; I - 50th suture line (4,0 whorls), ×10.

3. Morphogeny of *Saghalinites teshioensis* MATSUMOTO

This investigation is based on 14 specimens collected from Upper Santonian/Lower Campanian strata of the Penzina area, northwestern Kamchatka. The embryonic shell (Ammonitella, Figs. 2 A–D) is small, having a diameter of 1,08 mm, and a whorl width of 0,77 mm. The primary constriction is well developed (Fig. 2 D) and situated at 284° from the proseptum. There are 8 septa between the proseptum and the primary constriction. The protoconch is oval in cross-section and has a maximum diameter of 0,43 mm, a minimum diameter of 0,38 mm, and a width of 1,00 mm (Figs. 2 A, B). The shell sculpture is represented by fine striae and strait constrictions. These very fine striae are present from the second half of the second whorl. Four to six constrictions per whorl start likewise from the second whorl. Interestingly, it is observed that some specimens (Fig. 2 E) have more septa up to the primary constriction and a greater angle of the Ammonitella than typical forms (Figs. 2 A–D).

The suture line (Fig. 3) has a typical tetragonitid configuration with a three lobate prosuture LU_2U_1 (Fig. 3 A) and a sixlobate primary suture $ELU_2U_3U_1I$ (Fig. 3 B). The sixth lobe U_3 (Figs. 3 C–G) is not reduced (Fig. 2 D), all lobes continue to develop. Highly interesting is the appearance of one more umbilical lobe, U_4 (Fig. 2 F), in the 19th suture line by division of the saddle U_2/U_3 (Figs. 3 H–J). The following suture development is determined by the integration of U_4, U_{3v} and U_{3d} into a deeply suspending sutural lobe S (Figs. 3 L, M). The lobes U_2 and U_1 remain individualized. The next new "lobes" are formed by lobe-division of U_{3v} to $U_{3vv}U_{3vd}$, than U_{3vd} to $U_{3vdv}U_{3vdd}$, and so on (Figs. 3 N, O). As a whole, the suture development has the formula $LU_2U_1 \rightarrow ELU_2U_3U_1I \rightarrow ELU_2U_4U_3U_1I \rightarrow ELU_2U_4U_{3v}U_{3d}U_1I \rightarrow ELU_2(U_4U_3 = S)\ U_1I$. The subdivided lobes occur always on the umbilical seam (Figs. 3 I–N).

4. Discussion of the suture ontogeny of lytoceratids

A detailed report about early suture developments in lytoceratids is given by SCHINDEWOLF (1968) and MIKHAILOVA (1983). The interest in *Tetragonitaceae* was initiated by the discovery of a sixlobate primary suture by SCHINDEWOLF (1968). Later on, HIRANO (1975) described a fourlobate primary suture in *Gaudryceras tenuiliratum* YABE, while KROVOSHAPKINA (1978) depicted six lobes.

MIKHAILOVA (1983) described three different types of suture ontogenies in the *Tetragonitaceae* which have a fivelobate primary suture, or a sixlobate primary suture either with or without reduction of U_3.

The actual knowledge about suture ontogenies in the *Tetragonitaceae* can be summarized as follows: Two groups among the late Cretaceous

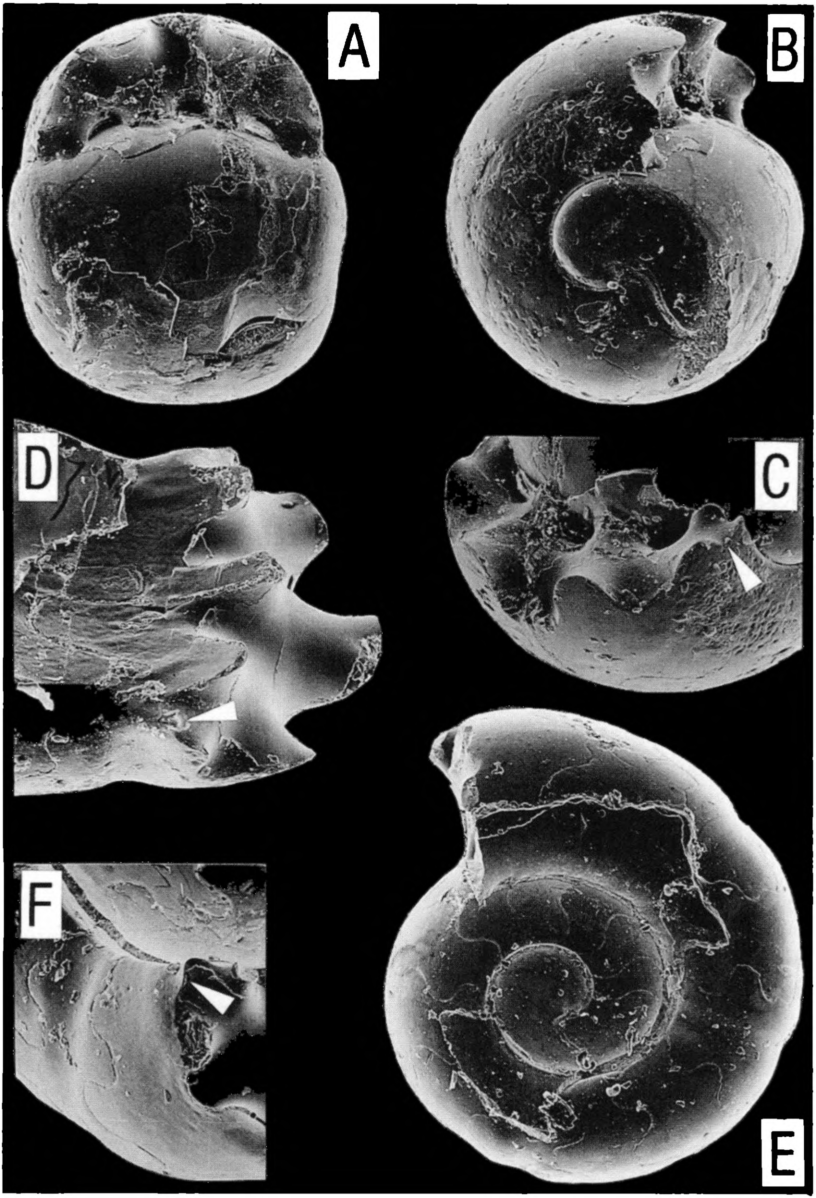


Fig. 2. Shell ontogeny of *Saghalinites teshioensis* MATSUMOTO. A–D – specimen GPIT 1731/1: A–B – protoconch and 7 chambers, ×50; C – general view of 8th septal surface, ×60; D – 8th chamber (primary constriction), ×80. E–F – specimen GPIT 1731/2: E – 1,5 whorls (18 chambers), ×35; F – 19th and 20th chambers, ×55. Lobes U_2 (C), U_3 (D) and U_4 (F) indicated by white arrows. All from the Santonian/Campanian boundary, Talovka River, northwestern Kamchatka.

Tetragonitaceae can be distinguished, the family *Tetragonitidae* HYATT, 1900, and the family *Gaudryceratidae* SPATH, 1927. *Tetragonitidae* comprise two different groups which are considered as subfamilies. These are characterized by the following sutural features:

1. Fivelobate primary suture, early appearance of a sixth lobe U_3 in the 4th–5th line, moderate sutural lobe ($S = U_{1v}$) and an individual lobe U_{1d}: *Gabbioceratinae* BREISTROFFER, 1947.
2. Sixlobate primary suture under reduction of lobe U_3 and a deeply suspending sutural lobe ($S = U_{1vd}$) with individual lobes U_{1vv} and U_{1d}: *Tetragonitinae* HYATT, 1900.

The 7th and 8th "lobes" develop by subdivision of the lobe U_1 in both groups. While in *Tetragonitidae* these two groups seem to represent two distinct evolutionary lines (subfamilies), in *Gaudryceratidae* the situation is quite different: *Gaudryceratidae* include three different types of suture development, i.e.:

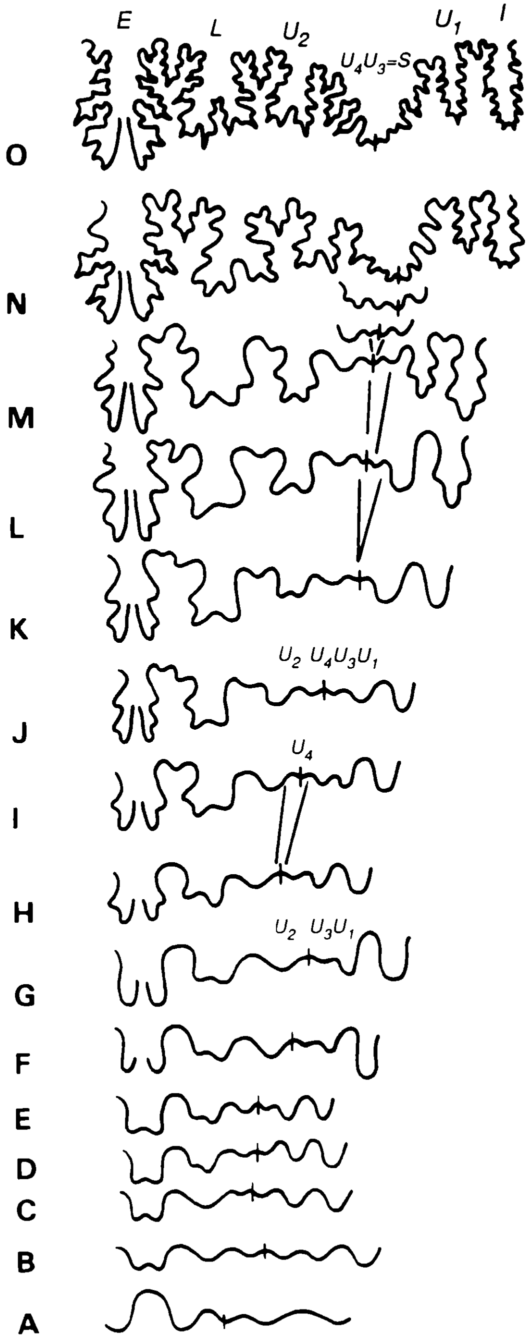
1. Formation of a deeply suspending sutural lobe ($S = U_1$) with: (A) fivelobate primary suture: Albian gaudryceratids; and (B) sixlobate primary suture with reduction of the lobe U_3: late Cretaceous gaudryceratids except *Saghalinites*.
2. Formation of U_4 by subdivision of the saddle U_2/U_3, the splitting of U_3 to $U_{3v}U_{3d}$ and an individualized lobe U_1: *Saghalinites*.

In this case, the transformation from (A) to (B) develops continuously and in parallel lines (*Anagaudryceras, Gaudryceras, Zelandites* ?) between Albian and the late Cretaceous. This means that these two suture developments cannot be systematically separated; they form the *Gaudryceratinae* s. str. The suture development of *Saghalinites* is so different that separation into a subfamily of its own should be considered.

5. Conclusions

The genera *Zelandites* MARSHALL and *Saghalinites* WRIGHT & MATSUMOTO have different types of suture ontogenies. The former has typical features of gaudryceratids: a threelobate prosuture, a sixlobate primary suture, and an early reduction of the sixth lobe U_1. The development of the lobes U_2 and U_1 is here corrected.

Fig. 3. Suture line ontogeny of *Saghalinites teshioensis* MATSUMOTO, specimen GPIT 1731/3. Santonian/Campanian boundary, Talovka River, northwestern Kamchatka. A – prosuture, × 25; B – primary suture, ×25; C–E – 5th, 7th, 9th (primary constriction) suture line, ×25; F–G – 11th (1,2 whorls), 16th (1,5 whorls) suture lines, × 16; H–K – 18th, 19th, 21st and 23rd (2,0 whorls) suture lines, × 14; L–M – 31st (2,5 whorls), 36th (2,8 whorls) suture lines, × 10; N–O – 55th (4,0 whorls), 63rd (4,5 whorls) suture lines, ×7.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The genus *Saghalinites*, however, has a specific type of suture ontogeny with the formation of an U_4 by subdivision of the saddle U_2/U_3, the splitting of U_3 to $U_{3v}U_{3d}$, and an individualized lobe U_1. During late ontogeny, U_4, U_{3v} and U_{3d} become amalgamated to form a deeply suspending lobe *S*. The division of the saddle U_2/U_3 is considered of high taxonomic ranking because this feature is unknown from any other tetragonitid. In any case, tetragonitids develop some "variegated" special types of suture ontogeny. If the sutural features of *Saghalinites* should appear in other taxa, a new subfamily should be separated.

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