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Involutinidae Bütschli (Foraminiferida) in the Carnian of the northeastern Dolomites (Italy)

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ABSTRACT - Thirteen species of foraminifers of the family Involutinidae Bütschli are described; seven of these are new, belonging to the genera *Aulotortus*, *Lamelliconus*, *Triadodiscus*, and *Prorakusia*. The latter genus is proposed here as new. The studied association comes from some Triassic outcrops in the Eastern Dolomites. These outcrops are stratigraphically situated at the boundary between S.Cassiano and Dürrenstein Formations (Austriacum Zone). The specimens are preserved in aragonite, and usually poorly affected by diagenesis. These are perforated foraminifers, with a wall architecture, made up of second order laminae not in phase chronologically and consisting of first order laminae. The laminar form of the test wall shows two main constructive models that, together with the enrolling modalities, are taken as the basis of the involutinid classification at genus level. The Triadodiscus model characterizes species of the genera *Triadodiscus*, *Lamelliconus* and *Prorakusia* that show planispiral enrolling, trochoidal enrolling and two stage ordering (planispiral + streptospiral) respectively. The Aulotortus model characterizes the genus *Aulotortus*, that is represented here by the species *A. sinuosus* with enrolling that varies from planispiral to highly oscillating. The umbilical thickenings, hardly perforated, consist of the superposition of both the second order laminae in the *Aulotortus*; whereas, in the *Triadodiscus*, they are made up of only the superpositon of the outer lamina's various whorls that show the tendency to form bosses in correspondence to the umbilicus. The group's phylogenesis, based on the features of lamination, enrolling and umbilical structures, can be summarized in two parallel lines of evolution. One starting from the early Triassic form *Triadodiscus eomesozoicus*, from which a group of forms radiates during the Carnian, with a characteristic Triadodiscus structural model. From this group, the *Involutina* species and their successive Norian radiation then originates. *Aulotortus sinuosus* is the initial form of a slower, but larger ranging, evolutionary line, that during the Norian is represented, in addition to *Aulotortus*, by genera such as *Auloconus* and *Angulodiscus*.

Key words: Involutinidae, Systematics, Upper Triassic, Dolomites.

RIASSUNTO - Vengono descritte 13 specie di Foraminiferi della famiglia Involutinidae Bütschli, di cui 7 proposte come nuove, appartenenti ai generi *Aulotortus*, *Lamelliconus*, *Triadodiscus* ed al gen. *Prorakusia* proposto qui come nuovo. L'associazione studiata proviene da alcuni giacimenti triassici delle Dolomiti orientali, stratigraficamente posti al passaggio fra le Formazioni di S. Cassiano e di Dürrenstein (zona ad Austriacum).Questi esemplari sono conservati in aragonite e, generalmente, sono poco diagenizzati. Si tratta di foraminiferi perforati, con architettura della parete del guscio bilaminare, data da lamine di 2° ordine sfasate nel tempo e costituite, a loro volta, da lamine di 1° ordine. La costituzione laminare del guscio presenta due principali modelli costruttivi che, insieme con le modalità di avvolgimento, vengono presi come base della classificazione degli involutinidi a livello di genere. Il modello Triadodiscus caratterizza le specie dei generi *Triadodiscus*, *Lamelliconus* e *Prorakusia* che presentano rispettivamente avvolgimento planispirale, trocoide e a due stadi (planispirale + streptospirale). Il modello Aulotortus caratterizza il genere *Aulotortus*, qui rappresentato dalla specie *A. sinuosus* con avvolgimento che va da planispirale a molto oscillante. Gli ispessimenti ombelicali, quasi imperforati, sono costituiti in Aulotortus dalla sovrapposizione di ambedue le lamine di 2° ordine; nel modello Triadodiscus, essi sono invece determinati soltanto dalla sovrapposizione dei vari giri della lamina esterna che mostrano, in corrispondenza dell'ombelico, la tendenza a formare papille. La filogenesi del gruppo, basata sui caratteri della laminazione, dell'avvolgimento e delle strutture ombelicali, è schematizzabile in due linee evolutive parallele. Una che inizia da *Triadodiscus eomesozoicus* del Trias inf., da cui si irradiano un gruppo di forme caratteristiche del Carnico, aventi il modello strutturale di Triadodiscus. Da questo, poi, prenderà origine *Involutina* spp. e la successiva radiazione norica. *Aulotortus sinuosus*, invece, è il capostipite di una linea evolutiva più lenta, ma più longeva, che, nel Norico, è rappresentata, oltre che da *Aulotortus*, anche da generi come *Auloconus* ed *Angulodiscus*.

Parole chiave: Involutinidae, sistematica, Triassico superiore, Dolomiti.

INTRODUCTION

Essay subject

In this paper we have considered the foraminifers of the family Involutinidae Bütschli which are present among the rich fauna of the Carnian sequence of the Dolomites. New studies have defined the taxonomic scheme of this group. However, in order to clarify the situation, we have referred to Loeblich & Tappan (1988) and Zaninetti (1984), who defined the family Involutinidae as follows:

1) spheric proloculus followed by enrolled, undivided, tubular deuteroloculus; 2) planispiral, oscillating, streptospiral and trochospiral coiling; 3) terminal, simple aperture; 4) calcareous wall, radial structure, originally aragonitic, but commonly recrystallized; 5) perforate wall; 6) symmetric or non-symmetric umbilical thickenings, bosses or nodes or pillarlike structures.

In Zaninetti's opinion (1984) the following genera are included in the family:

Involutina Terquem,1862
Auloconus Piller,1978
Aulotortus Weynschenk, 1956
Coronipora Kristan,1958
Hottingerella Piller,1983
Lamelliconus Piller,1978
Planispirillina Bermudez,1952
Semiinvoluta Kristan,1957
Triadodiscus Piller, 1983
Triasina Majzon,1954
Trocholina Paalzow, 1922
Trocholinopsis Piller, 1983

Studied material

For many years, beautiful invertebrate fossil faunas from the S.Cassiano Fm. *auctorum* have been known and collected. Dr.Rinaldo Zardini was a major collector and expert of these faunas from Cortina, Misurina and the Braies areas. He provided the incoherent samples from which the majority of the foraminifers studied here were extracted, by washing. They are therefore free from inglobing sediment. This is important as the majority of the Triassic Involutinids are only known from sections randomly oriented within microfacies.

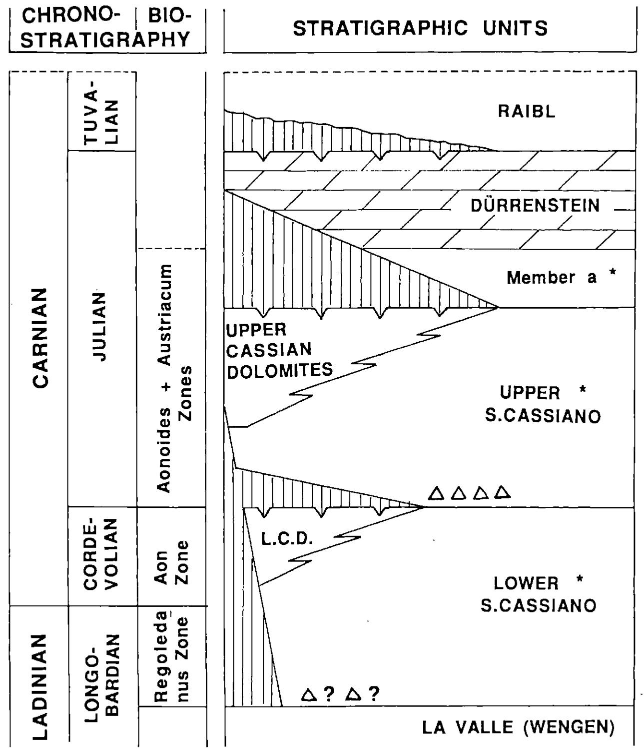


Fig. 1 - Chronostratigraphic setting and Upper Ladinian-Carnian units of the north-eastern Dolomites based on Russo *et al.* (1991). Lithologic units (marked by an asterisk) have been used *sensu* Russo *et al.* L.C.D.= Lower Cassian dolomites.

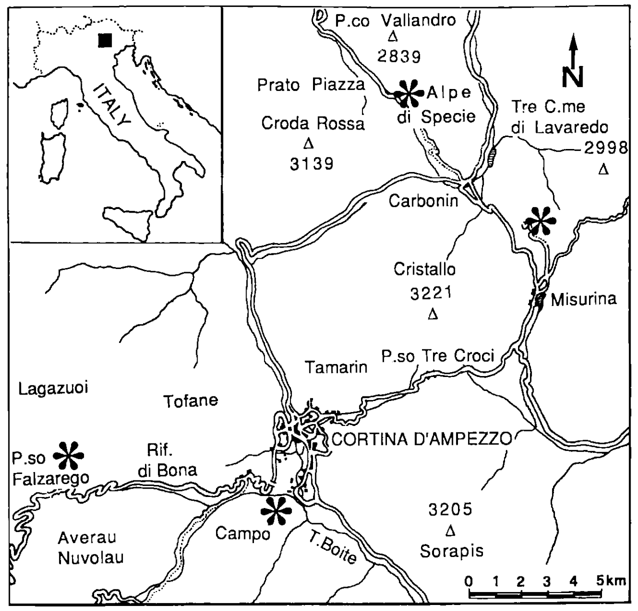


Fig. 2 - Detailed map of the localities (asterisk) where material was collected.

The studied material is deposited in the collections of the Paleontological Institute of Modena University (Italy).

Involutinids from the Alpe di Specie (Braies, South Tirol) have been studied by Oberhauser (1957) and are mentioned by other Austrian authors.

Geological setting and collecting sites

The Ladinian-Carnian deposits of the Dolomites mainly represent carbonate platforms and coeval basinal sediments.

The Carnian platforms - Cassian Dolomite - consist mainly of steeply clinostratified, strongly dolomitized, megabreccias deposited as talus beds prograding on the basinal sediments of the S.Cassiano Fm.

The Cassian platforms and their coeval S.Cassiano deposits are organized in two depositional sequences (Fig. 1, based on Russo *et al.,* 1991).

The first sequence includes the Lower Cassian Dolomite and S.Cassiano of Cordevolian age; the second one, the Upper Cassian Dolomite and S.Cassiano of Julian age (Fig. 1).

Above the S.Cassiano Fm., we find the Dürrenstein Fm., made up of well stratified white dolomite. Russo *et al.* (1991) have described in the Alpe di Specie area a new "member a" in the lower part of Dürrenstein Fm. This member is made up of autochthonous carbonatic sedimentation that was deposited in shallow waters, at the maximum level of the carbonatic platform's progradation during the second cycle. Thus, Russo *et al.* (1991) consider "member a", which had been traditionally included in the S.Cassiano Fm., as the initial part of the Dürrenstein cycle.

The majority of the foraminiferids studied here mainly come from Alpe di Specie where "member a" crops out, and from Campo (Cortina d'Ampezzo) and Misurina where the presence of this member is assumed (Fig. 2). Some are also studied from Falzarego Pass ("Tra i sass" locality) (Fig. 2). In other localities, where the basinal facies of the S.Cassiano Fm. outcrops, some rare specimens of these foraminiferids have also been found (Vettorel, 1988).

RESULTS AND DISCUSSION

Taxonomic results

The following systematic scheme results from this study:

Order	FORAMINIFERIDA	D'Orbigny, 1826
Suborder	INVOLUTININA	Hohenegger & Piller, 1977
Family	INVOLUTINIDAE	Bütschli, 1880
Genus	*Aulotortus*	Weynschenk, 1956
	A. sinuosus	Weynschenk, 1956
Genus	*Lamelliconus*	Piller, 1978
	L. artiskomorphos	n. sp.
	L. cordevolicus	(Oberhauser, 1964)
	L. cucullatus	n. sp.
	L. biconvexus	(Oberhauser, 1957)
	L. depressus	n. sp.
	L. minor	(Oberhauser, 1957)
	L. ventroplanus	(Oberhauser, 1957)
Genus	*Prorakusia*	n.gen.
	P. primigenia	n. sp.
	P. salaji	n. sp.
Genus	*Triadodiscus*	Piller, 1983
	T. eomesozoicus	(Oberhauser, 1957)
	T. incrustans	n. sp.
	T. inceptus	n. sp.

This work refers to the suprageneric systematic scheme of Piller (1978), Zaninetti (1984) and Loeblich & Tappan (1988).

We have purposely neglected the suprafamilial taxonomic levels (Piller,1978) as well as the subfamilial rank because phylogenetic connections between genera have not yet been completely clarified.

In fact, several genera are at the moment still under discussion, because of homeomorphism between the Involutinidae and the families Archaediscidae, Lasiodiscidae and Hemigordiopsidae which belong to different suborders.

For definition of the genera we adopted the characters of the test's lamination, as suggested by Piller (1978) and Altiner & Zaninetti (1981), but also the morphological characters, particularly the deuteroloculus coiling.

In this study we have not taken into account *Pragsoconulus robustus* Oberhauser, classified by Loeblich & Tappan within the Involutinidae, even though it is frequently found in the Austriacum Zone and in the studied outcrops, because we have doubts as to whether it belongs to this group and to the order Foraminiferida.

Mineralogic and chemical observations

The species that represent the Carnian genera of involutinids, have been analyzed by A. Loschi-Ghittoni, of the "Istituto di Mineralogia e Petrografia dell'Università di Modena", with X-ray powder methods. The diffraction patterns (Fig. 3) show an aragonitic composition and the well preserved state of the studied samples. Except for the presence of the quartz peak, these diffraction patterns are similar to these published by Piller (1978), of *Involutina turgida*. It is thus confirmed that the calcite peak can be referred to secondary filling of the lumen of the chambers. This peak is not present in the diffraction pattern of the *Lamelliconus biconvexus* test (Fig. 3d), the samples of which have been selected carefully to exclude those with filling. This was possible for the peculiar shape of the tests (Fig. 4). They are trochoidal in shape with the proloculus at the top of the cone and the second chamber disposed as a coil just under the dorsal surface of the cone, on top of the massive "umbilical thickening". The simple

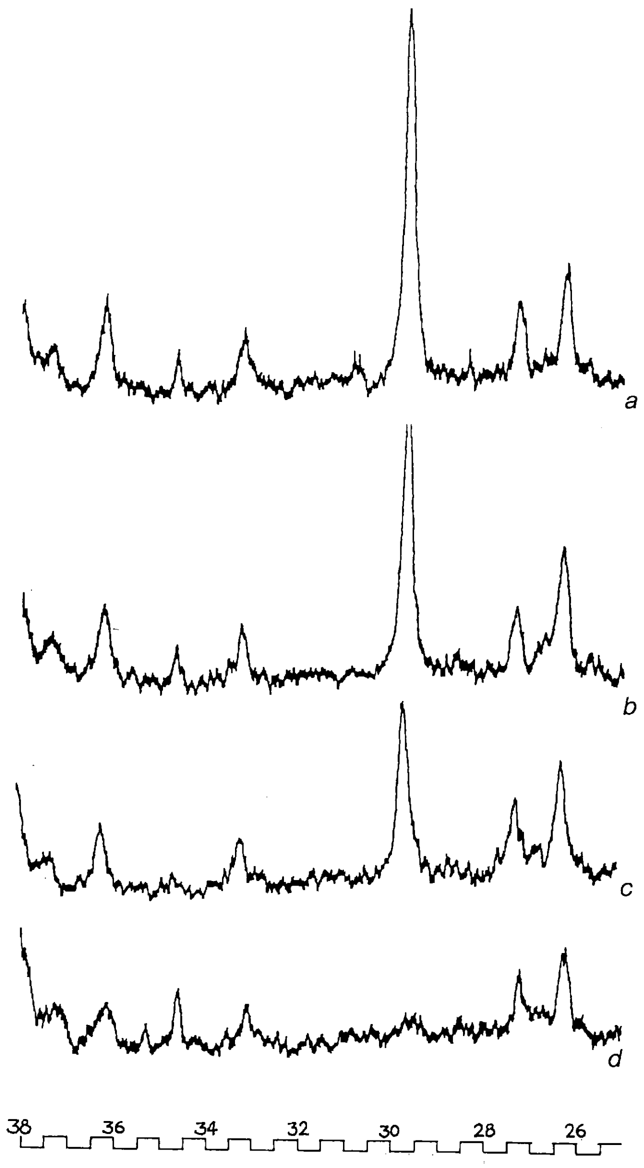


Fig. 3 - X-ray diffraction patterns of : a) *Triadodiscus eomesozoicus*, b) *Prorakusia salaji*, c) *Aulotortus sinuosus*, d) *Lamelliconus biconvexus*.

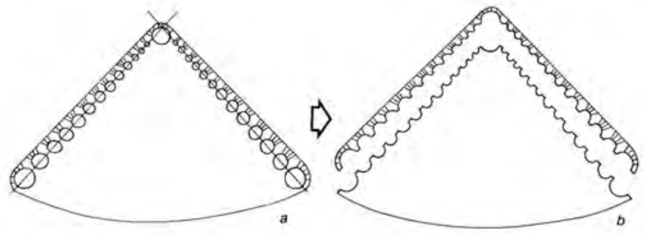


Fig. 4 - *Lamelliconus* sp. axial schematic section showing : a) the easily detached surface of the umbilicus bulk from the dorsal cover; b) the two above -mentioned parts detached.

breakage of the thin contacts between the coiling whorls of the deuteroloculus determines the detachment of the dorsal wall of the cone, that outwardly covers the same coil (Fig. 4). This permits observation of eventual fillings that separate on their own or can be detached with the application of ultrasonic waves.

An analysis has been carried out on some foraminiferal tests with an EDAX microprobe linked to a SEM Philips 500 with the EDS method. The analyzed tests come from localities of Campo, Misurina and Alpe di Specie (see Fig. 2). This analysis confirms the presence of small diagenetic changes in the studied specimen. The measurements were performed on the test wall and lumen filling of the chambers.

Test wall analysis - We have shown (Fig. 3) that the test walls have an aragonitic composition. Among the minor elements of carbonate, the average Sr content was 9,000 ppm in Misurina, 5,000 ppm in Alpe di Specie and 3,700 ppm in Campo. The specimens from Campo and Alpe di Specie also contained small quantities of Fe and S.

It is interesting to consider the composition, certainly of secondary formation, of the lateral wall of the conic tests in *Lamelliconus* sp. from Campo. These samples show the following alterations of colour and micromorphology: a) the original white colour has changed to red; b) the fibrous aragonite has formed into an aggregate of large rhombic crystals (Pl. VI, Fig. 1). Analysis of these specimens has shown that the chamber wall, that lies upon the coil of the deuteroloculus, is composed of Si, K and Al. This composition cannot be related in any way to the abrasive used to prepare the sample. In fact, the "umbilical mass" analysed in the same sample shows an aragonitic composition and does not include the above listed elements.

Analysis of the filling of the chamber lumina - The analysis suggests, in relation to the presence of minor elements, that the infillings are composed of calcite. We can thus justify the presence of the calcite peak in the majority of the diffraction patterns obtained. We usually found a high percentage of Fe, that seemed to be linked to the presence of S. The presence of Mg was only found in the Alpe di Specie samples.

It is also worth mentioning the infilling of the *Prorakusia* sp. tests from Campo. There is a significant reduction in the amount of Ca and Si, K, Al, and Fe are detected. This kind of infilling in the *Prorakusia* sp., can also explain the transformation we find in the lateral red wall of many *Lamelliconus* sp. In fact, the thin lateral wall of *Lamelliconus* specimens is extremely perforated. The pores form a link with the empty space of the underlying chambers. Consequently, when the chambers and pores of the lateral wall are filled, the crystallisation of the flowing liquid destroys the tissue and forms a reddish crest of the same infilling composition that we find in *Prorakusia* specimens from Campo. This kind of infilling helps to explain the quartz peak found by the authors in *Involutina turgida*.

We can sum up by saying that in the degree of conservation of the involutinids in the analyzed outcrops, the ranking, in decreasing order is: Misurina, Alpe di Specie, Campo.

WALL LAYERING MODELS AS A CRITERION FOR DEFINING THE GENERA

At first, the involutinid genera were few and much more enlarged in their definition.

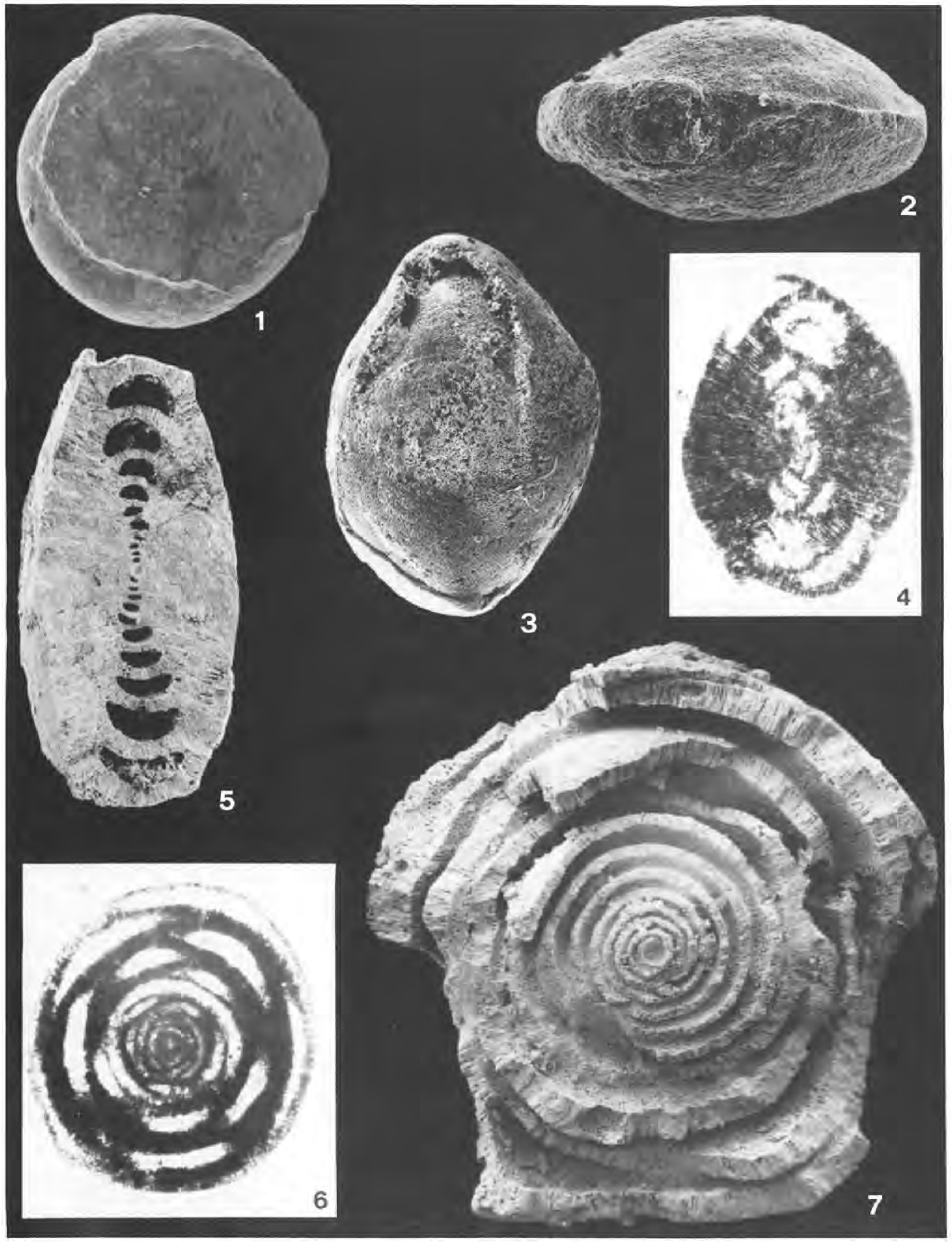
Oberhauser (1957) had placed all the Carnian species of the involutinids in the genus *Trocholina* (*Paratrocholina*). Until quite recently, the planispiral forms of involutinids were classified as belonging to the genus *Involutina* Terquem, while the trochospiral forms were classified as belonging to the genus *Trocholina* Paalzow. Only the most complex genus *Triasina* was classified on its own.

Later, all the Carnian species where classified as *Aulotortus* Weynschenk by Loeblich & Tappan (1964). It was also possible (*fide* Piller, 1983) to differentiate all the post-Carnian involutinids from the Carnian ones, due to the presence of bosses in the umbilical areas of the post-

EXPLANATION OF PLATE I

Aulotortus sinuosus Weynschenk, 1956

Fig. 1 - Exterior, side view. The last part of the wall is broken. SEM picture; x 50.
Fig. 2 - Exterior, edge view showing the last part of deuteroconch with terminal aperture. SEM picture; x 95.
Fig. 3 - Exterior, edge view of spheroidal specimen showing the horseshoe-shaped aperture. SEM picture; x 50.
Fig. 4 - Axial thin section showing oscillating plane of coiling and radial test perforations; Light microscope micrograph; x 80.
Fig. 5 - Axial section of flat and planispiral specimen. SEM picture; x 66.
Fig. 6 - Equatorial thin section showing oscillating plane of coiling. Light microscope micrograph; x 53.
Fig. 7 - Equatorial fresh fracture surface. SEM picture; x 78.



Carnian specimens, whereas the umbilical areas of the Carnian involutinids are completely smooth.

Piller (1978, 1983) studied the microarchitecture of this group and recognized two kinds of wall architecture and on the basis of which he proposed two groups of genera (see later).

We define "wall architecture" as the geometry and arrangement of the crystal units, forming the wall of deuteroloculus. The arrangement of the crystals within these units we define as "wall structure". Because the individual architectural units are more developed in one direction, they are called laminae and/or lamellae. The discontinuity of crystal growth allows the identification of the laminae.

In the literature on foraminiferids there is some disagreement about definition and illustration of these architectural units. Therefore, the meaning implied by the use of the terms "non-laminar" (-lamellar), "mono-laminar", "multi-laminar" (-lamellar) is uncertain. For instance, according to Loeblich & Tappan (1964, p. C 98): «...hyaline calcareous forms are lamellar, for with each new chamber added a layer (lamella) is added over the exterior of the entire previously formed test».

We are not able to discuss here all the problems related to foraminiferal wall architecture in general. Nevertheless, we think that the above definition can easily also include the bilocular forms, because the wall of a long deuteroloculus is periodically increasing, the pieces being added like chambers.

To conclude, we think that the involutinid's test can also be defined as multilamellar, because - as already noted by Piller (1978) - it is composed of smaller laminae organized into larger laminae which are added over the previously formed test. According to Piller, the smaller ones are called 1st order laminae (L1), while the larger ones are called 2nd order laminae (L2). The 1st order laminae grow gradually and periodically complete the 2nd order laminae. The latter sourround the empty space of the second chamber on three sides, thus forming spiral half-tubes.

Piller (1978) subdivided the planispiral forms in 3 genera (*Mesodiscus* Piller, *Aulotortus* Weinschenk, and *Involutina* Terquem) each having different architecture (and structure) and, in the same way, he also subdivided the trochospiral forms into 3 genera (*Lamelliconus* Piller, *Auloconus* Piller, *Trocholina* Palzoow).

The generic division of Piller, based on wall architecture, has been accepted (with some reserve) by other foraminiferal workers. However, Altiner and Zaninetti (1981) think that the observable wall architecture in *Aulotortus* and *Involutina* are more or less the same, if we do not consider the bosses that are only present in the latter genus. These authors present their own architectural scheme (Altiner and Zaninetti, 1981, Fig. 6c) and compare it with Piller's (1978) and other authors (Oberhauser,1964; Koehn-Zaninetti,1969; etc.). A comparison of the scheme of Altiner and Zaninetti (1981) with that of Piller (1978) notes the following differences: second order lamination constitutes only a half whorl at a time in Piller's opinion, whereas they constitute a whole whorl according to Altiner and Zaninetti. In the reconstruction given by these last two authors, the first order lamination proceeds by one half turn at a time.

The material studied here, has shown that the test wall of the Carnian involutinids is substantially made up of two second order laminae: L2a, L2b. This peculiar lamination scheme of these involutinids is shown by two different models: Triadodiscus and Aulotortus models, the former also includes two submodels. According to Piller, we use these architectural models for defining the genera.

Triadodiscus model - This model (Fig. 5A) has been obtained by analysing an axial section of *Triadodiscus eomesozoicus* Piller (Pl. IV, Fig. 1). In this model, the laminae L2a have laterally reduced extensions. Therefore, the umbilical sectors are exclusively made up of the superposition of the lateral-umbilical offshots of laminae L2b. In these sectors, the L2b laminae seem not to be constituted of continuous L1 laminae, but of small irregular crystal plates.These are the layers of reduced dimension which arise from the discontinuity of the L1 laminae.

Lamelliconus and Prorakusia submodels - The figures of Pls VII and IX show that *Lamelliconus* sp. and *Prorakusia* sp. appear to also show the lamination model of Triadodiscus. These submodels differ from the Triadodiscus model in having a non-planispiral coiling.

In the Lamelliconus submodel (Pl. VII, Fig. 2), the dorsal laminae are usually very thin or absent as the coil is trochoid, and therefore dorsal thickening is absent. The L1 laminae are more regular than in *Triadodiscus*.

In the Prorakusia submodel (Pl. IX, Fig. 3), the 2nd stage is streptospiral and consequently the laminar structure is irregular.

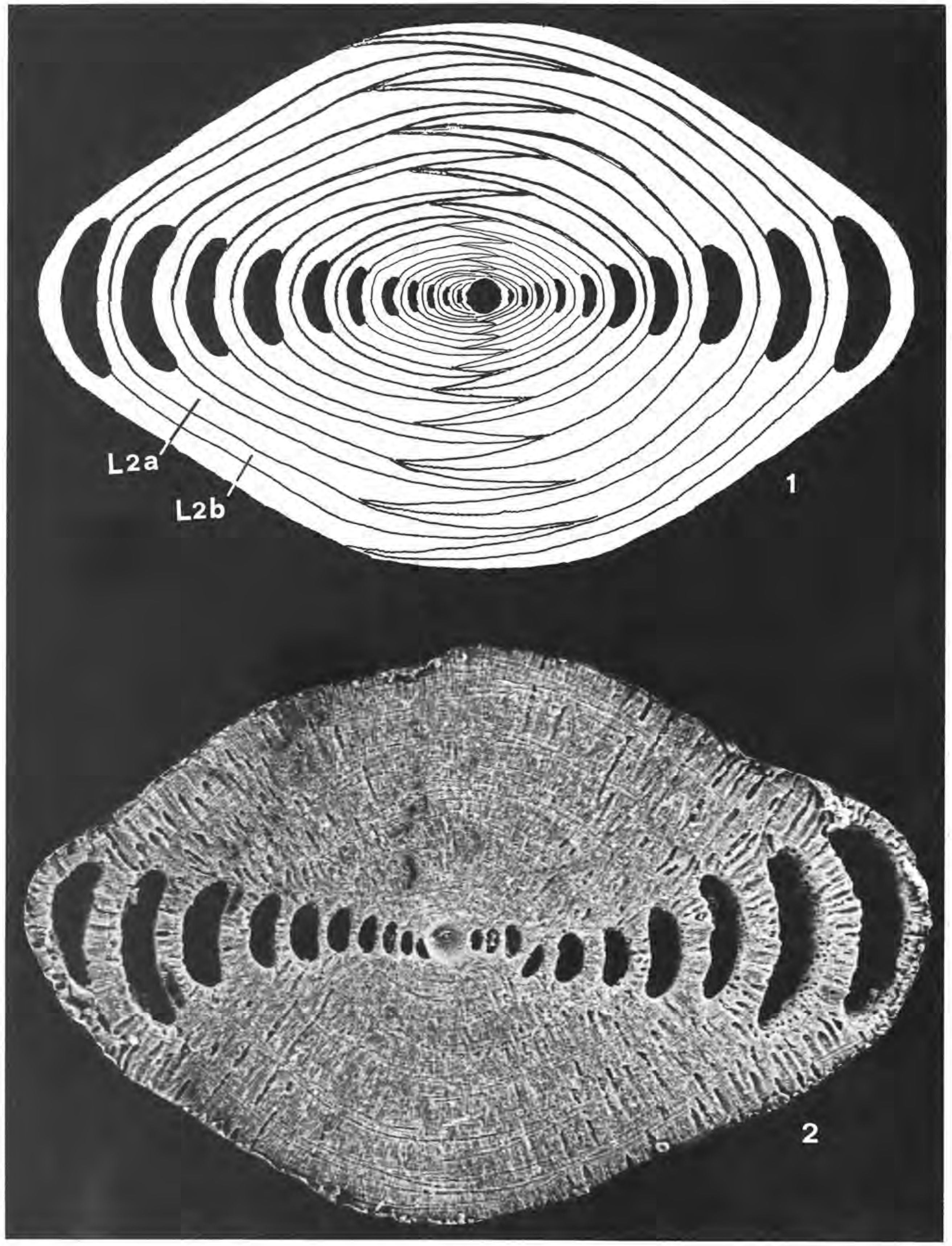
Aulotortus model - This model (Fig. 5B) has been obtained by an analysis of an axial section of *Aulotortus sinuosus* Weynschenk with planispiral coiling (= *A.pragsoides* Oberhauser) (Pl. II, Fig. 2). Nevertheless, oscillating forms of the same species are similar in construction. In this model (Pl. II, Fig. 1) the L2 laminae of each whorl

EXPLANATION OF PLATE II

Aulotortus sinuosus Weynschenk, 1956

Fig. 1 - Diagram showing in the axial plane the 2nd order wall laminae arrangement, drawing from the Fig. 2 below. The L2 laminae of each whorl have prolonged lateral extensions that reach the umbilicus, where they taper and separate each other, interdigiting with the laminae of other side test. The L2a lamina is not isochronous with the L2b lamina of the same whorl. They are separated by a time corresponding to one whorl formation.

Fig. 2 - Polished axial section etched showing the coiling and wall structure made of 1st and 2nd order laminae. The last whorl appare evolute because it is incomplete build. A lot of extraumbilical perforations are also visible. SEM picture; x 223.



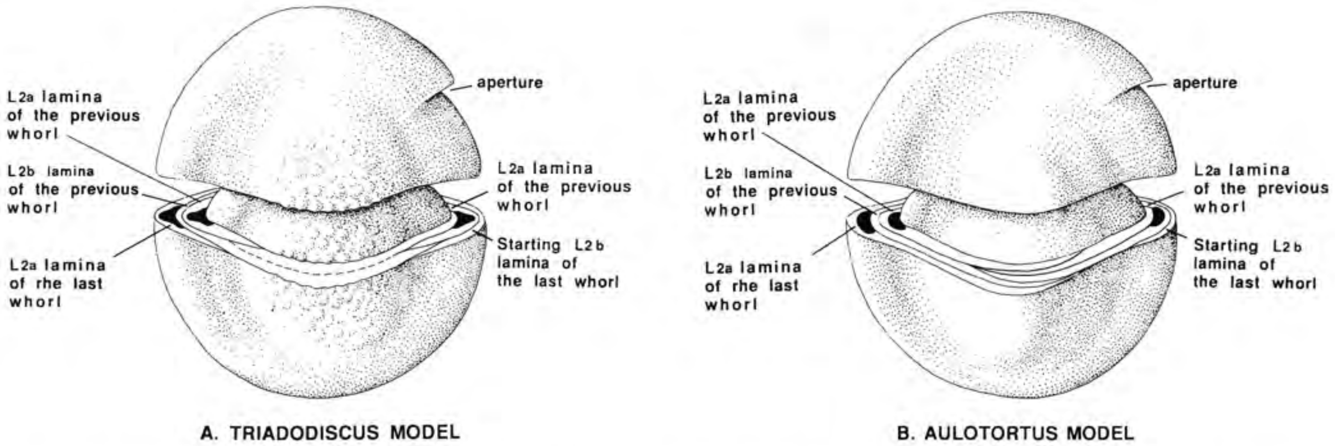


Fig. 5 - Schematic drawing of an involutinid transversally cut. The later whorls section show the test layers arrangement according to Triadodiscus model (A) and to Aulotortus model (B).

have prolonged lateral extensions that reach the umbilicus, where they taper and separate each other, interdigiting with the laminae of other side test. Consequently, the umbilical sectors consist of the jointing between extremities of the L2 laminae that converge into the umbilicus. The L2a lamina is not isochronous with the L2b lamina of the same whorl. They are separated by a time corresponding to one whorl formation. The L1 lamellae are continuous inside the second order laminae.

Comparing the lamination models defined here and those given by other authors we conclude that:

1) Piller (1978) close interpreted the lamination of *Aulotortus* , but considered isochronous the L2 laminae of the same whorl; whereas the lamination of *Triadodiscus* and *Lamelliconus* were misinterpreted. Even if we have not observed in our samples Piller's layer Dh, we think that it may be a secondary layer.

2) The interpretation of Altiner and Zaninetti (1981, Fig. 6c) is close to that given here for *Triadodiscus*, in respect to the discontinuity of the first order laminae in the umbilical zone within the continuity of the 2nd order laminae.

Structure of the test wall - The SEM photos (Pls. II, IV, VII and IX) show that the layers of the studied tests are formed of sub-units consisting of acicular crystals. The long axis coincide with the c-axis. The direction of this axis is not constant in the different sub-units. This must have implications as regards the optical behaviour of the test sections. In fact, in thin section, the wall of the studied involutinids is completely dark (Pl. I, Figs 4, 6; Pl. III, Fig. 2; Pl. VI, Fig. 9; Pl. VIII, Fig. 2). This optical behaviour is typical of porcellaneous tests and does not agree with the "hyaline" character that appears in the current diagnosis of the Involutinidae. However, the subdivision of foraminiferids into "porcellaneous" and "hyaline" is no larger relevant because it preceeds studies using the SEM. Currently, the term porcellaneous seems to be reserved to the monolamellar wall with random disposition of the crystals (Mg-calcite), typical of the Miliolina. On the other hand, the perforated multilamellar wall of the involutinids should be closer in frame to the "hyaline" groups, in spite of its optical behaviour in thin section.

Architectural features of the test

Perforations - The old argument on the perforations of involutinid tests, may now be considered outdated, despite the doubts raised by the study of recrystallized material. The present study has removed all doubts in relation to the Carnian species, since they show many perforations in the extraumbilical area of the test (Pl. II, Fig.

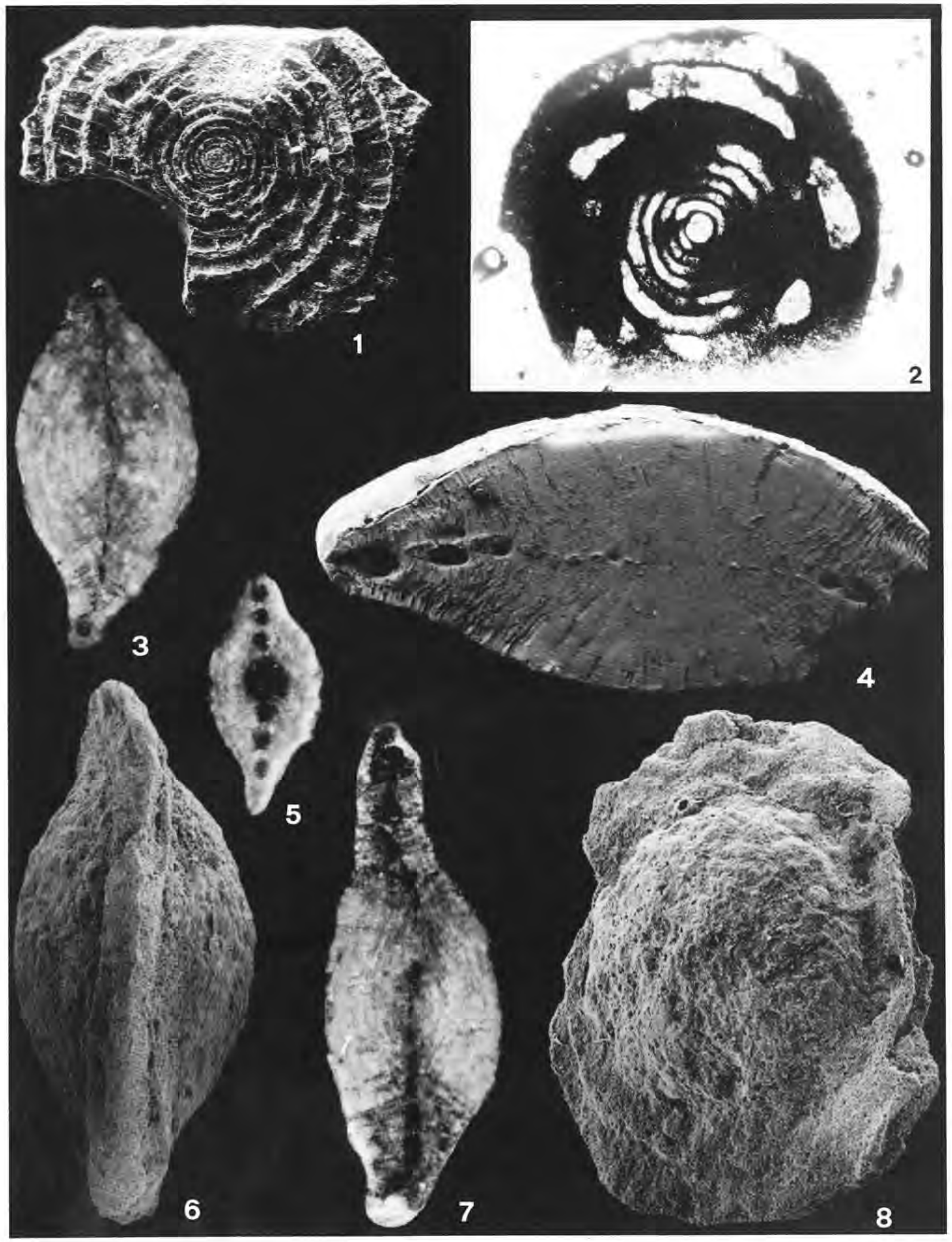
EXPLANATION OF PLATE III

Triadodiscus eomesozoicus (Oberhauser, 1957)

Fig. 1 - Microspheric test split along the median plane. SEM picture; x15.
Fig. 2 - Equatorial thin section showing oscillating plane of coiling. Optical microscope micrograph; x 30.
Fig. 4 - Polished axial section, etched (with Tritriplex). SEM picture; x 36.

Triadodiscus inceptus n.sp.

Fig. 3 - Polished axial section. Optical microscope micrograph; x 47.
Fig. 5 - Axial polished section of megalospheric test. Optical microscope micrograph; x 56.
Fig. 6 - Holotype. Exterior, edge view showing the umbilical thickenings. SEM picture; x 54.
Fig. 7 - Polished axial section. Optical microscope micrograph; x 46.
Fig. 8 - Exterior, side view. SEM picture; x 60.



2; Pl. III, Fig. 4). These perforations have a diameter of approximately ten microns.

Umbilical thickenings - The umbilical feature of the Carnian involutinids tests depends on the lamination models.

In the Triadodiscus model the umbilical sectors are formed by superposition of the lamellae L2b, that in this zone are made of small irregular crystal plates (Pl. IV). In the genus *Lamelliconus*, formation of the trochoidal coiling of the deuteroloculus has determined the lack of bilateral symmetry with respect to the equatorial plane and given rise therefore to a unique ventral umbilical sector (Pl. VII, Fig. 2).

It is often difficult to identify the umbilical area of *Prorakusia*, due to the presence of the 2nd streptospiral stage. However, there always exists less perforated areas in the dorsal and ventral zones.

In the Aulotortus model, the umbilical sectors are determined by superposition of the edges of the L2a and L2b laminae of the test that taper and intersect in this area. This is showed also by De Castro (1990).

Previous authors, erroneously attributed the umbilical thickenings to "callosity" due to secondary infillings. They thought it probably owing to the subsequent facts:

1) Many involutinid forms are evolute in the final part or in the last whorl, because the L2a and L2b layers are not in phase chronologically.

2) The umbilical sectors show a different consistency in thin section, because they are much less crossed by perforations, unlike the marginal areas.

Chamber shape and arrangement: an additional criterion for defining the genera - The bilocular test of the Carnian involutinids possesses a proloculus or embrional chamber, micro- (B form) or megalospheric (A form) in relation to the nuclear dimorphism. The deuteroloculus, or second chamber consists of a long undivided coiled tube. The aperture is simple and terminal. Enrolling of the deuteroloculus of the Carnian involutinids can be of the following types:

1) planispiral; 2) oscillating; 3) trochospiral; 4) composite: planispiral + streptospiral.

The test is usually involute. However, it is often evolute near the aperture.

Various authors (Zaninetti and Bronniman, 1977, 1978; Mehl and Noe, 1990) have emphasized a remarkable example of homeomorphism between the foraminiferid families Involutinidae Bütschli (middle Triassic-Cretaceous), Archaediscidae and Lasiodiscidae (early Carboniferous) and the family Hemigordiopsidae (Carboniferous-Permian, Triassic?) which belongs to the suborder Miliolina. These foraminiferids are similar in construction with two chambers. The enrolling modalities of the deuteroloculus are the important character for determining homeomorphism. This is more marked between the Involutinidae and Hemigordiopsidae rather than with the Archaediscidae, with whom they could have a phylogenetic link.

Generally, the authors who studied the already quoted homeomorphic groups don't take into account the coiling modality as a generic character. For instance, a whole spectrum of forms have been described by Mehl & Noe (1990, Fig. 2) for the genus *Hemigordius*.

Some who have been studied involutinids also persists in this opinion. Piller (1983), instead, based the establishment of the genera firstly on the wall architecture and, secondly on coiling modalities. In fact, a unique coiling modality corresponds to each Piller's wall architectural model, and also to those studied here. Therefore, we use a combination of the characters, wall architecture and coiling modality, for defining the genera.

CONCLUDING REMARKS

Involutinid features

The excellent preservation of the specimens from the studied localities permits us to specify characters for the whole family Involutinidae Bütschli.

The mineralogic composition of the studied Involutinids consists of aragonite. Diagenetic alteration becomes evident with a decrease in aragonite-Sr content and recrystallization of the perforated test regions.

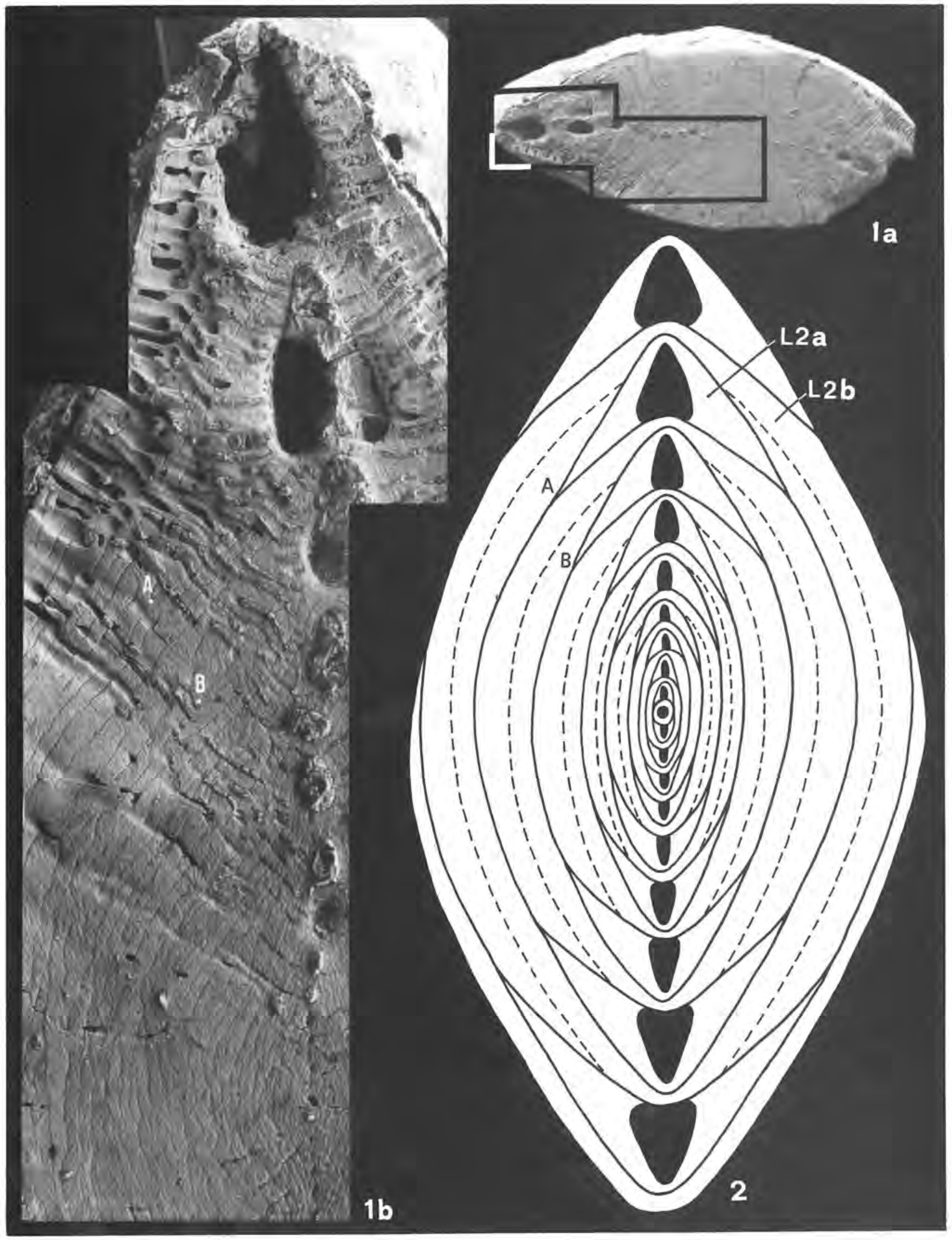
Perforations are an inherent constructive peculiarity of all studied involutinids. They are concentrated outside the umbilical regions which therefore appear to be massive.

The studied involutinids are constructed of two second order laminae (L2); the L2 laminae are in turn made of first order laminae (L1). The growth of the two L2 laminae is not in phase chronologically. Therefore near the aperture the involute forms of the involutinids appear to be partially evolute. Contrary to Zaninetti's claim (1976, p. 170), this is not a phylogenetic character because it is evident in specimens of every age.

EXPLANATION OF PLATE IV

Triadodiscus eomesozoicus (Oberhauser, 1957)

Fig. 1 - Axial section with the outline of the detail seen beside; x 28.
Fig. 1b - Fig. 1a detail at strong magnification (x 130) showing the wall structure made of 1st and 2nd order laminae. SEM picture.
Fig. 2 - Schematic arrangement in axial plane of 2nd order wall laminae. A and B are corresponding points. It is difficult to recognize the limit (dashed line) between the L2b lamina of an half turn and that of the next one included between subsequent discontinuity. The discontinuity between L2b laminae of the same whorl is not clear, because L1 laminae (making up the L2b) are irregular and discontinuous, particularly in the umbilical sector, where they forms the crystal plates. The last L2b lamina is visible increasing.



The range and form of the L2 laminae concur to define the genera and to determine the feature of the umbilical thickenings. It is accettable as a phylogenetic character. In particular, for species of the genus *Triadodiscus*, the L2b laminae forming the umbilical thickenings prove to be discontinous in axial section and they form small crystal plates. We interpret these plates as sections of bosses made of L1 lamellae undulations. These should constitute the beginning of a process, with phylogenetic character, that transmits the imperceptible undulations of the L1 lamina to the L2b laminae, in post-Carnian forms showing bosses and pillar-like structures in the umbilical region. Deuteroloculus enrolling concurs with the lamination of the test in defining the genera. It appears to be a phylogenetic character that follows inherent logic in the spectrum of forms seen in figure 6; these are completely theoretical and hypotetical, in which the observed enrollings are arranged in order of possible morphological changes.

Hypothesis on involutinid phylogeny

The family Involutinidae *sensu* Loeblich & Tappan, 1988, spans from the Permian to the middle Cretaceous. The genus *Triadodiscus,* derived from a planispiral form (probably of the genus *Permodiscus* according to those who support a derivation from Archaediscidae, *i.e.* Gazdzicki, 1983), may also be considered synonymous with *Permodiscus* (Salaj *et al.*,1983). In the Authors' opinion the subsequent phyletic lines would have originated later, *Triadodiscus* → *Aulotortus, Triadodiscus* → *Lamelliconus,* and successively the other phyletic lines.

However if we consider the phylogenetic characters emphasized in the previous chapter -*i.e.* lamination, test enrolling, boss formation and the pillar-like structures of the umbilical regions - we may then reconstruct the involutinid phylogeny as in figure 7. *Triadodiscus eomesozoicus* and *Aulotortus sinuosus*, that are already present in the lower-middle Trias, having two different lamination they seem to have given the origin to different and parallel evolutive lines. We might suppose that, during the Upper Anisian-Ladinian, the Lamelliconus trochoidal coil forms derived from *Triadodiscus eomesozoicus*, through the accentuation of the tendency of the deuteroloculus whorls' translation. But, in the Dolomitic area the first representatives of *Lamelliconus* are located in the S.Cassiano Fm. samples that may be ascribed to the middle-upper part of the Aon Zone (Cordevolian) in the basinal facies. The *Lamelliconus* species seems to be the only ones present within this facies.

In the genus *Prorakusia* the forms with composed enrolling (planispiral + streptospiral) may still derive from *Triadodiscus eomesozoicus*. We hypothesize the lines *Triadodiscus eomesozoicus* → *Prorakusia primigenia* → *P. salaji.* A form with a long primary planispiral stage and with a very short streptospiral secondary stage first derives from a planispiral ancestor; afterwards a form with a short planispiral stage at the beginning and a well-developed streptospiral secondary stage would be derived from this. It should have been possible to hypothesize a derivation

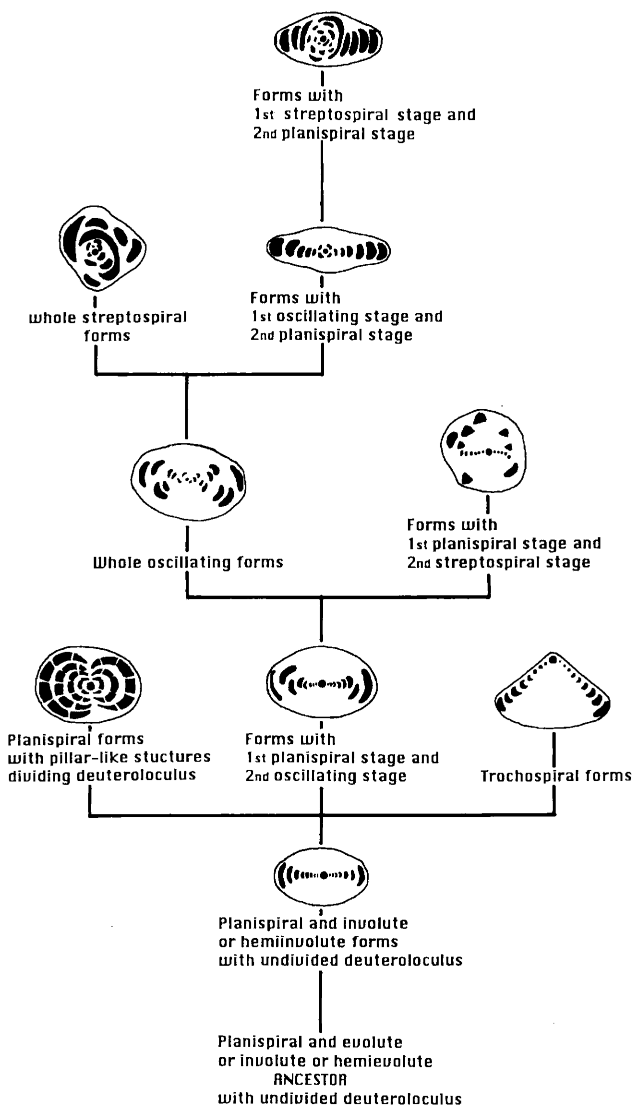


Fig. 6 - Diagram illustrating the different coiling tests in axial section and hypothesized mechanical derivation relationships of the coiling forms.

of *Prorakusia* from a phenotype of *Aulotortus sinuosus* with an initial planispiral part and an oscillating adult part (called *Rakusia* Salaj) but the microarchitecture of *Prorakusia* does not indicate this derivation. As far as we know the stratigraphic distribution of *Prorakusia* is that of *Angulodiscus gaschei praegaschei* given by Salaj *et al.* (1983) because we think that *A.gaschei praegaschei sensu* Salaj is synonymous with *Prorakusia salaji.*

During the Norian-Raethian, there is a general substitution of species according to an iterative model of evolution (Norris,1991). The forms with bosses and pillars of the gen. *Involutina* may have originated from *Triadodiscus inceptus*, that could be defined as an *Involutina* species without pillar-like structures. From the *Involutina* spp. branch originated the forms with trochoid coiling (*Trocholina* spp.) and other planispiral forms. *Triasina* also probably comes from the same branch, because the deuteroloculus segmentation is given by pillars and not by true septa (Loeblich & Tappan, 1988). For *Aulotortus sinuosus* it should, in theory, have forms with a coil that become gradually more oscilla-

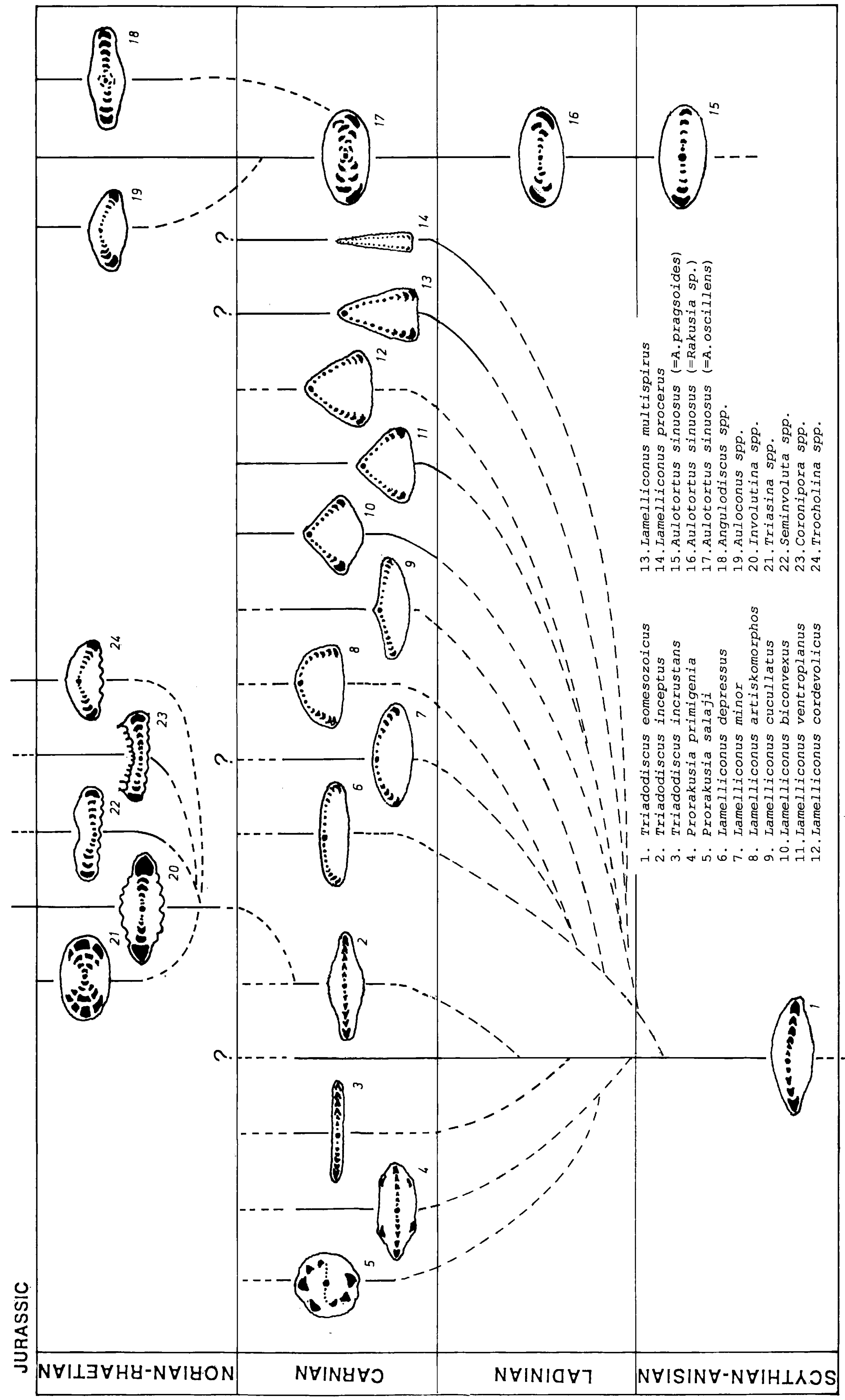


Fig. 7 - Stratigraphic distribution and suggested evolutionary trends of the involutinids, based on wall structure and on the mechanical derivation relationships of coiling. For the Norian-Rhetian, only the genera are indicated.

tory with time , but we were not able to verify this hypothesis here. *Aulotortus*' phyletic line is slower than that of *Triadodiscus* and, only during the Norian, gives origin to trochoidal forms of the genus *Auloconus*, as Piller's (1978, Fig. 9) structural scheme shows. We think that it also gives rise to *Angulodiscus*, because forms with an initial streptospiral stage can derive only from forms with a completely oscillating deuteroloculus (see scheme Fig. 6), realized in the Carnian only in *Aulotortus sinuosus* phenotypes.

SYSTEMATIC DESCRIPTION

Order FORAMINIFERIDA D'Orbigny, 1826
Suborder INVOLUTININA Hohenegger & Piller, 1977
Family INVOLUTINIDAE Bütschli, 1880

Genus *Aulotortus* Weynschenk,1956

1956 *Aulotortus* Weynschenk, p. 26
1988 *Aulotortus* Weynschenk - Loeblich & Tappan p. 296; pl. 310, Fig. 6-10 (cum syn.).

Type species - *Aulotortus sinuosus* Weynschenk, 1956

Description - Lenticular aragonitic test, perforated. Globular proloculus followed by second tubular chamber, enrolled, undivided. The enrolling is commonly oscillating. It forms approximately one half turn at a time, that is made of two second order lamellae (L2), "V" shaped and superimposed which converge on the umbilicus. These L2 are made of very regular first order lamellae (L1). The aperture has a terminal position.

Remarks - Until the sixties the genus *Aulotortus* included all the Carnian involutinid forms. It replaced the name *Trocholina*, used in the fifties. *Trocholina* was after-wards referred only to the trocoid forms of the Norian-Rhaetian or later. The majority of authors consider the genus *Rakusia* (emend. Salaj) as synonymous with *Aulotortus* and sometimes also with *Angulodiscus*. In particular, Zaninetti considers *Rakusia* synonymous with *Aulotortus* on the basis of observations of Salaj's illustration. Actually, plates 103-104 and others in Salaj *et al.* (1983) seem to confirm Zaninetti's interpretation (1976) that it is due to thin sections of specimens of *Aulotortus sinuosus*, that have been sectioned in planes that do not completely coincide with the axial plane.

The microarchitecture (Pl. II; Text-Fig. 5B) of the type-species of this genus has been described and well illustrated by Piller (1978). This species is more similar to that of *Triadodiscus eomesozoicus* than Piller thought, but it differs in the following peculiarities:

1) a different degree of enfolding the first L2 lamella; 2) discontinuity and joining of the L2 lamellae in the umbilical area; 3) regularity and continuity of L1 lamellae. The tube (Dh) that directly surrounds the deuteroloculus described by Piller, does not appear to be present.

Stratigraphic range - Anisian- middle Jurassic.

Aulotortus sinuosus Weynschenk, 1956
Pl. I, Fig. 1-7; Pl. 2; Text-Fig. 8

1956 *Aulotortus sinuosus* Weynschenk,p. 27.
1978 *Aulotortus sinuosus* Weynschenk - Piller, p. 45 (*cum syn.*).
1990 *Aulotortus sinuosus* Weynschenk - De Castro, p. 195, pl. 1, 2; pl. 3 figs 1-2,7-13; pl. 4, figs 4-10.

EXPLANATION OF PLATE V

Triadodiscus incrustans n. sp.

Fig. 1 - Detail of a sponge bearing some encrusting specimens; Optical microscope micrograph; x 15.
Fig. 5 - Fractured specimen; on the left side is visible the deuteroconch fractured along the equatorial plane. SEM picture; x 40.

Lamelliconus depressus n. sp.

Fig. 2 - Exterior, edge view showing, on the right, the deuteroloculus section. SEM picture; x 52.
Fig. 3 - Holotype. Polished axial section. Optical microscope micrograph; x 100.

Lamelliconus minor (Oberhauser, 1957)

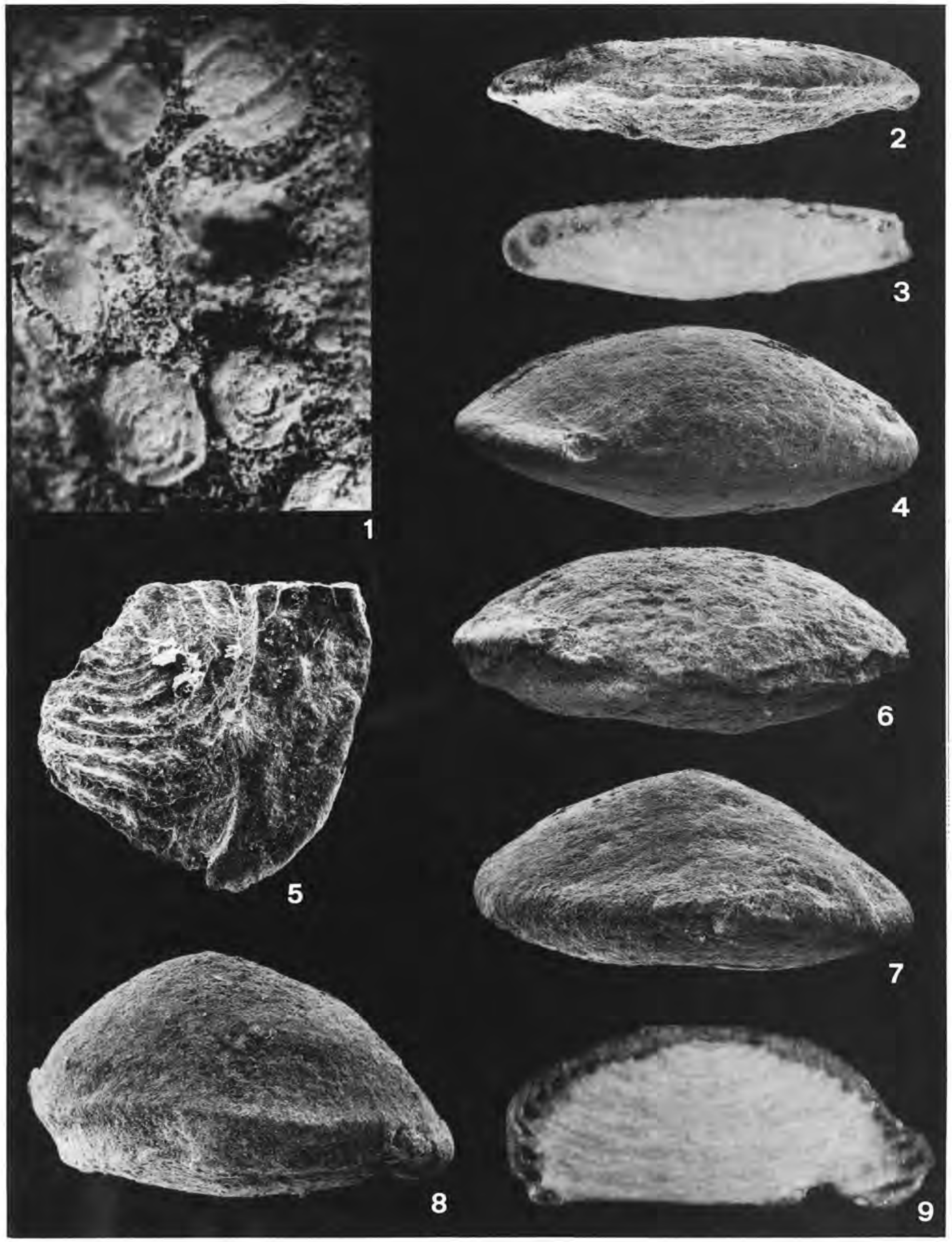
Fig. 4 - Exterior, edge view showing aperture on the left side; SEM picture; x 50.
Fig. 6 - Exterior, edge view. SEM picture; x 50.

Lamelliconus ventroplanus (Oberhauser, 1957)

Fig. 7 - Exterior, edge view of specimen with very small "H". SEM picture; x 52.

Lamelliconus artiskomorphos n. sp.

Fig. 8 - Exterior, edge view. SEM picture; x 57.
Fig. 9 - Holotype. Polished axial section. Optical microscope micrograph; x 77.



Material - 10 specimens from Alpe di Specie, 65 from Campo, 60 from Misurina, and 25 from Falzarego Pass.

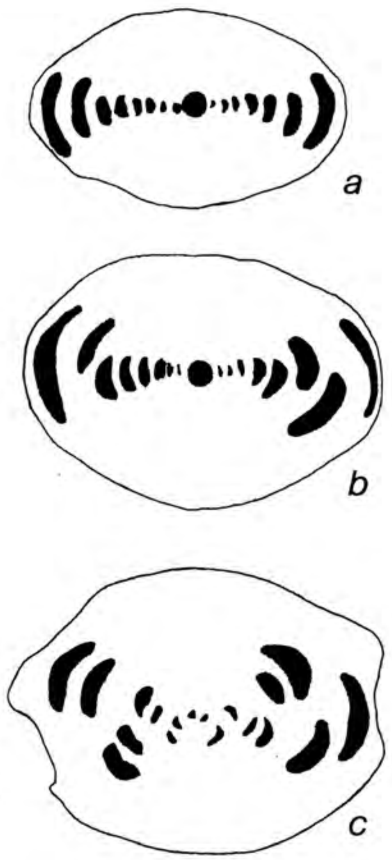


Fig. 8 - Initial (a), intermediate (b), and final (c) oscillation step in the deuteroloculus coiling whole range of *Aulotortus sinuosus*, as visible in axial section.

Description - Aragonitic test, lenticular, perforated. Globular proloculus followed by a second tubular chamber, enrolled, undivided. Enrolling varies from planispiral to very oscillating. Aperture in terminal position. Diameter: 1-1.5mm; thickness: 0.3-0.7 mm.

Remarks - Oberhauser (1964) destinguished two different forms in the material from Alpe di Specie: a) basically planispiral forms, that he called *Permodiscus pragsoides*; b) forms with oscillating deuteroloculus coiling , classified as *Permodiscus pragsoides* var. *oscillens*. The latter form has been adopted by almost all authors, however on a subspecies level. An exception is represented by Salaj *et al.* (1983) which distinguished *Permodiscus pragsoides* Oberhauser, *Aulotortus sinuosus* Weynschenk and raised to the species rank the Oberhauser's var.*oscillens*. On the other hand, Piller (1978) and De Castro (1990) think that the planispiral and oscillating forms (Fig. 8) belong to a single species. We believe that Piller's position is currently more acceptable for the following reasons: a) we have never found completely planispiral forms; b) planispiral and oscillating forms occur in the same outcrop; c) between the planispiral and completely oscillating forms are some intermediate forms in which two distinct form groups cannot be recognized. We belive that the degree of oscillation in the deuteroloculus coiling of this species is a phenotypic character because it can exist in the same structure of reef with different substratum and energy.

Stratigraphic range - Anisian - Rhaetian.

Genus *Lamelliconus* Piller, 1978

1978 *Lamelliconus* n. gen., Piller, p. 71 (cum syn.).

EXPLANATION OF PLATE VI

Lamelliconus biconvexus (Oberhauser, 1964)

Fig. 1 - 1a.Polished axial section. x 40; 1b. Enlarged detail (x 300) of Fig. 1a, showing the preserved umbilical tissue and the recrystallized lateral wall of the conic test. SEM picture.
Fig. 6 - Exterior, edge view. SEM picture; x 54.
Fig. 8 - Polished axial section. SEM picture; x 53.

Lamelliconus ventroplanus (Oberhauser, 1957)

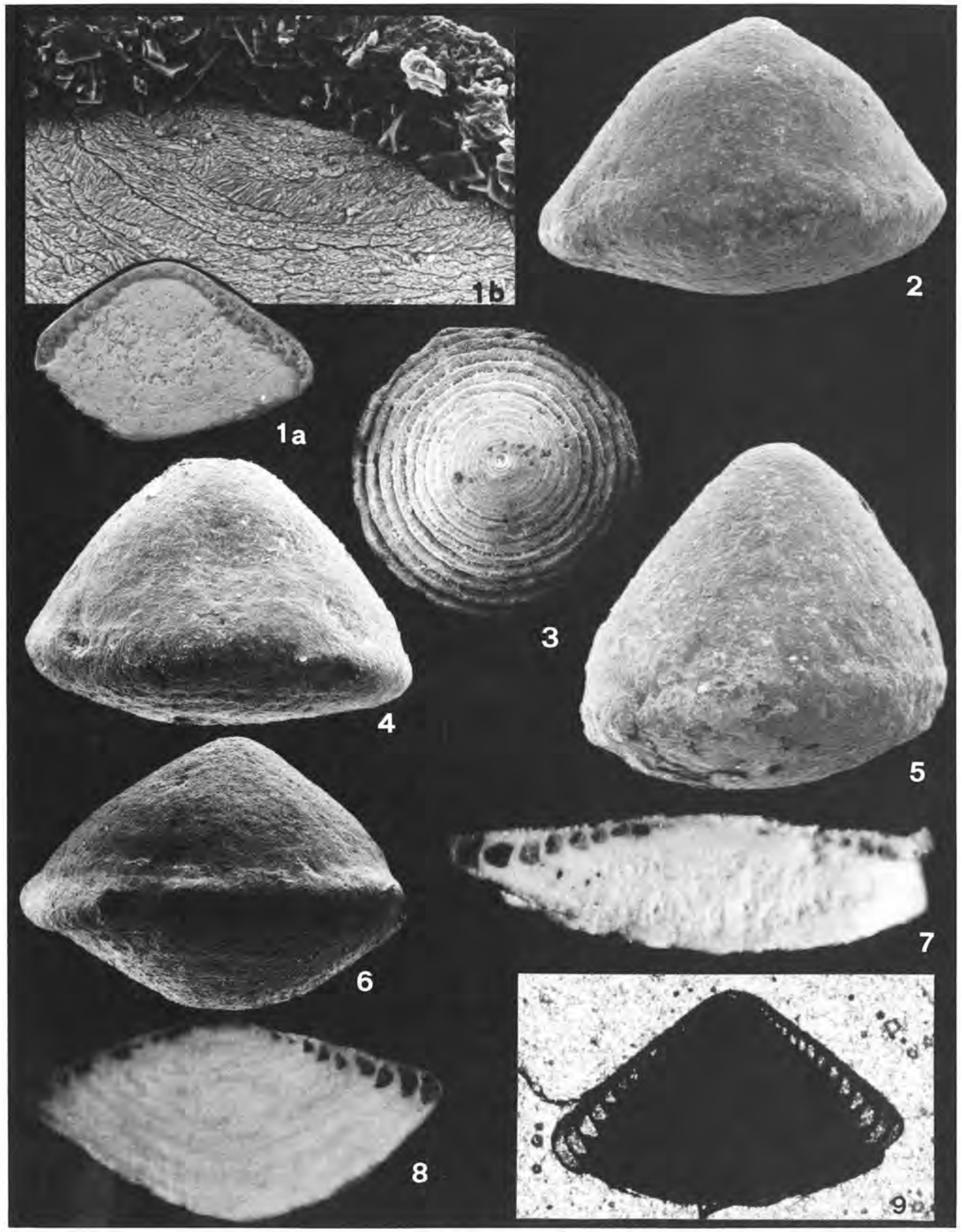
Fig. 2 - Exterior, edge view. SEM picture; x 55.
Fig. 3 - Apical view of a specimen without the dorsal wall of the conic test. SEM picture; x 30.
Fig. 4 - Exterior, edge view. SEM picture; x 54.
Fig. 9 - Axial thin section. Optical microscope micrograph; x 35.

Lamelliconus cordevolicus (Oberhauser, 1964)

Fig. 5 - Exterior, edge view. SEM picture; x 50.

Lamelliconus cucullatus n.sp.

Fig. 7 - Holotype. Polished axial section. Optical microscope micrograph; x 90.



1988 *Lamelliconus* Piller- Loeblich & Tappan, p. 295; pl. 309, Figs 1-4.

Type species - *Trocholina (T.) biconvexa* Oberhauser, 1957.

Description - Aragonitic, perforated, involute test. The dorsal profile is conic or pagoda-shaped, sometimes dome-shaped or even flat. The umbilical profile is flat or convex. The aperture is situated on the basal circumference. The spheric proloculus is located at the top of the dorsal side. The deuteroloculus is tubular, undivided, and trochoidally enrolled. The lumen of the chamber is very small and the coil near the dorsal surface can be observed. Therefore the test layers form a thick "umbilical mass". The wall is formed of two layers (L2 laminae). The first constitutes a little more than a half tube around the deuteroloculus and has on top a second continuous layer on the umbilical area and a tapered layer on the lateral-dorsal area (Pl. VII, Fig. 2). The second order laminae are made up of first order L1 lamellae.
This genus, that includes Carnian forms with a trochoidal enrolling, is also represented in the studied localities by many species. Essentially, the following characters have been used here to define the species: 1) dorsal profile of the forms in axial section, which depend on the rotation modality; 2) height of the coil, which depend on the translation of the turns; 3) umbilical profile of the forms in axial sections, which depend on the test structure.
The form is described qualitatively by parameters indicated in figure 9. On the basis of the considered parameters, we have identified 7 species belonging to this genus, as is schematically shown in the same figure.

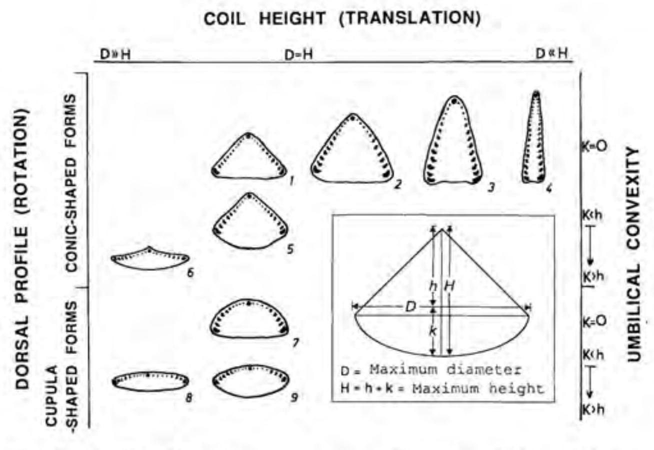


Fig. 9 - Realized form spectrum according to variation of three geometrics parameters (dorsal profile, coil height, umbilical convexity) of the *Lamelliconus* test. 1. *L. ventroplanus;* 2. *L. cordevolicus;* 3. *L. multispirus;* 4. *L. procerus;* 5. *L.biconvexus;* 6. *L. cucullatus;* 7. *L. artiskomorphos;* 8. *L. depressus;* 9. *L. minor.* The 3 and 4 forms are not met in the outcrops studied. They are known only from the underlying facies (S.Cassiano Fm. *sensu stricto*).

Stratigraphic range - Ladinian - Carnian.

Lamelliconus artiskomorphos n. sp.
Pl. VII, Figs 8,9

Origin of the specific name - From the greek *artiskos* = small loaf and *morphos* = shape.

Holotype - The polished axial section of the specimen illustrated in Pl. V, Fig. 9. (MPUM Cat. n. 24301).

Type locality - Campo.

Type level - Upper Julian, Austriacum Zone.

Material - 35 specimens from Campo, 10 from Alpe di Specie, 3 from Misurina.

Description - The profile is dome-shaped with a flat umbilical surface. The deuteroloculus forms about ten turns. The dimensions of the holotype are D = 2 mm, H = 1 mm.

Stratigraphic range - It is cited here for the first time in the Upper Carnian (Julian) of the Dolomites.

Lamelliconus biconvexus (Oberhauser, 1957)
Pl. VI, figs 1,6,8

1957 *Trocholina (Trocholina) biconvexa* Oberhauser, p. 263, figs 26-37.
1976 *Trocholina biconvexa* Oberhauser - Zaninetti, pag.174, pl. 15, figs 4-6 (*cum syn.*).
1983 *Lamelliconus biconvexus biconvexus* (Oberhauser) Salaj *et al.*, p. 147, pl. 128, Fig. 1.

Material - 100 specimens from Alpe di Specie; 25 from Campo; 3 specimens from Misurina.

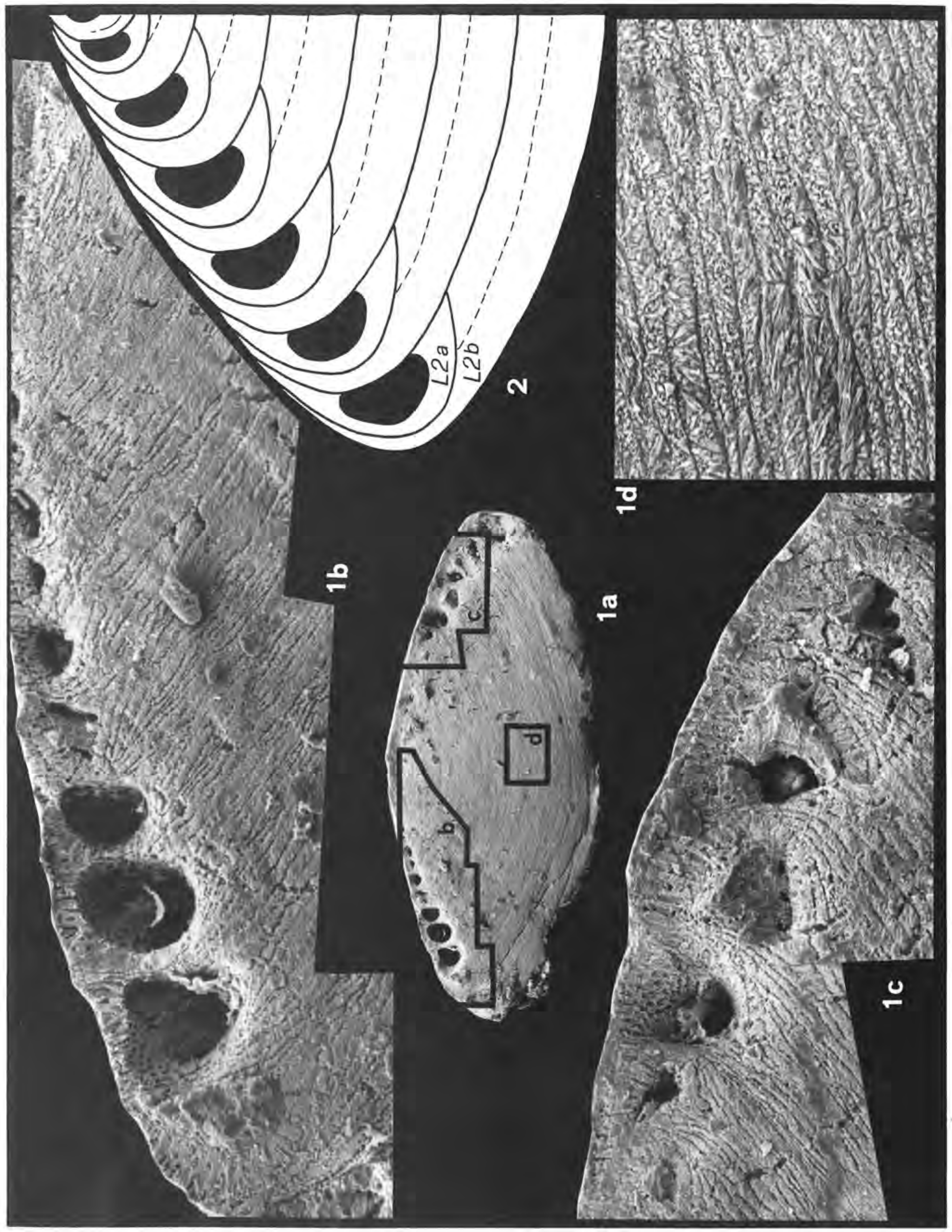
Description - Conic shape with a strongly convex umbilical surface. D = 1-1.5mm; H = 0.3-0.8 mm.

Stratigraphic and geographic range - Upper Ladinian?-Car-

EXPLANATION OF PLATE VII

Lamelliconus minor (Oberhauser, 1957)

Fig. 1 - 1a. Axial section showing the outlines of Fig. 1b,1c,1d details. SEM picture; x 60. 1b. Axial section detail showing the wall laminae close to deuteroconch lumen. SEM picture; x 270. 1c. Axial section detail showing the wall laminae close to the deuteroconch lumen. SEM picture; x 270. 1d. Detail of the umbilical structure. Axial section. SEM picture; x 650.
Fig. 2 - Diagram showing in the axial plane the 2nd order wall laminae arranged. It is difficult to recognize the limit (dashed line) between the L2b lamina of an half turn and that of the next one included between subsequent discontinuity.



nian of a zone that is comprehensive of central and southern Europe, Turkey, to south-eastern Iran.

Lamelliconus cordevolicus (Oberhauser, 1964)
Pl. VI, Fig. 5

1964 *Trocholina cordevolica* Oberhauser, p. 206, pl. 1.
1983 *Lamelliconus cordevolicus* (Oberhauser)- Salaj *et al.*, p. 147, pl. 124, Fig. 8; pl. 128, Fig. 2.

Material - 5 specimens from Alpe di Specie, 5 from Campo and 2 from Misurina.

Description - Conic shape with a flat umbilical surface. D = 1.3 mm; H = 1.2 mm.

Stratigraphic range - Carnian of Italy and Slovakia.

Lamelliconus cucullatus n. sp.
Pl. VI, Fig. 7

Origin of the specific name - From the latin *cucullatus* = hooded.

Holotype - Polished axial section of the specimen illustrated in Pl. VI, Fig. 7 (MPUM Cat.n. 24302).

Type locality - Misurina.

Type level - Upper Julian, Austriacum Zone.

Material - 3 specimens from Misurina.

Description - Very flat. Pagoda-shaped with a convex umbilical surface. The dimensions of the holotype are D =1.2mm; H =0.3 mm.

Stratigraphic range - It is cited here for the first time in the Upper Carnian (Julian) of the Dolomites.

Lamelliconus depressus n. sp.
Pl. V, Figs 2, 3

Origin of the specific name - *Depressus* = flat, for the very flat outer shape of the test.

Holotype - Polished axial section of the specimen illustrated in Pl. V, Fig. 3 (MPUM Cat. n. 24303).

Type locality - Alpe di Specie.

Type level - Upper Julian, Austriacum Zone.

Material - 250 specimens from Alpe di Specie, 8 from Campo.

Description - Very flat biconvex lens shaped. The dimensions of the holotype are D = 1.5 mm; H = 0.25 mm.

Remarks - This form is not easy to distinguish from other flat coiled species.

Stratigraphic range - It is cited here for the first time in the Upper Carnian (Julian) of the Dolomites.

Lamelliconus minor (Oberhauser 1957)
Pl. V, Figs 4,6; Pl. VII

1957 *Trocholina (T.) biconvexa minor* Oberhauser, p. 265, pl. 21, figs 34-37, text-fig. 1.

Material - 150 specimens from Alpe di specie; 10 specimens from Campo, 6 from Misurina.

Description - The test has a biconvex shape that is slightly asymmetrical on the equatorial plane. The dimensions of the holotype are D = 1.75 mm. H = 0.75 mm.

Remarks - The variety of *T.biconvexa minor* Oberhauser is revised to species.

Stratigraphic and geographic range - Ladinian?, Carnian (Julian) of Dolomites, Austria, Carpathians. Dubiously in late Norian of China (He Yan & Yue Zhi-Lan, 1987).

Lamelliconus ventroplanus (Oberhauser,1957)
Pl. V, Fig. 7; Pl. VI, Figs 2-4, 9

1957 *Trocholina (Trocholina) ventroplana* Oberhauser, p. 262, pl. 20, figs 15-23.
1976 *Trocholina ventroplana* Oberhauser-Zaninetti, p. 181, pl. 10, figs 19, 20 (*cum syn.*).

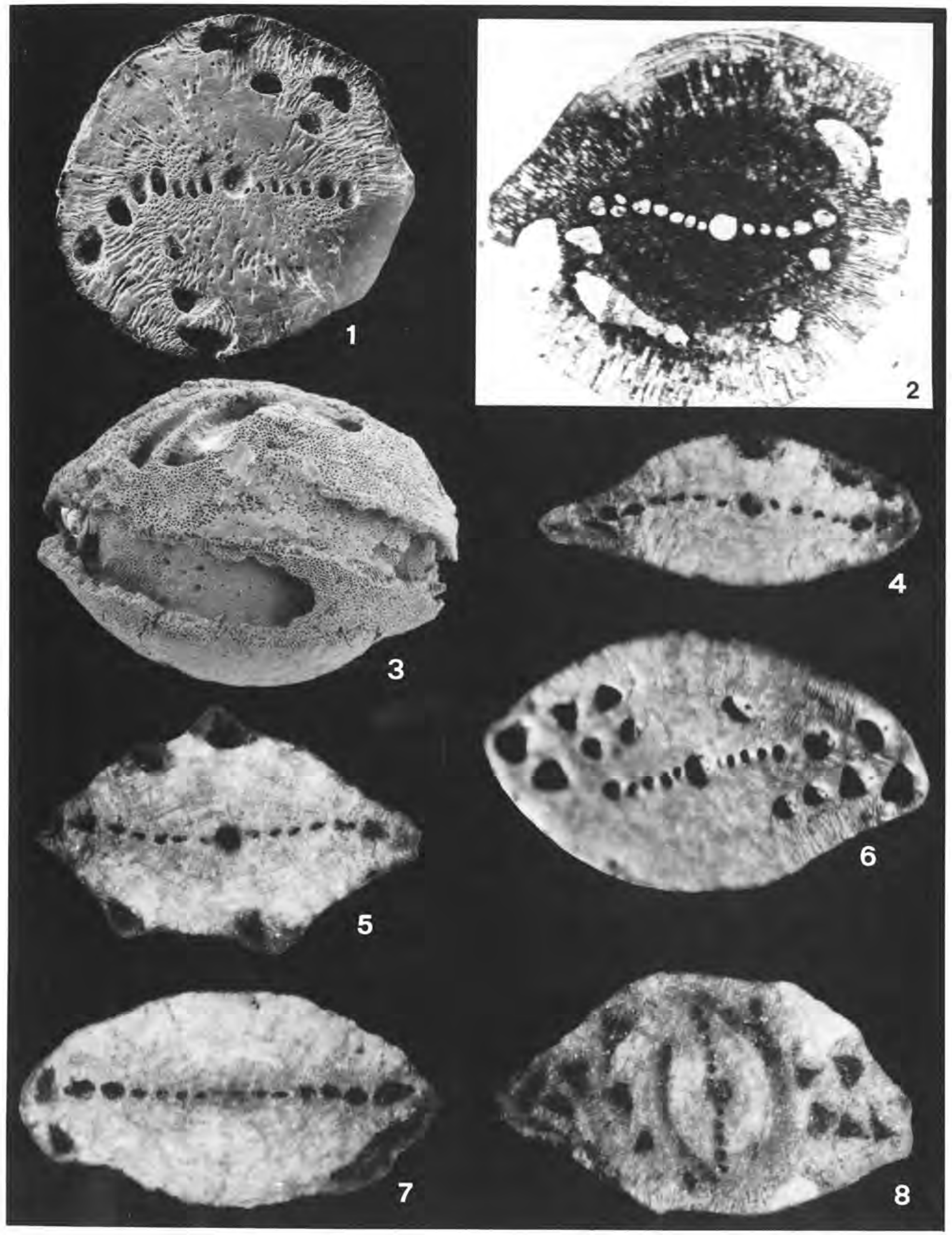
EXPLANATION OF PLATE VIII

Prorakusia salaji n. sp.

Fig. 1 - Holotype. Polished axial section showing the initial part of the deuteroconch streptospiral stage, casually coinciding with the section plane. SEM picture; x 40.
Fig. 2 - Axial thin section. Optical microscope micrograph; x 70.
Fig. 3 - Superficially fractured specimen showing streptospiral stage. SEM picture; x 45.
Fig. 6 - Polished axial section. SEM picture; x 60.
Fig. 8 - Polished axial section. Optical microscope picture; x 40.

Prorakusia primigenia n. sp.

Fig. 4 - Polished axial section. Optical microscope picture; x 47.
Fig. 5 - Polished axial section. Optical microscope picture; x 55.
Fig. 7 - Polished axial section. Optical microscope picture; x 45.



1983 *Lamelliconus ventroplanus* (Oberhauser) - Salaj *et al.*, p. 148, pl. 96, Fig. 2.

Material - 70 specimens from Campo; 10 specimens from Alpe di Specie.

Description - Conic shape, with a flat umbilical surface. D = 1 mm.; H = 0.75 mm.

Remarks - Zaninetti (1976) also points out that this species is similar to *L.biconvexus,* and it can be distinguished from the latter by the flat instead of convex umbilical surface.

Stratigraphic and geographic range - Ladinian?, Carnian of Italy, Austria, Slovakia, Turkey and probably China.

Genus *Prorakusia* n. gen.

Origin of the generic name - The name consists of *Pro* = "in place of" and *Rakusia,* that is the name of a genus erected by Salaj, which we are regarding has junior synonym of *Aulototus.*

Type species - *Prorakusia salaji* n. sp.

Diagnosis - Perforated aragonitic test, almost completely involute, ranging from flat to globular. Outer surface smooth or with bosses, or with keels. Spherical proloculus and deuteroloculus with two coiling stages. Planispiral juvenile stage or slightly helicoidal with circular section of small diameter. Streptospiral adult stage. In this stage the tube has a subtriangular section with a lumen much larger than that of the first stage. In the last turns, the form often tends to become evolved and breakage of the protruding part of the tube construct the keels, that can be seen on the outer surface of many specimens. The type of test microstructure is very close to that of *Triadodiscus.*

Remarks - We agree with Zaninetti & Rettori (pers. comm.) who consider the illustrations of *Rakusia oberhauseri* in Salaj *et al.* (1983, pl. CIII, Fig. 4; pl. CIV, Fig. 4) as lateral, not axial, sections of a specimen of *Aulototus sinuosus.* This makes inconsistent the type species of the genus (*R. oberhauseri*) and leads us to consider *Rakusia* as synonymous with *Aulototus.* The investigations on rock thin-sections can have caused this problem. In fact, in unoriented rock cuts, oblique sections are seldom in an optimal axial position. Moreover, normally test costruction is not completely regular. Thus, in border-line cases, the section pictures are different and difficult to explain. In this case, Salaj *et al.* (1983) recognized a different enrolling modality from a specimen section with a turn, in the oscillating stage, casually normal to the juvenile enrolling. The diagnosis of *Rakusia* Salaj describes well the architectural features of a group of our specimens that do not belong to any of the involutinid genera described to date. We think suitable to institute a new genus with a diagnosis and a name similar to that of *Rakusia* Salaj.

Moreover, we point out that Salaj *et al.* (1983) described the specimens - which we consider to belong to the genus *Prorakusia* - in the genus *Angulodiscus* Kristan. This seems strange, because *Angulodiscus* Kristan emended by Salaj is described as having a streptospiral juvenile coiling followed by a planispiral stage. That is exactly the opposite of the composite enrolling that we can observe in the Salaj's specimens. These have been called by the same author *Angulodiscus gaschei praegaschei* Zaninetti. We instead erect for the samples studied by Salaj and for ours, a new species dedicate to Dr. J. Salaj and we designate it as type species of the genus. The above discussion is schematically summarized in figure 10.

For *Aulototus*, the difference exists in the enrolling modalities in addition to the microstructural features. The conformation of the test layers in *Prorakusia* (Pl. IX, Fig. 3) is more similar to that of *Triadodiscus* (Pl. IV, Fig. 2) rather than that of *Aulototus* (Pl. II, Fig. 1).

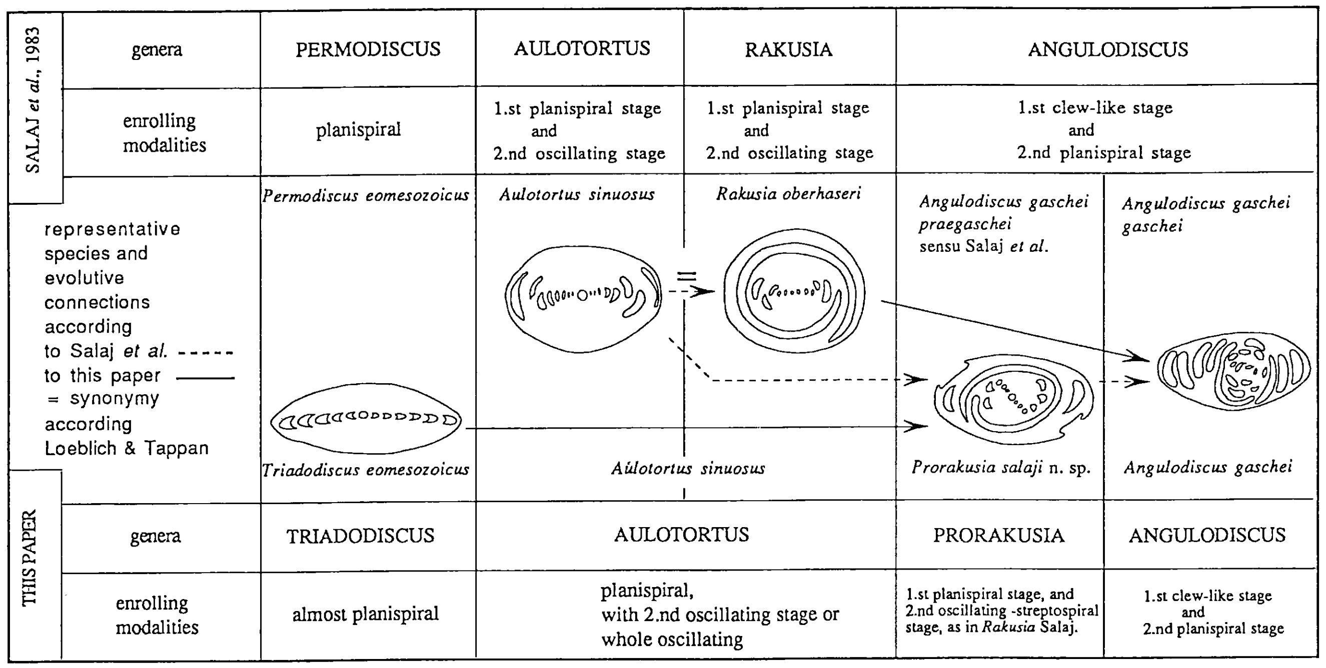


Fig. 10 - Comparison between two different evolutionary models: Salaj *et al.,* 1983 - this paper.

Different forms of *Prorakusia* have been recognized in the studied localities. The outer shape of the *Prorakusia* specimen shows several specific characters; but unfortunately they are not visible in the axial sections, and therefore, they would not be detected in unoriented thin sections. These characters include the presence or absence of the keeled surfaces or zones with bosses. Therefore, we are able to distinguish, among the studied material, only two characteristic species: *Prorakusia salaji* n. sp. and *P. primigenia* n. sp. The distinction between these two species is based upon the characters in the axial section. *P. salaji* shows a short juvenile planispiral stage (5 turns) and a well developed streptospiral stage (about 5-6 turns). Whereas, *P. primigenia* has a well developed planispiral stage and a very short streptospiral stage (1 or 2 turns or slightly more).

Stratigraphic range - It is quoted here for the first time from the upper Carnian (Julian) of the Dolomites. However, illustration by various authors depicts a wider stratigraphic and paleobiogeographic range (Gazdzicki & Stanley, 1983; Salaj *et al.,* 1983; He Yan & Zhi-lan, 1987).

Prorakusia primigenia n. sp.
Pl. VIII, Figs 4, 5, 7

Origin of the specific name - From the latin *primigenia* = "first in temporal order", because we believe it is the first form with *Prorakusia* characteristics that descended directly from *Triadodiscus.*

Holotype - Polished axial section of the specimen illustrated in Pl. VIII, Fig. 5.(MPUM Cat. n. 24305).

Type locality - Campo (Cortina d'Ampezzo).

Type level - Upper Julian, Austriacum Zone.

Material - 10 specimens from Campo.

Description - Perforated, aragonitic test. Flat shape. Outer surface with carinae. Spheric proloculus and undivided tubular deuteroloculus, enrolled in two ways. At first planispiral for ten turns, then streptospiral for approximately 1-2 turns. The deuteroloculus sections in the planispiral part are similar to those of *Triadodiscus.*

Remarks - Because of the similarity in axial section (Pl. VIII, Figs 4, 5, 7) with *Triadodiscus eomesozoicus* (Pl. III, Fig. 4), it could be confused with the latter if the peripheral streptospiral turns had been destroyed. For the similarities cited above, that are also apparent at a microstructural level, we think that it is a species directly linked phylogenetically to *Triadodiscus eomesozoicus* on one side and with *Prorakusia salaji* on the other.

Stratigraphic range - It is cited here for the first time from the upper Carnian.

Prorakusia salaji n. sp.
Pl. VIII, Figs 1-3, 6, 8; Pl. IX

1983 *Angulodiscus gaschei praegaschei* Koehn-Zaninetti - Salaj *et al.,* pl. 117 and pl. 119, figs 1, 3, 4.

? 1983 *Aulototus praegaschei* (Koehn-Zaninetti) - Gazdzicki & Stanley, p. 86, Fig. 5.

? 1987 *Aulototus* cf.*bulbus* Hc - He Yan & Yue Zhi-lan, p. 217, pl. 7, Fig. 9.

Origin of the specific name - It is dedicated to Dr. Jozef Salaj who described this species (under the name *Angulodiscus gaschei praegaschei* Koehn-Zaninetti) and the genus *Rakusia* replaced here by *Prorakusia.*

Holotype - Polished axial section of the specimen illustrated in Pl. VII, Fig. 1, Pl. IX, Figs 1, 2 (MPUM Cat. n. 24306).

Type locality - Alpe di Specie.

Type level - Upper Julian, Austriacum Zone.

Material - 250 specimens from Misurina, 115 from Campo, 40 from Alpe di Specie, 3 from Falzarego Pass.

Description - Perforated aragonitic test. Shape biconvex to subspheric. In the globular shape, the outer surface shows keels enrolled as a ball of wool with bosses. Sphaeric proloculus and undivided tubular deuteroloculus, enrolled in two different ways (Fig. 11). At first planispiral or nearly planispiral for 4-6 turns, then streptospiral for as many turns. The deuteroloculus section strongly increases passing from the enrolling stage to the next one.

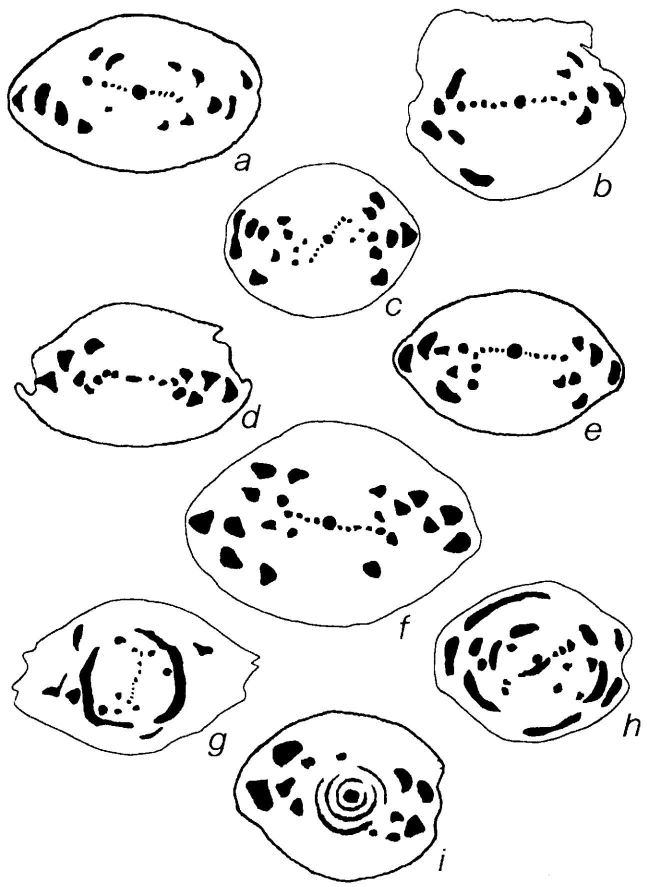


Fig. 11 - *Prorakusia salaji* n. sp. axial sections and one (i) equatorial.

Stratigraphic range - It is cited here for the first time in the upper Carnian (Julian) of the Dolomites. But the illustrations of various authors indicate a wider stratigraphic and paleobiogeographic range (Gazdzicki & Stanley, 1983; Salaj *et al.*, 1983; He Yan & Zhi-lan, 1987).

Genus *Triadodiscus* Piller, 1983
(nom. subst. pro *Mesodiscus* Piller, 1978 (non *Mesodiscus* Minot, 1877))

1957 *Trocholina (Paratrocholina)* Oberhauser, p. 259;
1978 *Mesodiscus* Piller, p. 41;
1988 *Triadodiscus* Piller - Loeblich & Tappan p. 295.

Type species - *Trocholina (Paratrocholina) eomesozoica* Oberhauser, 1957.

Description - Involute biconvex lens-shaped. Spheric proloculus, planispiral deuteroloculus, sometimes slightly oscillating, undivided. Wall made of two layers; the first forms a semitube around the deuteroloculus and is topped by a second layer that covers the entire test and makes it involute. Every one of these lamellae, of second order, is composed of many first order lamellae that, in the umbilical areas, become irregular crystals plates. The lamellae are abundantly perforated in correspondence to the chamber sections, in the peripherical zone of the test, whereas they are nearly unperforated in the umbilical areas.

Stratigraphic range - Scythian - Carnian, Rhaetian?

Triadodiscus eomesozoicus (Oberhauser,1957)
Pl. III; Figs 1, 2, 4; Pl. IV

1957 *Trocholina (Paratrocholina) eomesozoica* Oberhauser, p. 266 pl. 21, figs 28-41;
1976 *Involutina eomesozoica* (Oberhauser) - Zaninetti p. 158, pl. 9, figs 24-32; pl. 10, Fig. 16; pl. 15, Fig. 22;
1978 *Mesodiscus eomesozoicus* (Oberhauser) - Piller, p. 9; pl. 1, figs 1-8 (*cum syn.*).

Material - 150 specimens from Misurina; 22 from Alpe di Specie.

Description - Involute discoidal form, Diameter = 2.5-3 mm.; thickness = 0.8-1 mm. The test periphery is weakly carina shaped or rounded. Planispiral enrolling or weakly oscillating. An undivided deuteroloculus follows a spheric proloculus.

Stratigraphic range - Scythian - Carnian.

Triadodiscus incrustans n. sp.
Pl. V; Figs 1, 5

Origin of the specific name - From the latin "*incrustans*" = encrustant.

Holotype - Specimen Cat. n. 24307 stored in the Paleontological Museum, Modena University (MPUM).

Type locality - Campo (Cortina d'Ampezzo).

Type level - Upper Julian, Austriacum Zone.

Material - 40 specimens from Campo, 5 from Alpe di Specie.

Description - Aragonitic test, perforated. Very flat discoidal. The test is usually undulated as a consequence of its flatness. Aperture in marginal position. In equatorial section it shows, in the center, an embrional chamber followed by a coiled deuteroloculus forming approximately ten turns. Diameter = 1.5 mm.; thickness = 0.2 mm.

Remarks - Zaninetti (1976) considered *Involutina tenuis* the flattest form within the Involutinae, now this species appears to be the flattest. This form is considered to be encrusted because specimens of porifera have been observed in the same outcrops bearing numerous specimens attributed to this species on the basis of thickness and of natural equatorial sections (Pl.V, Fig. 1).

Stratigraphic range - It is cited here for the first time from the Upper Carnian (Julian, Austriacum Zone).

Triadodiscus inceptus n. sp.
Pl. III; Figs 3, 5-8

Origin of the specific name - From the latin "*inceptus*"=initial, because we think the form gives origin to species of the genus *Involutina* Jones.

Holotype - The specimen illustrated in Pl. III, Fig. 6. (MPUM Cat. n. 24308).

Type locality - Campo.

Type level - Upper Julian, Austriacum Zone.

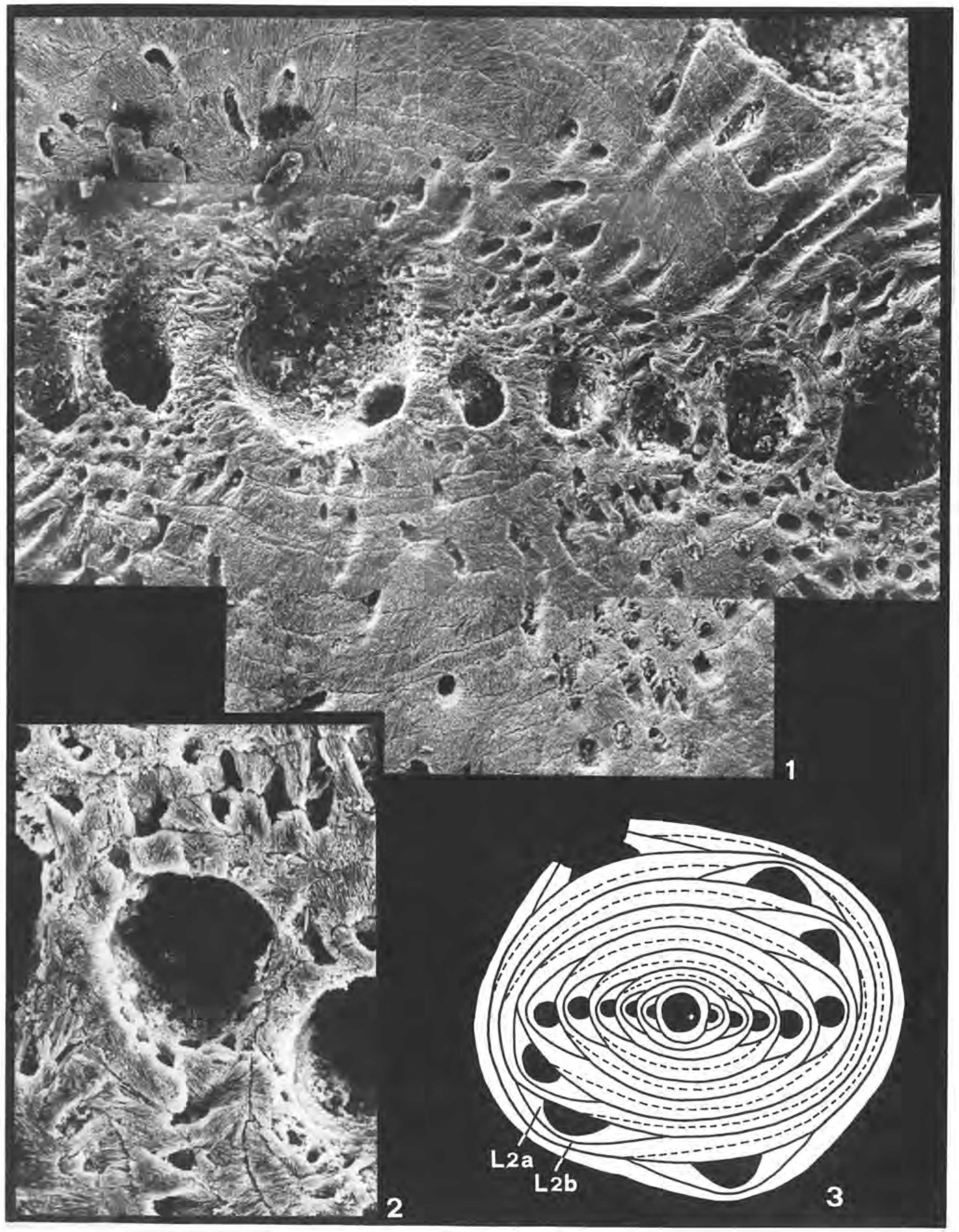
Description - Aragonitic perforated test. Flat form with a very thin periphery and a prominent umbo irregularly

EXPLANATION OF PLATE IX

Prorakusia salaji n. sp.

Fig. 1 - Fig. 1 of Pl. VIII detail at strong magnification (x 260) showing the wall structure of the planispiral juvenile stage. SEM picture.
Fig. 2 - Fig. 1 of Pl. VIII detail strongly enlarged (x 330) showing the wall structure around of a lumen of deuteroloculus section in streptospiral adult stage. SEM picture.
Fig. 3 - Diagram showing in the axial plane the 2nd order wall laminae arrangement. It is difficult to recognize the limit (dashed line) between the L2b lamina of an half turn and that of the next one included between subsequent discontinuity.

PLATE IX



covered by white bosses. Spherical proloculus and undivided tubular deuteroloculus, nearly planispiral. The deuteroloculus sections look like those of *Triadodiscus eomesozoicus*. We find the A form, very small, with a large proloculus and with deuteroloculus forming 3-4 whorls.

Remarks - Externally this form looks like *Involutina* sp. However, it does not have pillars in the umbilical zone but only bosses.

Stratigraphic range - It is cited here for the first time from the Upper Carnian (Julian, Austriacum Zone).

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