Newsl. Stratigr.	42 (3)	223–247	6 Fig.	Berlin · Stuttgart, 30. 4. 2008

Interesting new ammonites from the Upper Jurassic of Argentina and their correlation potential: new possibilities for global correlations at the base of the Upper Tithonian by ammonites, calpionellids and other fossil groups

by Arnold Zeiss and Héctor A. Leanza*

with 7 figures

Abstract. Two ammonites from the Vaca Muerta Formation cropping out at the southern slope of Cerro Lotena (Neuquén Basin, Argentina) are described for the first time: 1) *Simplisphinctes* (*Lotenia*) *neuquenensis*, n. subgen., n. sp., and 2) a completely preserved adult microconch of *Windhauseniceras internispinosum* (Krantz). The beds which contained the ammonites belong to the lowermost Upper Tithonian *Windhauseniceras internispinosum* Zone. These new findings, especially *Simplisphinctes* (*Lotenia*) *neuquenensis*, allow providing further arguments for the correlation between the *W. internispinosum* Zone of the Andean Jurassic Province and the *Simplisphinctes* [*abnormis*] Zone of the Mediterranean Jurassic Province. In this context it should be emphasized that at the base of the Upper Tithonian global biostratigraphical correlations are possible by various other guide fossil groups, such as calpionellids (chitinoidellids).

For example, in the western part of the Mediterranean area, the *Simplisphinctes* Zone can be correlated with the *Chitinoidella boneti* Subzone of the *Chitinoidella* Zone. This Subzone can be identified also in Cuba in the *S.* (*Paralytohoplites*) *caribbeanus* Zone allowing an improvement of age calibration of this zone. This *Simplisphinctes* Zone belongs to the lowermost Upper Tithonian and not to the upper Middle Tithonian as hitherto assumed. This is in accordance with a morphological analysis and comparison with *Simplisphinctes* s. str. and *S.* (*Paralytohoplites*).

Furthermore, our results allow a refinement of the chronostratigraphic position of the *Chitinoidella boneti*-Subzone in Europe and place the zone in the lowermost Upper Tithonian.

Another important fossil group for global correlations at the Middle/Upper Tithonian boundary are radiolarians; in Argentina, radiolarians indicating the youngest radiolarian association with *Vallupus hopsoni* and representing the Zone 4, upper Subzone 4 beta of Pessagno have been found in the *Windhauseniceras internispinosum* Zone.

Calcareous nannofossils and dinoflagellates can also deliver useful data. The differing stratigraphic calibration potentials of these fossil groups are discussed.

* Authors' addresses: Prof. Dr. A. Zeiss, Institute of Paleontology, University of Erlangen-Nürnberg, Loewenichstr. 28, 91054 Erlangen, Deutschland; now: Albert-Schweitzer-Str. 19, 91080 Uttenreuth, Deutschland, E-Mail: arnold.zeiss@t-online.de; Prof. Dr. H. A. Leanza, Servico Geológico Nacional and CONICET, Av. Julio A. Roca 651 – Piso 10, 1322 Buenos Aires, Argentina, E-Mail: hleanz@mecon.gov.ar

DOI: 10.1127/0078-0421/2008/0042-0223

0078-00421/08/0042-0223 $ 6.25

Zusammenfassung. Zwei Ammoniten aus der Vaca Muerta Formation vom südlichen Abhang des Cerro Lotena (Neuquén Becken, Argentinien) werden erstmals beschrieben: 1) *Simplisphinctes* (*Lotenia*) *neuquenensis*, n. subgen., n. sp. und 2) ein vollständig erhaltener adulter Mikroconch von *Windhauseniceras internispinosum* (Krantz). Die Fundschicht beider Arten liegt in der Zone des *Windhauseniceras internispinosum* des untersten Ober-Tithoniums. Die beiden neuen Funde, insbesondere *Simplisphinctes* (*Lotenia*) *neuquenensis*, liefern weitere Argumente für die Korrelation der Zone des *W. internispinosum* der andinen Jura-Provinz mit der *Simplisphinctes* [*abnormis*] Zone der mediterranen Jura-Provinz. In diesem Zusammenhang sei betont, dass an der Basis des Ober-Tithoniums globale Korrelationen mit verschiedenen Leitfossilgruppen möglich sind – neben Ammoniten – vor allem mit Calpionellen (Chitinoidellen).

Im Westteil des Mediterrangebietes konnte z. B. gezeigt werden, dass die *Simplisphinctes* Zone mit der *Chitinoidella boneti* Subzone der *Chitinoidella* Zone korreliert werden kann. Diese Subzone lässt sich in Kuba mit der *S.* (*Paralytohoplites*) *caribbeanus* Zone parallelisieren; damit ist eine bessere Alterseinstufung dieser Zone als bisher möglich: diese Zone gehört in das unterste Ober-Tithon und nicht in das oberste Mittel-Tithon. Dies Ergebnis lässt sich auch mittels eines morphologischen Vergleichs zwischen *Simplisphinctes* s. str. und *S.* (*Paralytohoplites*) nachvollziehen. Auch in Europa lässt sich somit die *Ch. boneti* Subzone der *Chitinoidella* Zone genauer als bisher stratigraphisch einstufen.

Eine andere wichtige Leitfossil-Guppe für Korrelationen an der Basis des Ober-Tithoniums stellen die Radiolarien dar; in Argentinien wurde in der Zone des *Windhauseniceras internispinosum* die jüngste Radiolarien-Assoziation mit *Vallupus hopsoni* gefunden, die in die Zone 4, obere Subzone 4 beta von Pessagno zu stellen ist.

Kalkiges Nannoplankton und Dinoflagellaten können ebenfalls wichtige Anhaltspunkte liefern. Das im Einzelnen unterschiedliche chronostratigraphische Potential dieser Gruppen wird diskutiert.

Resumen. Se describen por primera vez dos ammonites de la Formación Vaca Muerta aflorante en el faldeo sur del Cerro Lotena (Cuenca Neuquina, Argentina): 1) *Simplisphinctes* (*Lotenia*) *neuquenensis*, n. subgen., n. sp. y 2) una microconcha adulta completamente preservada de *Windhauseniceras internispinosum* (Krantz). Las capas que contienen los citados ammonites corresponden al más bajo Tithoniano Superior, Zona de *Windhauseniceras internispinosum*. Estos nuevos hallazgos, especialmente *Simplisphinctes* (*Lotenia*) *neuquenensis* permiten aportar nuevos argumentos para la correlación entra la Zona de *W. internispinosum* de la Provincia Andina Jurásica con la Zona de *Simplisphinctes* [*abnormis*] de la Provincia Mediterránea Jurásica. En este aspecto, debe enfatizarse que en la base del Tithoniano Superior son posibles correlaciones globales mediante diferentes grupos de fósiles guías – además de ammonites – especialmente calpionélidos (chitinoidélidos).

Además, en la parte occidental de la región Mediterránea, la Zona de *Simplisphinctes* puede ser correlacionada con la Subzona de *Chitinoidella boneti* de la Zona de *Chitinoidella*. Esta Subzona puede ser identificada también en Cuba en la Zona de *S.* (*Paralytohoplites*) *caribbeanus*, pudiendo así mejorarse la calibración de su edad. Esta zona, como aquí se demuestra, pertenece al más bajo Tithoniano Superior y no al más alto Tithoniano Medio. Esto concuerda con el análisis morfológico y comparación entre *Simplisphinctes* s. str. y *S.* (*Paralytohoplites*). También en Europa la posición cronoestratigráfica de la Subzona de *Boneti* puede ser más precisamente calibrada como del más bajo Tithoniano Superior.

Otros importantes grupos de fósiles para correlaciones globales en las cercanías del límite Tithoniano Medio/Superior son los radiolarios; en Argentina fue encontrada en la Zona de *Windhauseniceras internispinosum* la más joven Asociación de Radiolarios con *Vallupus hopsoni*, que se ubica en la Zona 4, alta Subzona 4 beta de Pessagno.

También el nannoplancton calcáreo y los dinoflagelados pueden proporcionar valiosos argumentos. El diferente potencial de calibración de estos grupos fósiles es discutido.

1 Introduction

During our research work on Upper Jurassic ammonites in western central Argentina carried out in 1989, we visited the 'Museo Prof. Dr. J. Olsacher' in Zapala (Neuquén province). In the collections exhibited there we noted two remarkable ammonites: one with single ribs, recalling the genus *Simplisphinctes* and the other, a coronate ammonite with lappets resembling *Windhauseniceras*.

Because of the known problems concerning global correlations in the Tithonian stage (cf. Zeiss 1979, 1983, 1986), these specimens seemed important, and we decided to come back on those after having finished our studies on the ammonites of the Middle/Upper Tithonian boundary beds from the lithographic limestones of the Zapala region. In the meantime, one of the authors had finished a monograph on an ammonite fauna of similar age of Central Europe (Zeiss 2001) and had engaged himself with the possibilities of multidisciplinary correlations at the base of the Upper Tithonian stage (Zeiss 2003); thus, the chances for a well-founded global correlation at that time were considerably extended. We present here correlation possibilities by ammonites, calpionellids (chitinoidellids), radiolarians, calcareous nannofossils and dinoflagellates. A short report with the first results of our investigations had been published by the authors some years ago (Zeiss & H. A. Leanza 1999).

2 Geographic and stratigraphic situation

The general stratigraphic position of the Vaca Muerta Formation in the Neuquén Basin is well shown by Legarreta & Uliana (1991, Fig. 1). The geographic and topographic situation of Cerro Lotena can be taken from Fig. 1.

Fig. 1. Topographic situation of the ammonite locality at the southern slope of Cerro Lotena hill, Neuquén Province, Argentina.

The specimens were collected by J. I. GARATE ZUBILLAGA, former Director of the above mentioned 'Museo', at the southern slope of the Cerro Lotena in beds of the Vaca Muerta Formation belonging to the *W. internispinosum* Zone (cf. H. A. LEANZA, 1980, Tab. 2). As shown later in this paper, this zone can now be considered to be of lowermost Upper Tithonian age. On the museum label it was not indicated from which bed in the section the two specimens were collected. Therefore, the facies in which the two specimens have been embedded was studied by one of us in detail (H. A. L.) who had undertaken much field

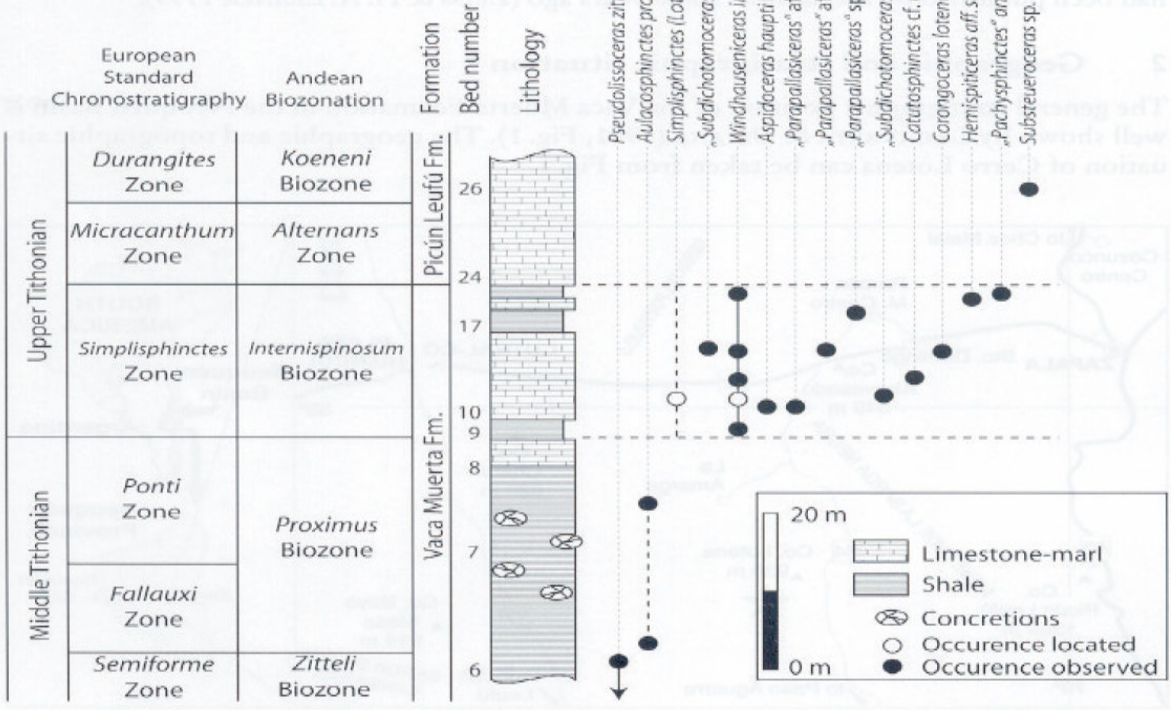

Fig. 2. Middle and Upper Tithonian stratigraphy and ammonite distribution at Cerro Lotena hill, after PARENT (2003b) and data of H. A. LEANZA (1980), modified and supplemented.

work on the section of Cerro Lotena (see LEANZA 1980). He concluded that the two specimens came most probably from bed 12; this location is indicated in Fig. 2 by open circles.

The section of Cerro Lotena has been described in detail by H. A. LEANZA (1980, p. 8–9) and later figured partially by PARENT (2003b). With some modifications and supplements we refigure the section here.

3 Description of the ammonites

3.1 Introduction

The ammonites described here belong to the South American group of *Himalayitidae*, which appeared in the Gulf of Neuquén in the upper Middle Tithonian stage, and developed a lot of diverging branches during the Upper Tithonian and Berriasian stage. Representatives of this group are known since the times of STEUER (1897); later they have been described mainly by BURCKHARDT (1903), HAUPT (1907), KRANTZ (1926, 1928) and WEAVER (1931).

A thorough revision has been undertaken by A. F. LEANZA (1945), which is the base for modern ammonite systematics and stratigraphy of the Tithonian/Berriasian boundary beds in the Neuquén Basin.

The ammonites of the Middle Tithonian were described by one of the authors (H. A. LEANZA 1980); also PARENT (2001, 2003a,b), PARENT & COCCA (2007) and PARENT et al. (2007) contributed some new observations. The authors will present an interesting supplement in near future that concerns the ammonite faunas at the Middle/Upper Tithonian boundary (ZEISS & H. A. LEANZA 2007 MS). Some preliminary contributions about these investigations were already published (H. A. LEANZA & ZEISS 1990, 1992, 1994).

For ammonites of the same age from the neighboring Chile, papers of CORVALÁN & PÉREZ (1958), CORVALÁN (1959) and BIRÓ-BAGOCZKY (1980, 1984) are of interest.

3.2 Abbreviations

3.2.1 Collections

M. O. Z. 'Museo Prof. Dr. Juan A. Olsacher', Zapala, Neuquén Province.
S. G. N. Servicio Geológico Nacional, Buenos Aires.

3.2.2 Measurements etc.

D = Diameter
H = Whorl height
W = Whorl width
U = Umbilicus width
Ir = Internal (primary) ribs
Er = External (secondary) ribs
Sr = Single ribs
M = Macroconch
m = Microconch

All measurements in mm, number of ribs per half whorl.

3.3 Taxonomy

Order	*Ammonoidea* Zittel, 1884
Suborder	*Ammonitina* Hyatt, 1889
Superfamily	*Perisphinctaceae* Steinmann, 1890
Family	*Himalayitidae* Spath, 1925

Nikolov (1982) considered the family *Himalayitidae* Spath, 1925 only as subfamily and placed it into the family *Berriasellidae* Spath, 1922. The latter, however, was later given also the rank of a subfamily and included in the family *Neocomitidae* Salfeld, 1921 (Wright 1980, Wright et al. 1996). But, the family *Himalayitidae* generally has been maintained (Donovan et al. 1980, Tavera 1985, Enay et al. 1998). A complete subdivision of this family into subfamilies has not been undertaken hitherto, but seems necessary; it would, however, need further investigations and discussions, which are beyond the scope of this paper; in order to gain some advance two exceptions are presented here.

? Subfamily *Suaritinae* Cantu-Chapa, 1998

The genus *Simplisphinctes*, together with *Pseudosimplisphinctes*, has been classified as *Himalayitidae* (Tavera 1985) as well as the related genus *Toucasiella* (Enay et al. 1998). But these genera are not typical *Himalayitidae* and cannot be included in a subfamily *Himalayitinae* s. str. Therefore, it should be discussed in future and in more detail, if those genera, which display mostly only simple ribs on the flanks, should be included in a separate subfamily '*Simplisphinctinae*', or arranged together with other related genera in a subfamily '*Micracanthoceratinae*'.

Also another possibility which has been given preference here, should be discussed, whether those genera could be included in an enlarged subfamily *Suaritinae* (see below). This subfamily was introduced by Cantú-Chapa (1998) for a related group of Upper Tithonian ammonites with looped ribs. To this new subfamily he attributed the genera *Suarites*, *Galeanites*, *Wichmanniceras*; and a species of *Corongoceras*, *Co. filicostatum*. This new subfamily was placed into the family *Neocomitidae*. With respect to the type material of the genus *Suarites* published by Cantú-Chapa (1968), we consider it more appropriate to include the subfamily in the family *Himalayitidae*, in which *Suarites* had been originally placed by Cantú-Chapa (1968). Apparently, most of these forms have inner whorls with simple ribs. There are closely related genera which present in the adult stage simple ribs instead of looped ribs. But, it is beyond the scope of this paper to discuss whether the definition of the subfamily *Suaritinae* could be enlarged, so that genera with single ribs, like *Acedevites* Cantú-Chapa, 1968, *Simplisphinctes* s. str. Tavera, 1985, *S.* (*Lotenia*) nov. subgen., *S.* (*Paralytohoplites*) Myczyński, 1996, *Pseudosimplisphinctes* Tavera, 1985 and *Toucasiella* Enay et al., 1998 could be included. Another similar genus, *Butticeras* Houša & Nuez, 1973 may also belong to this group; it was classified by Myczyński (1999) as *?Himalayitidae*.

This group is a special development at the base of *Himalayitidae*, spreading out in different parts of the western Tethys and adjacent sea-basins, e. g. *Simplisphinctes* s. str. (1) and *Toucasiella* (2) in Southern Europe and Northern Africa, *S.* (*Paralytohoplites*)

(3) in Central and *S.* (*Lotenia*) (4) in Southern America. These genera are most probably the origin of further developments, e. g. from (1) to *Pseudosimplisphinctes*, from (2) to *Durangites*, from (3) to *Acedevites* and *Suarites*, and from (4) to *Wichmanniceras*.

As we want to avoid the establishment of further subfamilies at the present state of knowledge, we provisionally place the genus *Simplisphinctes* into the subfamily *Suaritinae*. But, until the above mentioned discussions on the taxonomic status of *Suaritinae* take place, we add the genus *Simplisphinctes* only with a question mark.

Genus *Simplisphinctes* TAVERA, 1985

Type species: *Simplisphinctes abnormis* (ROMAN, 1936)

As already noted by IMLAY (1942) his new species '*Lytohoplites*' *caribbeanus* (= now *Paralytohoplites*) is very close to '*?Himalayites*' *abnormis* ROMAN, 1936 (= now *Simplisphinctes*). Therefore, we consider *Paralytohoplites* MYCZYŃSKI, 1996 as a subgenus of *Simplisphinctes*. This subgenus can be considered as origin of the mexican branch of Suaritinae. Another branch is represented in South America by *Simplisphinctes* (*Lotenia*) n. subgen. (see below) and the specialized genus *Wichmanniceras* A. F. LEANZA, 1945.

Subgenus *Lotenia* n. subgen.

Type species: *Simplisphinctes* (*Lotenia*) *neuquenensis* n. sp.

Derivatio nominis: Derived from Cerro Lotena (Neuquén Province), where the type species has been found.

Diagnosis: A subgenus of *Simplisphinctes* which displays nodes only at the endings of the flank ribs at the external side of the shell. No bipartite and no looped ribs are present. Nodes and ventral sulcus are well developed.

Description: Same as for the species.

Remarks: CANTÚ-CHAPA (1998) had united some Upper Tithonian taxa with looped ribs (*Suarites*, *Wichmanniceras*, *Galeanites* and *Corongoceras filicostatum*) in his new subfamily *Suaritinae*. This characteristic prevents at present the unanimous inclusion of the new subgenus *Lotenia* in this unit; which could be envisaged by the otherwise similar habitus of this genus. On the other hand, we suppose that the genus *Wichmanniceras* more probably belongs in the vicinity of *Simplisphinctes* s. str. and related genera, like *Toucasiella*. However, members of these genera frequently have a second row of tubercles on the ribs at the outer third of the flanks, a denser and more retrocostate ribbing and a different external side. These characteristics separate these otherwise similar looking genera from *Lotenia* and *Wichmanniceras* (see also below).

***Simplisphinctes (Lotenia) neuquenensis* n. sp.** (Fig. 3/1–2 and Fig. 4)

Holotype: *Simplisphinctes* (*Lotenia*) *neuquenensis*, P 1627 M. O. Z., illustrated in Figs. 3/1–2, 4.

Derivatio nominis: After the Neuquén Province (Argentina), in which the type locality of the new species is situated.

Diagnosis: Discoidal and evolute shell, with simple and sharp, radial ribs, each one ending with an acute node on the external margin, accompanying a well-developed ventral groove; internal whorls not densely ribbed.

Differential diagnosis: The differing characters of the new species from otherwise similar species of related genera are either the external side or the sculpture on the flanks or both. The flanks, e. g., are looking similar to *Wichmanniceras mirum* but not the marginal area and the external side; however, *W. mirum*, if more precisely observed, has flanks which are decorated with more numerous and marginally looped ribs. *S. (P.) caribbeanus* shows ribs crossing the ventral side, whereas species of *Simplisphinctes* s. str. like *S. abnormis* and *S. rivasi* display not so well developed nodes, which are more like short transverse ribs ending at a very shallow furrow. In this respect, larger specimens of *Toucasiella gerardi* are similar in general, but smaller ones display sharper ribs with more acute nodes. In addition, many specimens of *Simplisphinctes* s. str. and *Toucasiella* are frequently more densely ribbed and have a second row of small tubercles on the external ribs at the outer part of the flanks, a character completely missing in *Lotenia* and *Wichmanniceras*; comparing the whorl dimensions the differences are in general not very great (see table below).
Material: One specimen: P 1627 M. O. Z., well preserved; consisting of the phragmocone and a part of the body chamber (holotype).

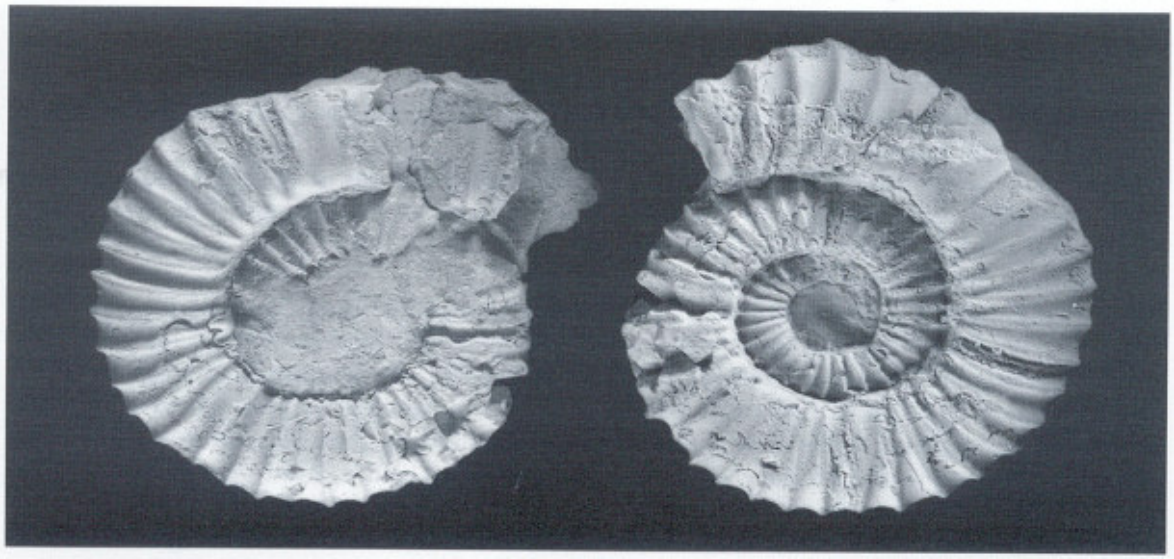

Fig. 3. **1–2** *Simplisphinctes* (*Lotenia*) *neuquenensis* n. subgen., n. sp., holotype: 1 = lateral view left, 2 = lateral view right, nat. size, MOZ 1627.

Measurements (in mm):

Specimen N°	D	U	H	W	W/H	U/D	H/D	W/D	SR
P 1627 M. O. Z. Holotype	60,6	25,8	18	18	1,00	0,40	0,30	0,30	18
Holotype at	48,0	23,0	16	16	1,00	0,48	0,33	0,33	21

For comparisons:

Specimen	D	U	H	W	W/H	U/D	H/D	W/D	SR
W. mirum Holotype	48,0	25,0	12,0	13,0	1,08	0,52	0,25	0,27	29
S. (P.) caribbeanus Holotype	48,0	20,0	17,0	?16,0	?0,94	0,42	0,35	?0,33	20
T. gerardi Holotype	27,3	11,5	10,0	9,0	0,90	0,40	0,37	0,33	20
T. gerardi Paratype	36,7	14,7	13,5	11,9	0,88	0,40	0,37	0,32	29
S. rivasi Holotype	59,4	27,5	18,6	18,0	0,97	0,46	0,31	0,31	28
S. rivasi Holotype at	46,8	22,3	14,3	14,0	0,98	0,48	0,30	0,30	26

Description: Shell of small to medium size, rather evolute; body chamber beginning at H = 22,5 mm, consisting of half a whorl, aperture missing. Cross-section of the whorls oval, the inner part being broader than high, converging towards the marginal region; umbilical walls steep, umbilical edges rounded; ribs always simple, sharp and in general radial (recticostate), sometimes slightly concave. Compared with other species of *Simplisphinctes* s. str., our specimen is less densely ribbed, and has retrocostate concave ribs only in a short part of the last whorl (at 44 mm diameter). At the end of the last whorl the ribs are on the left side recticostate or slightly prorsicostate; on the right side concave to projected ribs prevail. Ribs ending at the external side with small nodes on each side of a deep ventral furrow.

Remarks: The main characteristics distinguishing the new species from related forms have already been discussed above. Here, some additional observations shall be given; while differences concerning the dimensions are mostly not very great, those of the sculptures are much more striking.

As already mentioned above (see differential diagnosis) similar species occur in the related genera (and subgenera) *Simplisphinctes* s. str, *Simplisphinctes* (*Paralytohoplites*), *Toucasiella* and *Wichmanniceras*.

A closely related species is *Simplisphinctes* (*Paralytohoplites*) *caribbeanus* (Imlay, 1942, Pl. 7, Fig. 1–2) from the late Jurassic of Cuba. As the measurement table shows, the closest match regarding shell dimensions and number of ribs is apparently with this species. Differences at the same size are the wider umbilicus, and on inner whorls, the smaller number of ribs and the small node-like endings of the ribs not observable in our specimen. The outer whorl of both species is ornamented with recticostate ribs, but the

Fig. 4. *Simplisphinctes* (*Lotenia*) *neuquenensis* n. subgen., n. sp., holotype, external view, nat. size, MOZ 1627.

external side is quite distinct (see differential diagnosis, above). The inclusion of this species in *Lytohoplites* was not justified because of its quite different ornamentation. Therefore, Myczyński (1996) established for this species the new genus *Paralytohoplites*, which we now consider as a subgenus of *Simplisphinctes* (see above).

As Schweigert & Zeiss (1998: 572) noted, there is some similarity of *Paralytohoplites* to the older and much smaller *Berckhemeria*, but apparently no relationship. But they remarked already that there could be relations to *Simplisphinctes* and related genera.

The new species is distinct from *Wichmanniceras mirum* from Argentina, which displays looped ribs. It is more related to species of *Simplisphinctes* s. str. and *Toucasiella* of Southern Europe and Northern Africa, which do not show such ribs. Although it appears rather close to *Simplisphinctes* s. str., it cannot be classified as a member because it does not exhibit dominant retroradiate ribs. A rather similar species of this subgenus is *Simplisphinctes* (*S.*) *rivasi* (Tavera, 1985, Pl. 29, Fig. 6–8). The ribbing, however, is denser and the ribs are always bent backwards and bear frequently a further row of tubercles on the external part of the flanks. Rather similar, but much smaller examples were described as *Toucasiella gerardi* (Enay et al. 1998, Figs. 1–21); in contrast to *Lotenia* they display occasionally also bifurcate ribs and bear like in *Simplisphinctes* s. str., often an additional row of tubercles on the ribs at the external parts of the flanks.

The morphological features of the new species could suggest that it is perhaps a microconch partner of the genus *Wichmanniceras* A. F. LEANZA. A typical macroconch of *Wichmanniceras* represents its type species *W. mirum* A. F. LEANZA (1945, Pl. 1, Fig. 4–5); but it is smaller than *S. (L.) neuquenensis*, more evolute, recticostate, and displays, at the end of the last whorl, distant ribs; also the nodes are more prominent. In *W. mirum* the external ribs are frequently bundled at the nodes of the external margin, which may be connected by fine ribs across the external furrow. This can also be seen in the much more densely ribbed Mexican *Wichmanniceras hernandense* (CANTÚ-CHAPA, 1968, Pl. 7, Fig. 2, 5 and 8). It seems more probably that *W. mirum* is a further development of the *Lotenia* branch of *Simplisphinctes*.

Occurrence: Vaca Muerta Formation (WEAVER 1931) at the southern slope of the Cerro Lotena, Neuquén Province, Argentina (cf. Fig. 2).

Age: Lowermost Upper Tithonian, *Windhauseniceras internispinosum* Zone.

Subfamily Windhauseniceratinae H. A. LEANZA & Zeiss, 1992

The subfamily has been established informally by H. A. LEANZA & ZEISS (1992, p. 1845); it will be discussed in more detail in our monograph of the Zapala ammonite fauna (ZEISS & H. A. LEANZA, MS 2007).

Genus *Windhauseniceras* A. F. LEANZA, 1945

(**Type species:** *Perisphinctes internispinosus* KRANTZ, 1926)

***Windhauseniceras internispinosum* (KRANTZ, 1926)** (Figs. 5/1–2 and Fig. 6)

1926 *Perisphinctes internispinosus* nov. sp. KRANTZ, p. 453, pl. 14 figs. 1–2 (lectotype), pl. 15 figs. 5–6 syntype).

1980 *Windhauseniceras internispinosum* (KRANTZ). – H. A. LEANZA, p. 43, pl. 8 fig. 4a–b (mi), pl. 9, fig. 1a–b (ma) – [with complete synonomy].

2003b *Windhauseniceras internispinosum* (KRANTZ). – PARENT, p. 354–358, tab. 1, figs. 1A–D (refiguration of the lectotype), fig. 1E–F (syntype) and fig. 2.

? 2007 *Windhauseniceras internispinosum* (KRANTZ, 1926). – PARENT et al. p. 20, Fig. 9–10.

Material: Two microconch specimens: P 1728 M. O. Z., a complete shell (cf. Fig. 5/1–2, 6) and S. G. N. 8940/4, lacking the last part of the body chamber (cf. H. A. LEANZA 1980, Pl. 8, Fig. 4a–b).

Measurements (in mm):

Specimen N°	D	U	H	W	W/H	U/D	H/D	W/D	Ir	Er
P 1728 M. O. Z.	70,9	33,8	20,8	23,8	1,14	0,48	0,29	0,34	17	34
S. G. N. 8940/4	60,1	30,6	17,8	20,7	1,16	0,51	0,30	0,34	18	32

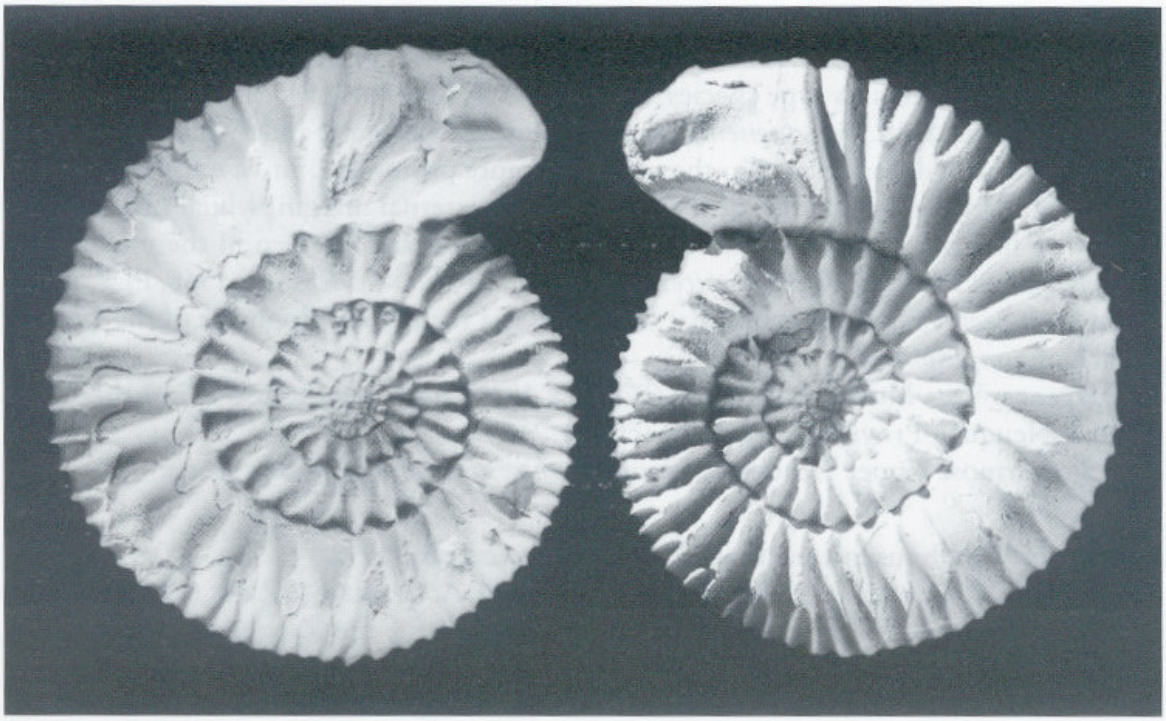

Fig. 5/1–2. *Windhauseniceras internispinosum* (Krantz), complete microconch, 1 = lateral view left, 2 = lateral view right, nat. size, MOZ P 1728.

Description: A rather evolute, adult shell, with lappets (microconch); whorl section coronate, with no external furrow. The body chamber occupies less than ¾ of the last whorl.

The ornamentation consists of simple, recticostate ribs on the inner part of the whorls, which split off into two secondary ribs. At the branching points small, spiniferous nodes are developed. These branching points are situated on the inner half of the ultimate whorls at the marginal edge, whereas they descend on the outer half until two thirds of the flank height. The splitting of the ribs is mostly biplicate, but occasionally triplicate; the secondary ribs of both sides of the specimen are connected zig-zag like on the venter, which is rounded and shows no furrow or any kind of ribbing interruption. Three constrictions are present on the last whorl. Simple ribs can be observed, as on the macroconch, only at the aperture; this is decorated by spoon-like lappets, reaching 1 cm in length.

Remarks: The specimen described here is the first microconch of the species with the complete aperture. H. A. Leanza (1980, Pl. 8, Fig. 4a–b) had figured a specimen displaying almost identical internal whorls; but without lappets at the last quarter of the ultimate whorl.

It should be mentioned, that the body chamber is preserved only partially at the lectotype of *Windhauseniceras internispinosum* (Krantz, 1926, Pl. 14, Fig. 1–2), but this specimen apparently represents a macroconch; for, a very similar specimen of this species, which was figured by H. A. Leanza (1980, Pl. 9, Fig. 1a–b) displays a complete, but simple margin of the aperture without lappets; thus, it can be interpreted as a complete

macroconch. The most important difference to the microconch can easily be traced by observing the ribbing style on the body chamber: there are no spiniferous nodes developed, but one can recognize on the last whorl the returning to a *Perisphinctes*-like sculpture: the specimen is variocostate. A still larger macroconch might be the specimen figured as *Hemispiticeras* aff. *H. steinmanni* (STEUER) by H. A. LEANZA (1980, p. 43, Pl. 9, Fig. 2a–b, text fig. 10a).

Recently, PARENT (2003b) published a re-evaluation of *Windhauseniceras internispinosum* and selected the lectotype of the species. When assuming that the lectotype is a large microconch, he overlooked two facts: (1) that H. A. LEANZA (1980, p. 43, Pl. 9 Fig. 1) has described the aperture of a similar specimen as 'simple, describing only a somewhat sigmoidal curve' – clearly a character of macroconchs, and (2) that variocostate ribbing is significant for macroconchs of Perisphinctidae (see CALLOMON 1963). Therefore, we consider the lectotype as an incomplete macroconch; the microconch is different from the lectotype as described above. Obviously, PARENT et al. (2007) now consider the sexual dimorphism of this species as explained here. Their specimens of adult microconchs are different Fig. 9A displays retroverse ribbing on last half whorl instead of recticostate ribbing; Fig. 9B is more involute than *W. internispinosum*; the bad preservation of the inner whorls does not allow a specific attribution. Therefore, it may be questioned, if these specimens are true *W. internispinosum*.

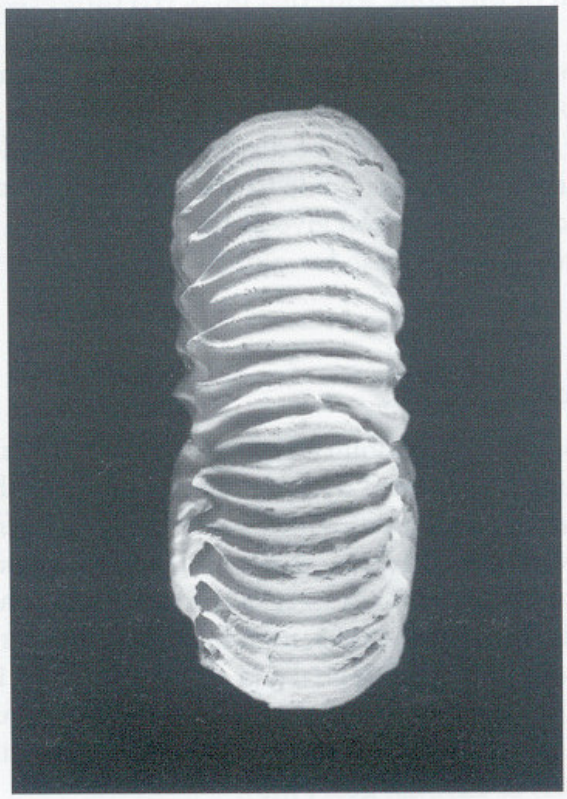

Fig. 6. *Windhauseniceras internispinosum* (KRANTZ), complete microconch, external view, nat. size, MOZ P 1728.

Occurrence: Vaca Muerta Formation (Weaver 1931) at the southern slope of Cerro Lotena, Neuquén Province, Argentina (cf. Fig. 2).
Age: Lowermost Upper Tithonian. *Windhauseniceras internispinosum* Zone.

4 Chronology and correlations

Global correlations at the base of the Upper Tithonian were rather limited until the second half of the last century. Only by the thorough description of a statigraphically well-collected, new ammonite fauna from the lowermost Upper Tithonian of Southern Spain by Olóriz & Tavera (1981) and especially by Tavera (1985) it was possible to propose more precise correlations (Olóriz & Tavera 1981, p. 229, Zeiss 1983, p. 431 and Tavera 1985, p. 344, Fig. 27) between different parts of Mediterranean Europe and elsewhere. Tavera (1985) proposed for the lowermost Upper Tithonian a correlation by three regional zones; namely the *Simplisphinctes* Zone of 'S España', the *Scruposus* Zone of the 'Submediterranean' and the *Internispinosum* Zone of 'C. y S. America', apparently assuming for them the same time range. As shown in this paper the correlation of the *Internispinosum* with the *Simplisphinctes* Zone is obvious. Concerning the *Scruposus* Zone, Zeiss (2001) demonstrated that only the lower part can be considered as equivalent of the *Simplisphinctes* Zone. With respect to the *Internispinosum* Zone it should be remarked that it is only used in South America (Chile and Argentina); but, as shown in this paper, a correlation of this zone with that of. *S. (P.) caribbeanus* of Central America (Cuba) is possible.

The best correlation tools at the base of the Upper Tithonian are species of the ammonite genera *Corongoceras, Simplisphinctes* s. l., *Oloriziceras* and of the calpionellid genus *Chitinoidella* (cf.Fig. 7). They will be discussed in detail below.

The discovery of further important guide fossils (radiolarians, calcareous nannofossils and dinoflagellates) and their evaluation give us the possibility to present a revised compilation providing a well-founded base for global correlations at the base of the Upper Tithonian Substage.

4.1 Ammonites (Fig. 7)

The most important correlation possibility between the *Simplisphinctes/Ol. magnum* and the *Internispinosum* Zone is presented by early species of the of the genus *Corongoceras* (e. g. *Co. lotenoense*, *Co. mendozanum*) which occur in the *Simplisphinctes/Ol. magnum* Zone of Europe and Northern Africa as well as in the *Internispinosum* Zone of South America (Argentina and Chile), cf. Tavera (1985); similar forms have also been found in Antarctica (Ross Island, det. A. Zeiss 1985, unpublished), cf. Whitham & Doyle (1989), Madagascar (Collignon 1960), the Himalayas (Krishna et al. 1982) and Japan (Sato 1962). A related, but apparently somewhat older species, *Co. praecursor*, has been described from Austria (Zeiss 2001) and seems to be also represented in Argentina, in the *Au. proximus* Zone (Zeiss & Leanza 2007, MS).

Another important correlation possibility can be established by the great similarity between the related South Spanish species *Simplisphinctes* (*S.*) *rivasi* Tavera and the

Argentinian species *Simplisphinctes (L.) neuqenensis* n. sp. It can be assumed that the time intervals in which these two species existed were more or less equivalent. Additionally, another related species, *Simplisphinctes (P.) caribbeanus* (IMLAY) from the Tithonian Stage of Cuba, is similar to *Simplisphinctes (S.) abnormis* from South Spain and North Africa and is apparently of the same age. Therefore, the genus *Simplisphinctes* and in particular these four species are very useful correlation tools between Southern Europe and North Africa and Central and South America.

The genus *Simplisphinctes* is rather widespread at the base of the Upper Tithonian stage of Europe and North Africa; it is represented in southern Spain (TAVERA 1985), northern Italy (SARTI 1988, ZEISS 2001), Morocco (BENZAGGAGH & ATROPS 1995, 1997) and Algeria (ROMAN 1936). TAVERA (1985) introduced for this genus the "*Zona de Simplisphinctes*" as "Taxon-range zone". This is the lowermost zone of the Upper Tithonian Stage in Southern Europe; an equivalent in Central Europe is the *Oloriziceras magnum* Zone (ZEISS & BACHMAYER 1989, ZEISS 2001). As demonstrated above, equivalents of this zone can also be recognized in South and Central America in the local zones of *Windhauseniceras internispinosum* and *Simplisphinctes (P.) caribbeanus*.

Consequently, we can state that the inclusion of the *Internispinosum* Zone (with *Wichmanniceras*) in the lowermost Upper Tithonian, as it was already stated by A. F. LEANZA (1945) nearly 60 years ago, was correct. Therefore, the late Middle Tithonian age for the *Internispinosum* Zone proposed by ARKELL (1956) followed by H. A. LEANZA (1980) and later by PARENT (2003b) and PARENT et al. (2007) can not be maintained. As already TAVERA (1985, p. 344) had documented, *Corongoceras lotenoense* and other early micracanthoceratids appear in the *Simplisphinctes* Zone of the lowermost Upper Tithonian age in Spain, allowing the age calibration of the *W. internispinosum* Zone in Argentina (see also above).

The same is valid for the *S. (P.) caribbeanus* Zone of Cuba (see below), which has been erroneously considered as being Middle Tithonian in age (MYCZYŃSKI 1989, 1999, MYCZYŃSKI & PSZCZÓŁKOWSKI 1994).

4.2 Calpionellids (Chitinoidellids), cf. Fig. 7

Calpionellids (Chitinoidellids) have been found in Mediterranean Europe and Africa as well as in Central America. They are very important for the correct dating of the *S. (P.) caribbeanus* Zone and the upper part of the *Chitinoidella* Zone in Mexico and Cuba.

The results of the investigations of BENZAGAGGH & ATROPS (1995, 1997) in Morocco have demonstrated that the *Chitinoidella boneti* Subzone of the *Chitinoidella* Zone can be correlated with the *Simplisphinctes* Zone as defined by TAVERA (1985); this means that its age is Early Late Tithonian.

However, the *Chitinoidella boneti* Subzone has been considered hitherto mostly as of late Middle Tithonian age or late Lower Tithonian [*sensu gallico*] age (cf. BORZA 1984, REMANE 1998, GRÜN & BLAU 1997, REHÁKOVÁ & MICHALÍK 1997, REHÁKOVÁ 2002). The reason for this may be caused by the fact that no characteristic ammonites have been found with these chitinoidellids and thus a direct dating by ammonites was not possible.

The new observations of BENZAGAGGH & ATROPS (l. c.) now offer a better possibility for an age determination of the *Boneti* Subzone. This is important because in Central

		Southern Europe, Northern		Cuba		Mexico		Argentina, Chile	Antarctic Peninsula
Upper Tithonian		*Durangites vulgaris*	*Crassicollaria*	*Durangites, Micranthoceras, Hildoglochiceras, Salinites, Corongoceras*	*Crassicollaria*	*Substeueroceras, Durangites, Salinites*	*Crassicollaria* sp.	*Substeueroceras koeneni*	*Blanfordiceras*
	Micracanthum	*Paraulacosphinctes transitorius*	*Ch. boneti*		*Ch. boneti*	*Corongoceras, Micranthoceras, Acevedites, Suarites*	*Chitinoidella* sp.	*Corongoceras alternans, Lytohoplites*	*Lytohoplites weaveri*
		Simplisphinctes, Co. lotenoense, Ol. magnum		*Simplisphinctes (P.) caribbeanus*		*Proniceras neohispanicum*		*Simplisphinctes (L.) neuquenensis, Windhauseniceras internispinosum, Co. lotenoense*	*Corongoceras involutum*
Middle Tithonian		*Ponti / Peroni*	*Ch. dobeni*	*Pseudolissoceras*	*Chitinoidella* sp.	*Volanoceras, Mazatepites, Kossmatia victoris, Pseudolissoceras*		*Aulacosphinctes proximus*	*Aulacosphinctes*
		Admirandum / Biruncinatum						*Pseudolissoceras zitteli*	*Kossmatia tenuistriata, Virgatosphinctes densepicatus*
		Richteri							
		Semiforme / Verruciferum							

Fig. 7. A tentative global correlation table of Middle and Upper Tithonian Ammonite and Calpionellid Zones (after FATMI & ZEISS 1999, and ZEISS 2001), modified and supplemented.

America (Cuba, México) this subzone can be identified within the *Chitinoidella* Zone, too. *Ch. boneti* and related forms have been found in many sections of Cuba (MYCZYŃSKI & PSZCZÓŁKOWSKI 1990, 1994) and in one section in México (ADATTE et al. 1996a). *Ch. boneti* existed in Cuba together with *S.* (*Paralytohoplites*) *caribbeanus*. There, the age interpretation as Late Middle Tithonian or Late Early Tithonian [sensu gallico] was erroneous. The *Ch. boneti* Subzone can be correlated with the Zone of *S.* (*Paralytohoplites*) *caribbeanus*. This species has originally been attributed to the "Upper Portlandian" (IMLAY 1942), which was later included corrrectly in the lower part of the Upper Tithonian by the same author (IMLAY 1980).

We regard as necessary to discuss some more details of the new correlation and age calibration. BENZAGGAGH & ATROPS (1995, 1997) demonstrated that the main occurrence of *Chitinoidella boneti* is in the lower and middle part of the *M. micracanthum* Zone. The lower part of this zone was treated by these authors as the "*Simplisphinctes* spp. Subzone"; in comparision to the original "Zona de *Simplisphinctes*" of TAVERA (1985) this unit is reduced. But it is more appropriate to maintain the original content corresponding to the occurrence of the genera *Simplisphinctes* and *Oloriziceras* and the main occurrence of *Ch. boneti* and related species (Horizons H1 and H2 of BENZAGAGGH & ATROPS). The upper part of the *Ch. boneti* Subzone (Horizon H3) corresponds approximately to the upper *Simplisphinctes* Zone and the lower *Transitorius* Zone of TAVERA (1985). In the new subdivision of GRÜN & BLAU (1997) it is approximately equivalent with their *Ch. bermudezi* Subzone of the *Chitinoidella* Zone. But, as *Ch. boneti* and *Ch. bermudezi* have the same vertical range in Morocco further studies in other regions seem to be necessary to clarify whether the different range of these species found in the section studied by GRÜN & BLAU (1997) is only a local one or can be observed in a wider area. In Cuba the uppermost part of the *Ch. boneti* Zone is included in the basal *Himalayites/Corongoceras* Zone, in which *Ch. bermudezi* has been found, which is also extending into the *Micracanthum* (*Corongoceras*) Zone in Morocco (cf. 'Horizon H3' in BENZAGGAGH & ATROPS 1995, 1997 and in Italy '*Bermudezi* Subzone' of GRÜN & BLAU 1997).

As explained above, the *Simplisphinctes* Zone [= *Simplisphinctes* (*S.*) *abnormis* Zone], the *Windhauseniceras internispinosum* Zone and the *Simplisphinctes* (*P.*) *caribbeanus* Zone can be considered as time equivalent. Therefore, the lower and middle part of the *Chitinoidella boneti* Subzone is corresponding to them. This is in good agreement with the stratigraphic indications of DOBEN (1963); when establishing his new species *Ch. boneti*, he wrote that it occurs directly below the *Calpionella*-bearing beds and in their lowest parts. His opinion that this would be around the Middle/Upper Tithonian boundary can now be interpreted more precisely. Following the publications of TAVERA (1985) and BENZAGGAGH & ATROPS (1995, 1997) the main occurrence of *Ch. boneti* has been found in the early Upper Tithonian *Simplisphinctes* Zone [or in the lower *Micracanthum* Zone]. Only another well-dated occurrence lies in beds of uppermost Middle Tithonian age (*Volanense* Zone), as KAISER-WEIDICH & SCHAIRER (1990) stated. But it should be kept in mind that these authors considered all their specimens of the *Chitinoidella* Zone as belonging to *Ch. boneti*. Curiously, the important paper of BORZA (1984) escaped their attention. Still more astonishing is that they claim to have observed cross-sections of *Ch. dobeni* as early as in the Lower Tithonian *H. hybonotum* Zone. A detailed revision seems necessary to

clarify the real taxonomic position of these specimens of "*Ch. boneti*" by using the papers of Borza (1984), Reháková & Michalík (1997), Olóriz et al. (1995) and Benzaggagh & Atrops (1995, 1997); in these it is clearly demonstrated that there are two subzones in the *Chitinoidella* Zone, a lower *Ch. dobeni* Subzone and an upper *Ch. boneti* Subzone. Thus, some of the specimens attributed to *Ch. boneti* by Kaiser-Weidich & Schairer (1990) probably belong to *Ch. dobeni* and/or related species.

Recently, Caracuel et al. (2002) published a range chart of calpionellids from western Sicily showing a joint occurrence of *Ch. dobeni* and *Ch. boneti* below the range of *Ch. boneti* alone. These authors considered both assemblages as equivalents of the *Burckhardticeras* Zone; but, there was no evidence by ammonites for this. Benzaggagh & Atrops (1997) did not observe a joint occurrence of *Ch. dobeni* and *Ch. boneti*. However, if we consider the *Chitinoidella* Subzones as interval zones (Reháková & Michalík 1997, Reháková 2000), the first ocurrence of *Ch. boneti* would indicate the beginning of the *Boneti* Subzone. Even if some specimens of earlier species are surviving; it can be assumed, that both assemblages correspond to some parts of the lower and middle *Simplisphinctes* Zone in Morocco, i. e. that they belong to the basal Upper Tithonian.

In Cuba, *Simplisphinctes* (*P.*) *caribbeanus* occurs in the sections of the Sierra del Rosario together with *Chitinoidella boneti* and *Ch. cristobalensis* (Myczyński & Pszczółkowski 1994), which are significant for the middle and upper part of the *Simplisphinctes* Zone in Morocco (Benzaggagh & Atrops 1995, 1997). Therefore, the inclusion of the Zone of *Simplisphinctes* (*Paralytohoplites*) *caribbeanus* in the uppermost Lower Tithonian cannot be further maintained. After the new data it belongs to the lowermost Upper Tithonian as equivalent to the Tethyan *Simplisphinctes* Zone (Tavera 1985). In the sections of the Sierra de los Organos, the vertical distribution of *Chitinoidella* species (cf. Myczyński & Pszczółkowski 1990, Tab. 1–2) shows that the main occurrence (*Ch. boneti* group) happened in the upper part of the *Chitinoidella* Zone (corresponding to the upper part of the *S.* (*P.*) *caribbeanus* Zone); in the lower part only specimens named '*Chitinoidella* sp.' have been found. The age of this lower part of the *Chitinoidella* Zone in Cuba is Middle Tithonian based on the ammonites found (l. c., p. 411, Tab. 2). Presumably it corresponds to the *Ch. dobeni* Subzone of the Mediterranean area. This distribution is similar to the distribution described by Olóriz & Tavera (1979, 1981) and Olóriz et al. 1995) for Southern Spain and Mallorca. There, the most frequent appearance of chitinoidellids (*Ch. boneti* group) has been found in the *Simplisphinctes* Zone, whereas the occurrence in the Middle Tithonian is rather restricted and limited to *Ch. dobeni*.

We conclude that at the base of the Upper Tithonian, the *Ch. boneti* Subzone of the Standard *Chitinoidella* Zone is well correlatable from Morocco to Turkey along the northern Mediterranean arch of the Tethys and also traceable to Cuba and Mexico by direct evidence of the Calpionellid (Chitinoidellid) guide fossils, and with corresponding ammonites to South America, the Antarctic Peninsula, India and Japan (cf. Zeiss 2001).

4.3 Radiolarians

Global correlation of the lowermost Upper Tithonian ammonite zone is also possible by radiolarians. In the Neuquén Basin, after the investigations of PUJANA (1991, 1996), a radiolarian assemblage with abundant *Vallupus hopsoni* characterizes the *Windhauseniceras internispinosum* Zone; this is the youngest occurrence of this assemblage in South America; it has been considered as being significant for the uppermost part of the Radiolarian Subzone 4 beta of PESSAGNO et al. (1987). Radiolarian Subzone 4 beta is succeeded by an association probably belonging to the *Corongoceras alternans* Zone. This level has delivered a fauna of the so-called '*Vallupus japonicus* Event'. Following the investigations on radiolarian biochronology of the Tethys and Antarctic Peninsula by BAUMGARTNER et al. (1995) and KIESSLING et al. (1999) the Radiolarian Subzone 4 beta of the subdivision of PESSAGNO et al. (1987) corresponds approximately with the Unitary Association Zone (UAZ) 12. Both author groups place the upper limit into the lower part of the Upper Tithonian.

In Central Europe, the base of Radiolarian Subzone 4 beta of PESSAGNO et al. (1987) which is characterized by the first appearance of *Vallupus hopsoni* is situated around the Upper Kimmeridgian/Lower Tithonian boundary (ZÜGEL 1997), that means much deeper than previously assumed. In Patagonia the deepest occurrence is at the base of the Middle Tithonian, and on the Antarctic Peninsula the base of this zone has been found in the Lower Tithonian. Radiolarian Subzone 4 beta can be followed onto the Japanese Islands, but until now its base is only well dated in Central Europe and Antarctica. As shown above, the upper limit of Subzone 4 beta corresponds with that of UAZ 12, whereas the middle and lower parts are corresponding with UAZ 11 (cf. KIESSLING et al. 1999). In the northern Tethys UAZ 11 and 12 are mainly used, whereas Subzone 4 beta has been recognized from the Americas (PESSAGNO et al. 1996) and Antarctica (KIESSLING et al. 1999) to Japan and the Pacific regions (MATSUOKA & YANG 1999). In the light of the new data from Central Europe and Antarctica, the age calibration for the lower limit of Radiolarian Subzone 4 beta needs probably to be revised in some areas. This is especially important for those regions where usually no direct dating by ammonites is possible, e.g. in Japan and the western Pacific.

4.4 Calcareous nannofossils and dinoflagellates

Calcareous nannofossils were investigated in the Neuquén Basin by SCASSO & CONCHEYRO (1999), resulting in a correlation of the *W. internispinosum* Zone with Calcareous Nannofossil Subzone NJ20b. In the correlation table of ADATTE et al. (1996a, 1996b) this subzone is correlated with the lower part of the "*Chitinoidella*" Zone, corresponding to the Middle Tithonian *Semiformiceras fallauxi* and Upper *Semiformiceras semiforme* Ammonite Zones (GARDIN 1997). Considering the above established correlations this looks like a somewhat too old age; but, as demonstrated above, the lower part of the *Chitinoidella* Zone, the *Ch. dobeni* Subzone, has been correlated by BENZAGGAGH & ATROPS (1995) with the upper Middle Tithonian (*Semiformiceras fallauxi* to *Djurjuriceras ponti* Zone). Thus, the age difference is not very great. Additionally it should be mentioned that

one index species mentioned by Gardin (1997), *P. beckmanni*, has also been found in the Zapala sections. The first occurrence of this species lies at the base of the *Peroni* [or *Ponti*] Zone (Gardin 1997, Tab. 65). Unfortunately, layers of this age (bed x+a, *Au. proximus* Zone) have not been investigated by Scasso & Concheyro (1999); thus, one cannot be sure, if that species occurs already in these older beds.

Investigations on dinoflagellates by Quattrocchio & Sarjeant (1992) and Quattrocchio et al. (1996) resulted in a subdivision of the Tithonian of the Neuquén Basin into four zones. Of these the zone of *Millioudodinium nuciforme* (Deflandre 1938) Sarjeant, 1982 is corresponding with the *Windhauseniceras internispinosum* Zone, meaning that this zone can be recognized also by dinoflagellates. The dinoflagellate index species has been described from coeval beds of Europe. The overlying zone of *Dichdogonyaulax culmula* (Norris 1965) corresponding to the *Corongoceras alternans* Zone is still more important as it is also used in NW Europe and thus a very good global correlation tool.

5 Conclusions

To summarize, good global correlation possibilities exist by using ammonites, chitinoidellids and radiolarians at the base of the Upper Tithonian. The same is true for calcareous nannofossils and dinoflagellates. The base of the Upper Tithonian is the second important correlation level in the Tithonian stage; a level which allows global correlations by various guide fossil groups. The first important correlation level lies at the base of the Tithonian stage (*Hybonoticeras hybonotum* or *Gravesia gigas* zones). Correlation at this level is mainly based on ammonites, but radiolarians may also serve as good correlation tools in the future.

While correlation to the Boreal realm appears rather easy at this first correlation level, still some difficulties arise at the second correlation level. However, as Kutek & Zeiss (1997) demonstrated, the base of the Upper Tithonian can be correlated with high probability with the base of the Middle Volgian (see also Zeiss 2001, Fig. 5).

Acknowledgements. We thank very much Mr. J. I. Garate Zubillaga †, Zapala, former director of the Museo Prof. Olsacher in Zapala (Neuquén Province, Argentina) for his kindness to loan us the specimens for our research project, and Mrs. Chr. Sporn, then at the Institute of Palaeontology, University of Erlangen-Nürnberg, for the well-done photographic work. Dipl.-Geol. Chr. Schulbert of the same institute kindly helped with the digital composition of the figures. The grants PIP 4529/96 – Resol. 2851/98 (CONICET) and DFG Ze 70/13 partly supported this paper.

Prof. Dr. G. Lüttig, Celle, kindly read the paper critically and made many useful proposals for the improvement of the text. We thank Dr. J. Erbacher, Hannover, for his comments and the improvement of the English text as well as Dr. K. H. Ribbert, Krefeld, and Dr. G. Schweigert, Stuttgart, for some further remarks.

References

ADATTE, T., W. STINNESBECK, J. REMANE & H. HUBBERTEN (1996): Paleogeographic setting of Center-East Mexico at the Jurassic/Cretaceous boundary, correlation with NE-Mexico. – Mitt. geol.-paläont. Inst. Univ. Hamburg, **77:** 379–393, Hamburg. [ADATTE et al. 1996a].

ADATTE, T., W. STINNESBECK, J. REMANE & H. HUBBERTEN (1996): Paleoceanographic changes at the Jurassic-Cretaceous boundary in the western Tethys, northeastern Mexico. – Cretac. Res., **17:** 671–689. [ADATTE et al. 1996b].

ARKELL, W. J. (1956): Jurassic Geology of the World. – 1–757, Edinburgh and London (Oliver & Boyd Ltd).

BAUMGARTNER, P. O., A. BARTOLINI, E. S. CARTER, M. CONTI, G. CORTESE, T. DANELIAN, P. DE WEVER, P. DUMITRICA, R. DUMITRICA-JUD, S. GORICAN, J. GUEX, D. M. HULL, N. KITO, M. MARCUCCI, A. MATSUOKA, B. MURCHEY, L. O'DOGHERTY, J. SAVARY, V. VISHNEVSKAYA, D. WIDZ & A. YAO (1995): Middle Jurassic to Early Cretaceous Radiolarian Biochronology of Tethys based on Unitary Associations. – Mém. Géol. (Lausanne), **23:** 1013–1048, Lausanne. [BAUMGARTNER et al. 1995].

BENZAGGAGH, M. & F. ATROPS (1995): Les zones à *Chitinoidella* et à *Crassicollaria* (Tithonien) dans la partie interne du Prérif (Maroc). Données nouvelles et corrélation avec les zones d'ammonites. – C.-R. Acad. Sci. Paris, **320**, serie IIa: 227–234, Paris.

BENZAGGAGH, M. & F. ATROPS (1997): Stratigraphie et associations de faune d'ammonites des zones du Kimméridgien, Tithonien et Berriasien basal dans le Prérif interne (Rif, Maroc). – Newsl. Stratigr., **35:** 127–163, Berlin-Stuttgart.

BIRÓ-BAGOCZKY, L. (1980): Algunos ammonites nuevos en la Formación Lo Valdés, Titoniano – Neocomiano, Provincia de Santiago (33° 50′ Lat. Sur), Chile. – Act. 2. Congr. argent. Paleont. y Bioestratigr. etc. Buenos Aires, 1978, **1:** 223–242, Buenos Aires.

BIRÓ-BAGÓCZKY, L. (1984): New contributions to the paleontology and stratigraphy of some Tithonian-Neocomian outcrops in the Chilean part of the Andean range between 33° 45′ and 35° Lat. S. – I. G. C. P. Project #171: Circum-Pacific Jurassic Rep. 2, special Pap. **3:** 1–17, Hamilton/Ontario.

BORZA, K. (1984): The Upper Jurassic – Lower Cretaceous parabiostratigrphic scale on the basis of Tintinnindae, Cadosinidae, Stomiosphaeridae, Calcisphaeridae and other microfossils from the West Carpathians. – Geologický Zborník, **35**/5: 539–550, Bratislava.

BURCKHARDT, C. (1903): Beiträge zur Kenntnis der Jura und Kreide Formation der Cordillere. – Palaeontogr., **50:** 1–145, Stuttgart.

CALLOMON, J. H. (1963): Sexual dimorphism in Jurassic ammonites. – Transact. Leicester Lit. Philos. Soc., **72:** 19–56, Leicester.

CANTÚ CHAPA, A. (1968): El límite Jurásico-Cretácico en Mazatepec, Puebla (México). – Ingeniería Petrolera, **8:** 5–26, México D. F.

CANTÚ CHAPA, A. (1998): Suaritinae new subfamily and *Galeanites garcense*, new genus and new species of the Upper Jurassic Perisphinctaceae ammonites. – Rev. mex. Cienc. Geol., **15:** 21–24, México, D. F.

CARACUEL, J. E., G. PARISI & G. ANDREINI (2003): Jurassic Calpionellid assemblages. – *In:* SANTANTONIO, M. (Ed.): General Field Trip Guidebook, 6th International Symposium on the Jurassic System: 57–59, Palermo.

COLLIGNON, M. (1960): Atlas des fossiles caracteristiques de Madagascar, Fasc. **VI** (Tithonique): 134–166, Tananarive.

CORVALÁN, J. (1959): El Titoniano de Río Leñas, prov. de O'Higgins, con una revisión del Titoniano y Neocomiano de la parte chilena del Geosinclinal Andino. – Inst. Invest. Geol., Bol. **3:** 1–65, Santiago de Chile.

CORVALÁN, J. & E. PÉREZ (1958): Fósiles guías chilenos. Titoniano – Neocomiano. – Inst. Invest. geológicos, Man. **1**, 1–48, Santiago de Chile.

Doben, K. (1963): Über Calpionelliden an der Jura-Kreide-Grenze. – Mitt. bayer. Staatsslg. Paläont. hist. Geol. **3:** 35–50, München.

Donovan, D. T., J. H. Callomon & M. K. Howarth (1980): Classification of the Jurassic Ammonitina. – *In:* House, M. R. & Senior, J. R., The Ammonoidea. – The System. Assoc., Spec. Vol., **18**, 101–155, London. [Donovan et al. 1980].

Enay, R., M. Boughdiri & G. Le Hégarat (1998): *Toucasiella* gen. nov., Himalayitidae (Ammonitina) nouveau du Tithonien supérieur: origine de *Durangites*. – C. R. Acad. Sci. Paris, Earth & Planet. Sci., **327:** 471–477, Paris. [Enay et al. 1998].

Gardin, S. (1997): Les bioévénements à Nannofossils calcaires. – In: Cariou, E. & Hantzpergue, P. (Coord.): Biostratigraphie du Jurassique ouest-européen et méditeranéen: zonations parallèles et distribution des invertébrés et microfossiles. – Bull. Centre Rech. Elf Explor. Prod., Mém. **17:** 305–329, Pau.

Grün, B. & J. Blau (1997): New aspects of calpionellid biochronology: proposal for a revised calpionellid zonal and subzonal division. – Revue Paléobiol., **16**(1): 197–214, Genève.

Haupt, O. (1907): Beiträge zur Fauna des oberen Malm und der unteren Kreide in der argentinischen Cordillere. – N. Jb. Min. Geol. Pal., Beil.-Bd. **23:** 187–236, Stuttgart.

Imlay, R. W. (1942): Late Jurassic fossils from Cuba and their economic significance. – Geol. Soc. Am., Bull. **53:** 1417–1477, New York.

Imlay, R. W. (1980): Jurassic Paleobiogegraphy of the Conterminous United States in Its Continental Setting. – Geol. Surv., Prof. Pap., **1062:** 1–134, Washington, D. C.

Kaiser-Weidich, B. & G. Schairer (1990): Stratigraphiche Korrelation von Ammoniten, Calpionellen und Nannoconiden aus Oberjura und Unterkreide der Nördlichen Kalkalpen. – Eclogae geol. Helv., **83**/2: 353–387, Basel.

Kiessling, W., R. Scasso, A. Zeiss, A. C. Riccardi & F. A. Medina (1999): Combined radiolarian-ammonite stratigraphy for the Late Jurassic of the Antarctic Peninsula: implications for radiolarian stratigraphy. – Geodiversitas, **21**(4): 687–713, Paris. [Kiessling et al. (1999)].

Krantz, F. (1926): Die Ammoniten des Mittel-und Ober-Tithons. – In: E. Jaworski, F. Krantz & H. Gerth: Beiträge zur Paläontologie und Stratigraphie des Lias, Doggers, Tithons und der Unterkreide in der Kordillere im Süden der Provinz Mendoza (Argentinien). – Geol. Rundsch., **17a:** 427–462, Stuttgart.

Krantz, F. (1928): La fauna del Titono superior y medio de la parte meridional de la provincia de Mendoza. – Acad. nac. Cienc. Rep. Argent., Act., **10**(4): 1–57, Córdoba.

Krishna, J., S. Kumar & I. B. Singh (1982): Ammonoid stratigraphy of the Spiti Shale (Upper Jurassic), Tethys Himalaya, India. – N. Jb. Geol. Paläont., Mh., **1982**(10): 580–592, Stuttgart. [Krishna et al.(1982)].

Kutek, J. & A. Zeiss (1997): The highest Kimmeridgian and Lower Volgian in Central Poland; their ammonites and biostratigraphy. – Acta geol. polon., **47:** 107–198, Warszawa.

Leanza, A. F. (1945): Ammonites del Jurásico superior y del Cretácico inferior de la Sierra Azul en la parte meridional de la provincia de Mendoza. – An. Mus. La Plata (N. S.), **1:** 1–99, La Plata.

Leanza, H. A. (1980): The Lower and Middle Tithonian ammonite fauna from Cerro Lotenia, Province of Neuquén, Argentina. – Zitteliana, **5:** 3–49, München.

Leanza, H. A. & A. Zeiss (1990): Upper Jurassic Lithographic Limestones from Argentina (Neuquén Basin): Stratigraphy and Fossils. – Facies, **22:** 169–186, Erlangen.

Leanza, H. A. & A. Zeiss (1992): On the ammonite fauna of the Lithographic Limestones from the Zapala region (Neuquén province, Argentina) with the description of a new genus. – Zbl. Geol. Paläont., (I), **1991**, 6: 1841–1850, Stuttgart.

Leanza, H. A. & A. Zeiss (1994): The lithographic limestones of Zapala (central Argentina) and their ammonite fauna. – Géobios **16:** 245–250, Lyon.

Legarreta, L. & M. A. Uliana (1991): Jurassic-Cretaceous marine oscillations and geometry of a back arc basin fill, central argentine Andes. – Spec. Publ. int. Ass. Sediment. **12:** 429–450, London.

MATSUOKA, A. & Q. YANG (1999): A direct Correlation between North American and Japan-pacific Radiolarian Zonal Schemes for the Upper Jurassic. – Georesearch Forum, **6:** 119–128, Zürich-Uetikon.

MYCZYŃSKI, R. (1989): Ammonite Biostratigraphy of the Tithonian of Western Cuba. – Ann. Soc. Geol. Polon., **59**/1–2: 43–125, Wroclaw.

MYCZYŃSKI, R. (1996): Discusión sobre la presencia de los géneros *Parodontoceras* SPATH, 1923 y *Lytohoplites* SPATH, 1925 en el Tithoniano de Cuba. – In: OLÓRIZ, F. & RODRÍGUEZ-TOVAR, F. J. (Eds): IV International Symposium Cephalopods – present and past. Granada, July 15–17, 1996, Abstr. Vol.: 125–126, Granada.

MYCZYŃSKI, R. (1999): Some ammonite genera from the Tithonian of western Cuba and their palaeobiogeographic importance. – Studia Geol.Polon., **114:** 93–112, Kraków.

MYCZYŃSKI, R. & PSZCZÓŁKOWSKI, A. (1990): Tithonian stratigraphy in the Sierra de los Organos, Western Cuba: correlation of the ammonite and microfossil zones. – In: PALLINI, G. et al.: Atti di secondo convegno internazionale Fossili, Evoluzione, Ambiente: 405–415, Pergola.

MYCZYŃSKI, R. & PSZCZÓŁKOWSKI, A. (1994): Tithonian stratigraphy and microfacies in the Sierra del Rosario, Western Cuba. – Stud. geol. polonica, **105:** 7–38, Krakow.

NIKOLOV, T. G. (1982): Les ammonites de la famille Berriasellidae SPATH, 1922. – 252 pp., Sofia (Ed. Acad. bulg. sci.).

OLÓRIZ, F., J. E. CARACUEL, B. MARQUES & F. J. RODRÍGUEZ-TOVAR (1995): Asociaciones de Tintinnoides en facies Ammonitico Rosso de la Sierra Norte (Mallorca). – Revista Española de Paleontología, N° Homenaje al Dr. Guillermo Colom: 77–93, Madrid. [OLÓRIZ et al.(1995)].

OLÓRIZ, F. & J. M. TAVERA (1979): El Tránsito Tithónico inferior – Tithónico Superior en las Cordilleras Béticas (Zona Sub-Betica). – Tecniterrae, **29:** 1–10, Madrid.

OLÓRIZ, F. & J. M. TAVERA (1981): El Jurassico superior en el sector central de la zona Sub-Bética, Introduccion al conocimiento de las Facies, Indices y Correlaciones. – R. Acad. Cienc. Exact., Fisic. y Natur., Curso Conferenc. Sobre el PIGG, **2:** 207–239, Madrid.

OLÓRIZ, F. & J. M. TAVERA (1983): Correlation of the Tithonian in Central Sector of the Betic Cordilleras (Spain) in the Light of Recent Studies. – Bull. Acad. Polon. Sci., Sér. Sci. de la Terre, **30**, No. 3–4: 147–156, Kraków.

PARENT, H. (2001): The Middle Tithonian (Upper Jurassic) ammonoid fauna of Cañadón de los Alzanes, Southern Neuquén – Mendoza Basin. – Boletin de Instituto de Fisiografía y Géología, **71**(1–2): 19–38, Rosario.

PARENT, H. (2003): The ataxioceratid ammonite fauna of the Tithonian (Upper Jurassic) of Casa Pincheira, Mendoza (Argentina). – Journ. S. Amer. Earth Sci., **16:** 143–165, New York. [PARENT (2003a)].

PARENT, H. (2003): Taxonomic and biostratigraphic re-evaluation of *Perisphinctes internispinosus* KRANTZ, 1926 (Upper Jurassic Ammonoidea). – Paläontologische Zeitschrift, **77**/2: 353–360, Stuttgart. [PARENT (2003b)].

PARENT, H. & S. E. COCCA (2007): The Tithonian (Upper Jurassic) ammonite succession at Portada Covunco, Neuquén-Mendoza Basin, Argentina. – Boletin de Instituto de Fisiografía y Geología, **77**(1–2), p. 25–30, Fig. 1–3, Rosario.

PARENT, H., A. SCHERZINGER, G. SCHWEIGERT & O. D. CAPELLO (2007): Ammonites of the Middle Tithonian Internispinosum Zone from Barda Negra, southern Neuquén-Mendoza Basin, Argentina. – Boletín del Istituto de Fisiografía y Geología, **77**(1–2), p. 11–24, Fig. 1–11, Rosario. [PARENT et al. (2007)].

PESSAGNO, E. A. JR., CH. D. BLOME, E. S. CARTER, N. MACLEOD, P. A. WHALEN & K. Y. YEN (1987): Studies of North American Jurassic Radiolaria. Part II. – Cushman Found. Foramin. Res., spec. Publ. **23:** 1–18, Norfolk/V. A. [PESSAGNO et al. (1987)].

PESSAGNO, E. A. JR., A. CANTÚ CHAPA, D. HULL, J. D. OGG & J. URRUTIA FACUGAUCHI (1996): New Data from North America on the placement of the Jurassic-Cretaceous Boundary. – Boll. 4°

Simp. Cretáceo do Brasil (1996): 15–20 – Campus Rio Claro/SP UNESP. [Pessagno et al. (1996)].

Pujana, I. (1991): Pantanelliidae (Radiolaria) from the Tithonian of the Vaca Muerta Formation, Neuquén, Argentina. – N. Jb. Geol. Paläont. Abh.: **180**(3): 391–408, Stuttgart.

Pujana, I. (1996): Occurrence of Vallupinae (Radiolaria) in the Neuquén Basin: Biostratigraphic implications. – In: Riccardi, A. C. (Ed.): Advances in Jurassic Research. Georesearch Forum **1–2:** 459–466, Zürich-Uetikon.

Quattrocchio, M. E., W. A. S. Sarjeant & W. Volkheimer (1996): Marine and terrestrial microfloras of the Neuquén Basin (Argentina): Palinological zonation. – In: Riccardi, A. C. (Ed.): Advances in Jurassic Research. Georesearch Forum **1–2:** 167–178, Zürich-Uetikon. [Quattrocchio et al., (1996)].

Quattrocchio, M. & W. A. S. Sarjeant (1992): Dinoflagellate cysts and Acritarchs from the Middle and Upper Jurassic of the Neuquen Basin, Argentina. – Rev. espan. Micropal., **24**/2: 67–118, Madrid.

Reháková, D. (2000): Calcareous dinoflagellate and calpionellid bioevents versus sea-level fluctuations recorded in the West-Carpathian (Late Jurassic/Early Cretaceous) pelagic environments. – Geol. Carpath., **51**,4: 229–243, Bratislava.

Reháková, D. (2002): *Chitinoidella* Trejo, 1975 in Middle Tithonian carbonate pelagic sequences of the West Carpathian Tethyan area. – Geol. Carpath., **53**,6: 369–379, Bratislava.

Rehákova, D. & J. Michalík (1997): Evolution and distribution of calpionellids – the most characteristic constituents of Lower Cretaceous Tethyan microplancton. – Cretaceous Research, **18:** 593–504, New York.

Remane, J. (1998): Les calpionelles: possibilités biostratigraphiques et limitations paléobiogéographiques. – Bull. Geol. France, **169**, 6: 829–839, Paris.

Roman, F. (1936): Le Tithonique du massif du Djurdjura (Province d'Alger). – Matér. carte géol. (1), Paléont., **7:** 1–43, Lyon.

Sarti, C. (1988): Biostratigraphic subdivision for the Upper Jurassic of the Venetian Alps (Northern Italy) on the base of ammonites. – In: Rocha, B. R. & Soares, A. F. (Eds): 2nd International Symposium on Jurassic Stratigraphy, **I:** 459–476, Lisboa.

Sato, T. (1962): Etudes biostratigraphiques des Ammonites du Jurassique du Japon. – Mém. Soc. Géol. France, N. S., **41**, Fasc. 1, Mémoire no. 94: 1–122, Paris.

Scasso, R. & A. Concheyro (1999): Nanofósiles calcáreos, duración y origen de ciclos caliza-marga (Jurásico tardío de la Cuenca Neuquina). – Rev. Asoc. geológica Argent. **54:** 290–297, Buenos Aires.

Schweigert, G. & A. Zeiss (1998): *Berckhemeria* n. g. (Passendorferiinae), eine neue Ammonitengattung aus dem Uniter-Tithonium (Hybonotum-Zone) von Süddeutschland. – N. Jb. Geol. Paläontol., Mh., **1998**(9): 559–576, Stuttgart.

Steuer, A. (1897): Argentinische Jura-Ablagerungen. Beiträge zur Kenntnis der Geologie und Paläontologie der argentinischen Anden. – Pal. Abh., N. F. **7**, 3: 127–222, Jena.

Tavera, J. M. (1985): Los ammonites del Titónico superior – Berriasense de la Zona Sub-bética (Cordilleras Béticas), Granada, España. – Tesis Doctoral. Universidad de Granada, 1–381, Granada.

Weaver, Ch. (1931): Paleontology of the Jurassic and Cretaceous from west central Argentina. – Univ. Washington, Mem. **1:** 1–469, Seattle.

Whitham, A. G. & P. Doyle (1989): Stratigraphy of the Upper Jurassic-lower Cretaceous Nordenskjöld Formation of eastern Graham Land, Antarctica. – Journal of South American Earth Sciences, **2**, no. 4: 371–384, New York.

Wright, C. W. (1980): Cretaceous Ammonoidea. – In: House, M. R. & Senior, J. R. (Eds.): The Ammonoidea. – The System. Assoc., Spec. Vol., **18:** 157–174, London.

Wright, C. W., J. H. Callomon & M. K. Howarth (1996): Cretaceous Ammonoidea. – Treat. Invertebr. Palaeont.: **L**/4 (revised), 362 pp., 216 figs., 2 tabs., Kansas.

Zeiss, A. (1979): Problema korrelacii v verchnej jure i nekotorye soobrazhenija o granice Jury i Mela. – In: Verchnaja jura i graniza ee c melovoj sistemoji: 14–27, Novosibirsk.

Zeiss, A. (1983): Zur Frage der Äquivalenz der Stufen Tithon/Berrias/Wolga/Portland in Eurasien and Amerika. Ein Beitrag zur Klärung der weltweiten Korrelation der Jura-Kreide Grenzeschichten im marinen Bereich. – Zitteliana, **10:** 427–438, München.

Zeiss, A. (1985): Preliminary determinations of Jurassic Ammonite species of Antarctic Peninsula. – Brit. Antarctic Survey [MS].

Zeiss, A. (1986): Comments on a tentative correlation chart for the most important marine provinces at the Jurassic-Cretaceous boundary. – Acta geol. hung. **29**(1–2): 27–30, Budapest.

Zeiss, A. (2001): Die Ammonitenfauna der Tithonklippen von Ernstbrunn/N. Ö. – Neue Denkschriften naturhist. Mus. Wien, **6:** 1–115, Wien.

Zeiss, A. (2003): The Upper Jurassic of Europe: its subdivision and correlation. – In: Surlyk, F. & J. R. Ineson (Eds): The Jurassic of Denmark and Greenland. – Geol. Surv. Denm. and Greenl., Bull., **1:** 75–114, Copenhagen.

Zeiss, A. & F. Bachmayer (1989): Zum Alter der Ernstbrunner Kalke (Tithon, Niederösterreich). – Ann. naturhist. Mus. Wien, **90**, A: 103–109, Wien.

Zeiss, A. & H. A. Leanza (1999): A new global correlation possibility at the base of the Upper Tithonian stage. – Terra Nostra, **99**/8: 86, Berlin-Steglitz.

Zeiss, A. & H. A. Leanza (2007): Upper Jurassic (Tithonian) Ammonites from the Lithographic Limestones of the Zapala region, Neuquén province, Argentina (MS).

Zügel, P. (1997): Discovery of a radiolarian fauna from the Tithonian of the Solnhofen area (Southern Franconian Alb, southern Germany). – Paläont. Z., **71:** 107–209, Stuttgart.