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NEW EFFORTS FOR A REVISION AND CORRELATION OF THE AMMONITE FAUNA OF THE NEUBURG FORMATION (TITHONIAN, SW GERMANY)

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Abstract. Ammonites collected bed-by-bed by the late K.W. Barthel allow a high biostratigraphic resolution of the succession of the Neuburg Formation (Unterhausen Member) into 2 regional Biochronozones (Ciliata Zone, Palmatus Zone) and 5 ammonite faunal horizons. The new finds are important for a revision of the taxa described in the monographs of Th. Schneid. The fauna consists of a Submediterranean stock of perisphinctids, together with some Tethyan and Subboreal faunal elements. Especially the co-occurring Tethyan immigrants *Volanoceras schwertschlageri*, *Virgatosimoceras rothpletzi*, and *Richterella* cf. *richteri* point to a correlation of basal parts of the Neuburg Formation with the Fallauxi Zone. In the younger faunal horizons the Tethyan influx strongly decreases, so that a direct correlation with the Tethyan standard zonation is impossible. Nevertheless, the ammonites of the younger horizons allow a correlation with the Subboreal zonal scheme.

Riassunto. Gli ammoniti raccolti strato per strato dal compianto K.W. Barthel permettono un'alta risoluzione biostratigrafica della successione della Formazione Neuburg (membro Unterhausen) in 2 Biocronozone regionali (Zona a Ciliata, Zona a Palmatus) e 5 orizzonti faunistici ad ammoniti. I nuovi ritrovamenti sono importanti per una revisione dei taxa descritti nelle monografie di Th. Schneid. La fauna consiste in un insieme submediterraneo di perisphinctidi, insieme con alcuni elementi faunistici tetidei e subboreali. Specialmente *Volanoceras schwertschlageri*, *Virgatosimoceras rothpletzi*, e *Richterella* cf. *richteri*, immigranti tetidei che si ritrovano insieme, indicano una correlazione della parte basale della Formazione Neuburg con la Zona a Fallauxi. Negli orizzonti faunistici più giovani, l'influsso tetideo decresce fortemente, tanto che una correlazione diretta con la zonazione standard tetidea è impossibile. Tuttavia, gli ammoniti degli orizzonti più giovani permettono una correlazione con lo schema zonale subboreale.

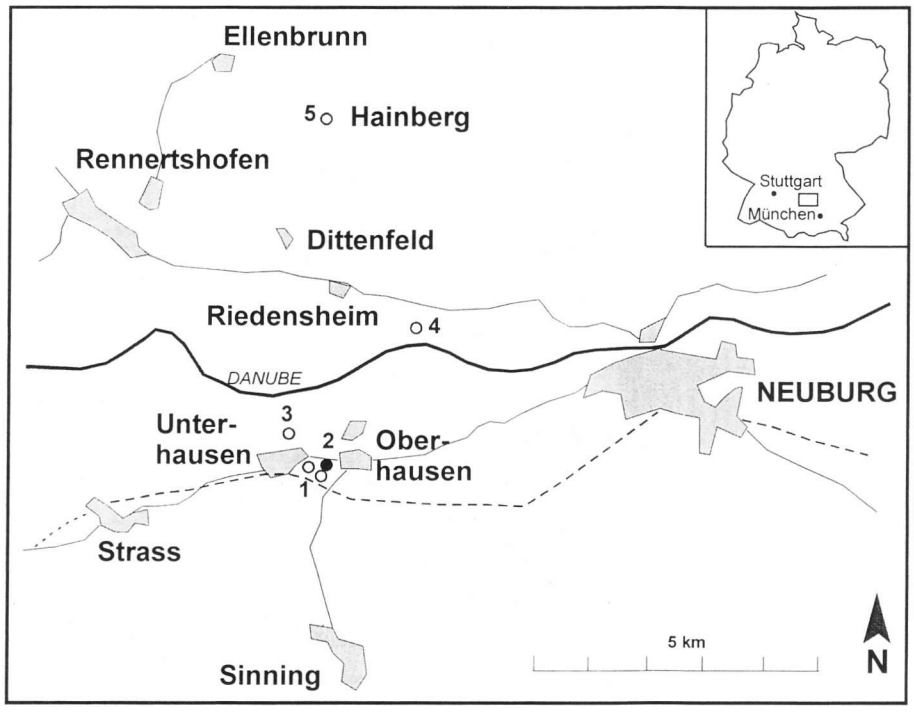

Fig. 1 - Location of exposures of the Tithonian Neuburg Formation in SW Germany. 1: quarries near railroad station of Unterhausen, 2: excavation of Barthel 1957 near Latour monument, 3: Flachsberg quarry, 4: Finkenstein, 5: Hainberg.

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Introduction

The surroundings of Neuburg (Fig. 1) provided the youngest ammonites hitherto known from Upper Jurassic strata of Franconia. This area, which was situated on the northern shelf of the Tethyan Ocean, is of high significance for a correlation of the Tethyan realm with adjacent bioprovinces. In the past, many efforts have been done to obtain a secure dating and correlation, mainly with Tithonian outcrops of SE France (St. Concors near Chambéry: Donze & Enay 1961; Ardèche area: Cecca 1988; Cecca & Enay 1991), and several ammonite taxa originally based on material from the Neuburg Formation were identified (and very often misidentified!) in wide-spread localities along the globe (e.g. Spath 1925; Roman 1936; Enay 1972; Kutek & Zeiss 1974, 1988, 1997; Enay & Geyssant 1975; Olóriz 1978; Olóriz & Tavera 1979; Sapunov 1979; Leanza 1980; Rossi 1984; Vigh 1984; Fözy 1988, 1989, 1993; Hantzpergue et al. 1998a, 1998b; Caracuel et al. 1998; Olóriz et al. 1999, Villaseñor et al. 2000).

Few ammonite species from the Neuburg Formation have been introduced very early in the literature by Oppel (1863) and Schlosser (1882), but the bulk of the material was described later in the exhaustive monographs of Schneid (1915, 1916). The material came from a series of about 30 metres of bedded micritic limestones, their exact finding levels, however, were unknown to Schneid, because the material had not been collected bed-by-bed.

In 1957, the late K.W. Barthel started an excavation campaign in the meanwhile abandoned quarry of Unterhausen, the type locality of the Unterhausen Member of the Neuburg Formation (Fig. 2). During this campaign, several hundreds of ammonites were collected bed-by-bed. In a number of publications, some glimpse on the material was presented (Barthel 1962, 1964, 1969, 1974), although only a minor part of the ammonite fauna was described besides several papers on bivalves, gastropods, decapods, and various microfossils. Some ammonites from the highest part of the underlying Rennertshofen Formation were published by Zeiss (1968). However, the most relevant stratigraphical data are available from the papers on some rare Tethyan perisphinctids and non-perisphinctid ammonites (Barthel 1962; Barthel & Geyssant 1973; Geyssant & Zeiss 1978). These were the base for a more recent critical analysis by Jeletzky (1989), which resulted in some conflict to former opinions, mainly advocated by A. Zeiss (Zeiss & Bachmayer 1989; Zeiss 2001).

In 1998, we started a re-examination of the type material of Schneid which is accompanied by a modern analysis of the large collections of K.W. Barthel. This includes the precise allocation of Schneid's ammonites to their horizons, the designation of lectotypes if necessary, the revision of Schneid's taxa after an analysis of the variation and ontogeny in both the types and the newly available material, the establishing of sexual dimorphism, and, last but not least, the phylogeny of the recognized successions of chronospecies. The material is housed in the collection of the "Bayerische Staatssammlung für Paläontologie und Geologie" at Munich (BSPM). Additional material was available in many other institutions, like the "Staatliches Museum für Naturkunde Stuttgart" (SMNS).

	Ammonite Zone	Formation	Member
? U. Tith.		Neuburg Fm.	Oberhausen Mb.
Lower Tithonian	Palmatus		Unterhausen Mb.
	Ciliata		
	Vimineus	Rennertshofen Fm.	
	Mucronatum	Usseltal Fm.	

Fig. 2 - Lithostratigraphic units in the Tithonian of Franconia (modified after Zeiss 1977a).

The succession of ammonite faunal horizons of the Neuburg Formation (Unterhausen Member)

The ammonites collected bed-by-bed from the Unterhausen Member of the Neuburg Formation (Fig. 3) allow the distinction of 5 ammonite faunal horizons (according to the concept of biostratigraphically isochronous faunal horizons explained by Callomon 1995). All of these horizons are mainly characterized by perisphinctids. The faunal horizons were formally already introduced by Scherzinger & Schweigert (1999). The *Glaber* horizon is renamed here as *Scoparius* horizon because its former index species, *Franconites glaber* (Schneid) was later also identified in the overlying *Palmatus* horizon.

Preliminary, brief overviews on the succession of certain ammonites were published by Barthel (1962) and by Kutek & Zeiss (1988). Additional investigations result in the recognition of three parallel dimorphic pairs of perisphinctids. Interestingly, during phylogeny, especially the macroconchs became very similar to each other so that a very careful analysis of their sculptural development is necessary for a secure distinction. Below, a list of ammonite taxa assigned to the faunal horizons is presented. Taxa cited in quotation marks need a further taxonomic revision.

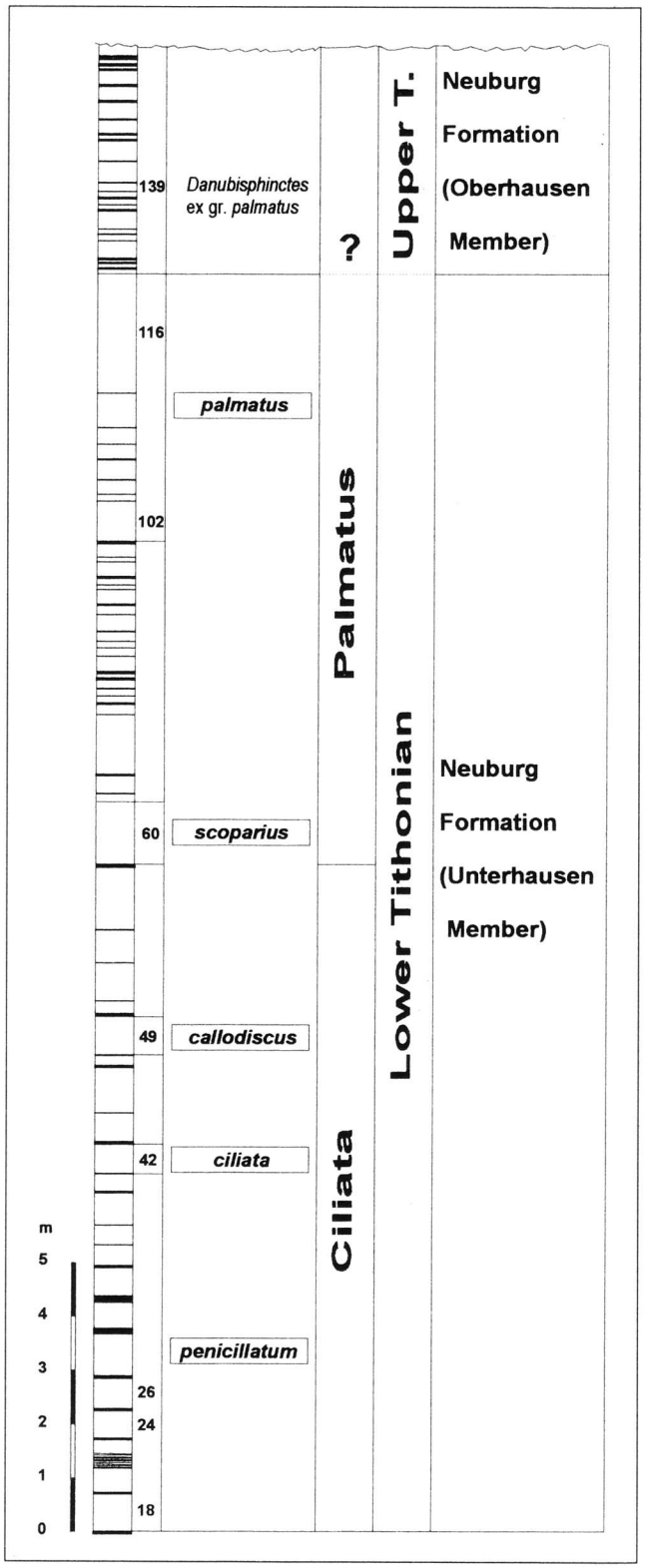

Fig. 3 - Idealised section of the Neuburg Formation (Unterhausen Member), at the type locality. Adapted from Barthel (1962), with high-resolution biostratigraphic subdivision.

Ciliata Zone

***Penicillatum* horizon**: *Sublithacoceras penicillatum* (Schneid) (M), "*Lemencia*" *pseudocontigua* (Donze & Enay) (m), *Franconites caesposus* (Schneid) (M), *Paraberriasella blondeti* Donze (m), *Danubisphinctes danubiensis* (Schlosser) (M), *Parapallasiceras praecox* (Schneid) (m), *Protancyloceras gracile* (Oppel) (m), *Volanoceras schwertschlageri* (Schneid) (M) (Pl. 1, fig. 3), *Virgatosimoceras rothpletzi* (Schneid) (M) (Pl. 1, fig. 1), "*Virgatosimoceras*" *broilii* (Schneid) (M), *Richterella* cf. *richteri* (Oppel) (m) (Pl. 1, fig. 4), *Calliphylloceras* sp. (?M), *Haploceras elimatum* (Oppel) (M), *Haploceras carachtheis* (Zeuschner) (m), "*Pseudolissoceras*" *concorsi* Donze & Enay (M) (Pl. 1, fig. 2), "*Glochiceras*" n. sp. (m), *Physodoceras neoburgense* (Oppel) (M), *Sutneria asema* (Oppel) (m), *Toulisphinctes rafaeli* (Oppel) (M), "*Perisphinctes*" *constrictor* Schneid (M), *Dorsoplanites lumbricarius* (Schneid) (?M).

***Ciliata* horizon**: *Sublithacoceras callizonus* (Schneid) (M) (Pl. 2, fig. 1), "*Lemencia*" *ciliata* (Schneid) (m) (Pl. 2, fig. 2), *Danubisphinctes* n. sp. (M), *Parapallasiceras* n. sp. (m), *Franconites jubatus* (Schneid) (M) (Pl. 2, fig. 4), *Paraberriasella* n. sp. (m) (Pl. 2, fig. 3), *Physodoceras neoburgense* (Oppel) (M), *Sutneria asema* (Oppel) (m), *Toulisphinctes rafaeli* (Oppel) (M).

***Callodiscus* horizon**: *Sublithacoceras callodiscus* (Schneid) (M), "*Lemencia*" n. sp. (m), *Danubisphinctes echidneus* (Schneid) (M), *Parapallasiceras* n. sp. (m).

Palmatus Zone

***Scoparius* horizon**: *Sublithacoceras* n. sp. (M), "*Lemencia*" *nitida* (Schneid) (m), *Danubisphinctes scoparius* (Schneid) (M), *Parapallasiceras* n. sp. (m), *Franconites glaber* (Schneid) (M).

***Palmatus* horizon**: *Danubisphinctes palmatus* (Schneid) (M) (Pl. 1, fig. 6), *Parapallasiceras spurius* (Schneid) (m) (Pl. 1, fig. 5), *Sublithacoceras* n. sp. (M), *Franconites glaber* (Schneid) (M), *Haploceras* sp. (M).

The older three of these faunal horizons, that means the *Penicillatum*, *Ciliata*, and *Callodiscus* horizons, are summarized in the Ciliata Zone of Schneid (1915), the younger two (*Scoparius* and *Palmatus* horizons) are included in the Palmatus Zone of Schneid (1915).

The ammonites described by Zeiss (1968) from the upper part of the Rennertshofen Formation are very close or even indistinguishable from those of basal parts of the overlying Neuburg Formation; in some sections there could be a chronological overlap between both formations.

Tethyan ammonites within the Neuburg faunas

Especially the lowermost faunal horizon of the Neuburg Formation (*Penicillatum* horizon), yields a larger number of ammonites with Tethyan affinity, which are most important for correlation purpose.

Already in 1973, Barthel & Geyssant tried to correlate the Neuburg succession with the Tethyan standard, but some of their determinations has led to contradictory interpretations. This concerns the misidentification of a fragmentary *Virgatosimoceras rothpletzi* (Schneid) as *V.* cf. *albertinum* (Catullo), thus pointing to a relatively old age of the basal part of the Neuburg Formation, starting already somewhere in the Albertinum Zone. However, all specimens of *Virgatosimoceras* (s.str.) from the Neuburg Formation including the types of *Simoceras rothpletzi*

Schneid and *Virgatosimoceras rothpletzi virgulifer* Geyssant & Zeiss come from the *Penicillatum* horizon, thus indicating the variability of a single chronospecies, the valid name of which is *V. rothpletzi* (Schneid). This species cannot be included in the same genus together with the co-occurring "*Simoceras*" *broilii* Schneid because of their totally different sculpture development. The latter belongs to another, still unnamed perisphinctid genus. A fragmentary record originally termed as "*Virgatosimoceras* (?) *broilii*" from strata of the *Palmatus* horizon (Barthel & Geyssant 1973) is a strange misidentification of a crushed *Danubisphinctes palmatus* (Schneid).

Aspidoceratids are represented by the relatively common *Physodoceras neoburgense* (Oppel) and its microconch partner *Sutneria asema* (Oppel), besides the very rare but palaeogeographically widespread *Toulisphinctes rafaeli* (Oppel). The single, very typical specimen of *Aspidoceras rogoznicense* (Zeuschner) figured by Schneid (1915, pl. 5, fig. 5, erroneously determined as "*Aspidoceras rafaeli*") could not be traced in the Munich collection and was probably lost during World War II.

Haploceratids are represented by *Haploceras carachtheis* (Zeuschner), *Haploceras elimatum* (Oppel), and, much rarer, by the macroconch "*Pseudolissoceras*" *concorsi* Donze & Enay (Pl. 1, fig. 2), which is conspecific with the Neuburg taxon "*P.*" *bavaricum* Barthel, and by a single specimen of the corresponding microconch originally described as "*Glochiceras* sp." (Barthel 1962, pl. 1, fig. 11). Although a Tethyan origin of the latter ammonite group was never questioned, we refrain from allocating them to the genus *Pseudolissoceras*, the type species of which (= *Pseudolissoceras zitteli* Burckhardt) from Argentina differs in many characters, especially in another architecture of the lateral lobe.

In the younger faunal horizons of Neuburg section, the Tethyan influx decreases remarkably, probably due to a falling sea level and changing current systems. In the *Palmatus* horizon, the uppermost ammonite bearing unit of the section, only few heavily crushed, insignificant *Haploceras* were found, erroneously identified as "*Pseudolissoceras*" *bavaricum* by Barthel (1962) and hence one of the main sources for an exclusively old dating of the finding level suggested by Jeletzky (1989). This erroneous identification was already recognized by Cecca (1988).

In the overlying Oberhausen Member, the lithofacies is typical of a shallow marine environment with abundant calcareous algae, oncoids, forams, echinoderms, and shelly debris. Few fragments of ammonites are too small for a secure identification, but most likely they still represent *Danubisphinctes* ex gr. *palmatus*.

Subboreal ammonites

Two monospecific taxa from the *Penicillatum* horizon were recently interpreted as Subboreal or even Boreal immigrants (Scherzinger & Schweigert 1999). However, our recent interpretation of the strange biplicate "*Perisphinctes*" *constrictor* Schneid as a macroconch *Sarmatisphinctes* appears doubtful in the light of newly studied material from the Lower Tithonian of SE France and S Germany, which is close to the lectotype of Schneid's species. Most probably "*Perisphinctes*" *constrictor* is a rare species of Submediterranean affinity.

The uniquely recorded *Dorsoplanites lumbricarius* (Schneid) points to a correlation with the Boreal Panderi Zone, but its correlation value is rather limited because of a widespread hiatus in the successions of the Russian Platform during the supposed age of the deposition of the lowermost Neuburg Formation.

More successful is a correlation based on the ammonite genus *Danubisphinctes* and its corresponding microconch *Parapallasiceras* (Pl. 1, figs. 5-6). *Parapallasiceras* is homoeomorphic with many other microconch perisphinctids from other palaeobiogeographical regions (e.g. Southern Spain, Argentina) and was hence often misidentified. In contrast to Zeiss (1968), Barthel (1974) and also later Zeiss (1977b) did not realise the evolution of the genus *Danubisphinctes* and included their younger representatives in a separate genus *Isterites*, which was supposed to occur together with late forms of *Danubisphinctes*. These younger forms have also been recorded from Central Poland (Kutek & Zeiss 1974, 1997), but not in the Klentnice beds as claimed by Zeiss (1977b).

Submediterranean ammonites

Besides the dimorphic genera *Danubisphinctes/Parapallasiceras* with its Subboreal to Submediterranean distribution, the main stock of perisphinctids of the Neuburg Formation exhibits a Submediterranean origin. They are represented by the dimorphic pairs *Sublithacoceras* [M] – group of "*Lemencia*" *ciliata* [m] (Pl. 2, figs. 1-2) and *Franconites* [M] – *Paraberriasella* [m] (Pl. 2, figs. 3-4). Their direct ancestors were found in the underlying beds of the Rennertshofen Formation, the ammonite fauna of which was almost exhaustively described by Zeiss (1968). Several Submediterranean ammonites of the *Penicillatum* horizon of the Neuburg Formation are also recorded from Savoy (St. Concors, SE France) (see Donze & Enay 1961; Barthel 1964; Zeiss 1968). Interestingly, the youngest representatives of *Sublithacoceras* became not only equally large as the co-occurring *Danubisphinctes*, but also got a very similar adult sculpture with virgatotome ribs. They are only distinguishable in regard of their different early sculptural stages and another mode of coiling. Possibly, this striking homoeomorphy was forced by palaeoecological factors or palaeoethological reasons. Among the three lineages of perisphinctids, the couple *Franconites/Paraberriasella* is still incompletely recorded in the younger horizons,

where the Submediterranean/Subboreal dimorphic pair *Danubisphinctes/Parapallasiceras* became predominant.

Correlations

For a correlation with the standard zonation, the most important ammonites are those of Tethyan origin. This was already stressed by Barthel & Geyssant (1973). Most interesting within these Tethyan immigrants is the occurrence of the simoceratid *Volanoceras schwertschlageri* (Schneid) (Pl. 1, fig. 3). Geyssant (1988) interpreted its occurrence in the succession of Neuburg as an example of punctuated equilibrium evolution, because the species *V. schwertschlageri* was at that time unknown from Tethyan successions, with the exception of a questionable record from the Western Alps (Thieuloy 1963). Her interpretation is very unlikely since in this case *Volanoceras schwertschlageri* should be more common in Submediterranean successions than in Tethyan ones. However, up to the present, the holotype is the only specimen from the Submediterranean. Some time later, several specimens of *Volanoceras* from Spain and Hungary were interpreted as *V. schwertschlageri* for morphological reasons, purely pointing to their prorsiradiate ribbing which is, however, only partly developed in one of the flanks of the holotype of *V. schwertschlageri* and appears not to be diagnostic (Olóriz 1978; Fözy 1988). These specimens were found to co-occur with *Volanoceras volanense* (Oppel), a species which is very characteristic of the late Early Tithonian Volanense Zone, which is an equivalent of the Ponti Zone. Meanwhile, we got several *V. schwertschlageri* from the Fallauxi Zone of the Subbetic Jurassic of southern Spain. These specimens were all found together with *Simoceras admirandum* (Zittel), an index species of the Tethyan Admirandum/Biruncinatum Subzone which is known to represent a time equivalent of the upper part of the Fallauxi Zone of the Tethyan standard (Cariou & Hantzpergue 1997). Moreover, the morphological analysis of the sculptural development during ontogeny within the representatives of *Volanoceras* showed that *V. schwertschlageri* is transitional between *V. krantzense* and *V. volanense*. We were also able to identify *V. krantzense* Cantú Chapa, previously only known from South America (= *Simoceras* aff. *volanense* Opp. in Krantz 1928), in southern Spain coming from beds belonging to the late Semiforme/Verruciferum Zone (for more details see Schweigert et al. 2002).

Additionally, we recorded a typical specimen of *Virgatosimoceras rothpletzi* (Schneid) from the Tithonian of Savoy. Originally, it was misidentified by Donze & Enay (1961, pl. 17, fig. 3) as a perisphinctid (for more details see Scherzinger & Schweigert, in preparation). This occurrence underlines the correlation between the Fallauxi Zone of SE France and parts of the Ciliata Zone of SW Germany. Of course, not all "*Virgatosimoceras rothpletzi*" hitherto published fit with this *Virgatosimoceras* chronospecies, which is typical of the *Penicillatum* horizon.

At least, within the fauna of the *Penicillatum* horizon, a single specimen of *Richterella* cf. *richteri* (Oppel) (Pl. 1, fig. 4) points to the lower part of the Tethyan Fallauxi Zone (Cecca 1986; Cecca & Enay 1991). It is characterized by a strong proverse projection of the secondaries forming a chevron-like sculpture on the venter, but lacking a ventral furrow like in other perisphinctids of this horizon. Very similar forms described as "*Richterella* aff. *richteri*" by Cecca (1986) and Cecca & Enay (1991) occur already in the upper part of the Semiforme/Verruciferum Zone. However, in the latter, the secondaries are projecting more gradually than in true *R. richteri*, so that the morphology of our specimen fits better with that of *R. richteri*.

As a result of the above data, the correlation of the *Penicillatum* horizon, and hence of the lower part of the Ciliata Zone, within the lower part of the Tethyan Fallauxi Zone, seems most convincing. Surely, because of the misidentification of a fragmentary *Virgatosimoceras rothpletzi* as *V.* cf. *albertinum* by Barthel & Geyssant (1973) it was reasonable to take the lower part of the Neuburg succession very close to the Darwini/Albertinum Zone, and to include the time interval of the Semiforme/Verruciferum Zone somewhere in these basal beds.

The subdivision of a *Palmatus* horizon and an overlying *Subpalmatus* horizon in central Poland and S Germany, which was adopted from crushed and fragmentary material (Kutek & Zeiss 1997; Zeiss 2001), is not reliable in respect of the poor preservation of the Polish material and the co-occurrence of both taxa within the same beds at their type locality at Neuburg. Moreover, an evolution of *Danubisphinctes* from a *palmatus* to a *subpalmatus* morphology is not recognizable even by means of statistics on the numerous material collected bed-by-bed from the Unterhausen section.

The youngest biostratigraphic horizon for the succession of the Neuburg Formation was formerly taken by the record of a single calpionellid in a reworked lithoclast termed as *Crassicollaria* by Barthel (1969). This record, however, appears rather doubtful in regard of the presence of only one questionable record in thin sections (although according to Barthel the determination was confirmed by J. Remane). A re-investigation of the thin section, which was said to contain the figured specimen, was not successful because it yielded neither a calpionellid nor anything else similar. Moreover, it is of little value, because the sample with the doubtful calpionellid was said to come from a limestone bed in a tectonically disturbed area, the exact position within the succession remains unclear. As a result, the upper boundary of the Neuburg section cannot be correlated directly with the Tethyan zonation.

Conclusions

The correlation of the basal limestone beds of the Neuburg Formation in Franconia with the Fallauxi Zone Tethyan standard is confirmed by age-diagnostic Tethyan immigrants like *Volanoceras schwertschlageri*, *Virgatosimoceras rothpletzi*, and *Richterella* cf. *richteri*. They all occur in the *Penicillatum* horizon of the Submediterranean Ciliata Zone. Although a high resolution of the higher parts of the Neuburg Formation by means of ammonite faunas into another 4 faunal horizons is fairly possible, the predominating Submediterranean or Subboreal character of the remaining ammonite groups prevents a direct correlation with the Tethyan standard. The upper limit for the deposition of these limestones formerly given by the reference of a single calpionellid specimen appears ambiguous.

The occurrence of *Danubisphinctes palmatus* both in the higher part of the Unterhausen Member and in the Subboreal Upper Jurassic of Central Poland establishes a very precise correlation also with the Russian Platform and some southward exposures.

As a result, the ammonite faunas of the Neuburg Formation reveal a step-by-step correlation between Tethyan, Submediterranean, and even Sub-/Boreal localities.

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PLATE 1

Fig. 1-4 - Age diagnostic Tethyan immigrants of the Neuburg Formation (Unterhausen Member).

Fig. 1 - *Virgatosimoceras rothpletzi* (Schneid), plaster cast of negative print, most probably from bed 26, *Penicillatum* horizon, BSPM 1913 IX 201. Fig. 2 - "*Pseudolissoceras*" *concorsi* Donze & Enay (= holotype *Pseudolissoceras bavaricum* Barthel), bed 28, *Penicillatum* horizon, BSPM 1957 VI 21. Fig. 3 - *Volanoceras schwertschlageri* (Schneid), holotype, most probably from bed 26, *Penicillatum* horizon, BSPM 1913 IX 200. Fig. 4 - *Richterella* cf. *richteri* (Oppel), lateral and ventral view; bed 24, *Penicillatum* horizon, BSPM 1957 VI 4495.

Fig. 5, 6 - Examples of dimorphic Submediterranean/Subboreal perisphinctids from the Neuburg Formation (Unterhausen Member).

Fig. 5 - *Parapallasiceras spurius* (Schneid) (m), bed 116, *Palmatus* horizon, BSPM 1957 VI 5201. Fig. 6 - *Danubisphinctes palmatus* (Schneid) (M), bed 116, *Palmatus* horizon, BSPM 1957 VI 5192.

All specimens are figured in natural size, except of Fig. 6 (x 0.75).

PLATE 2

Fig. 1-4 - Examples of dimorphic Submediterranean perisphinctids from the Neuburg Formation (Unterhausen Member).

Fig. 1 - *Sublithacoceras callizonus* (Schneid) (M), bed 42, *Ciliata* horizon, BSPM 1957 VI 4843. Fig. 2 - "*Lemencia*" *ciliata* (Schneid) (m), bed 42, *Ciliata* horizon, BSPM 1957 VI 4744. Fig. 3 - *Paraberriasella* n. sp. (m), bed 42, *Ciliata* horizon, BSPM 1957 VI 4560.

Fig. 4 - *Franconites jubatus* (Schneid) (M), bed 42, *Ciliata* horizon, SMNS 64860.

All specimens are figured in natural size, except of Fig. 1 (x 0.75).

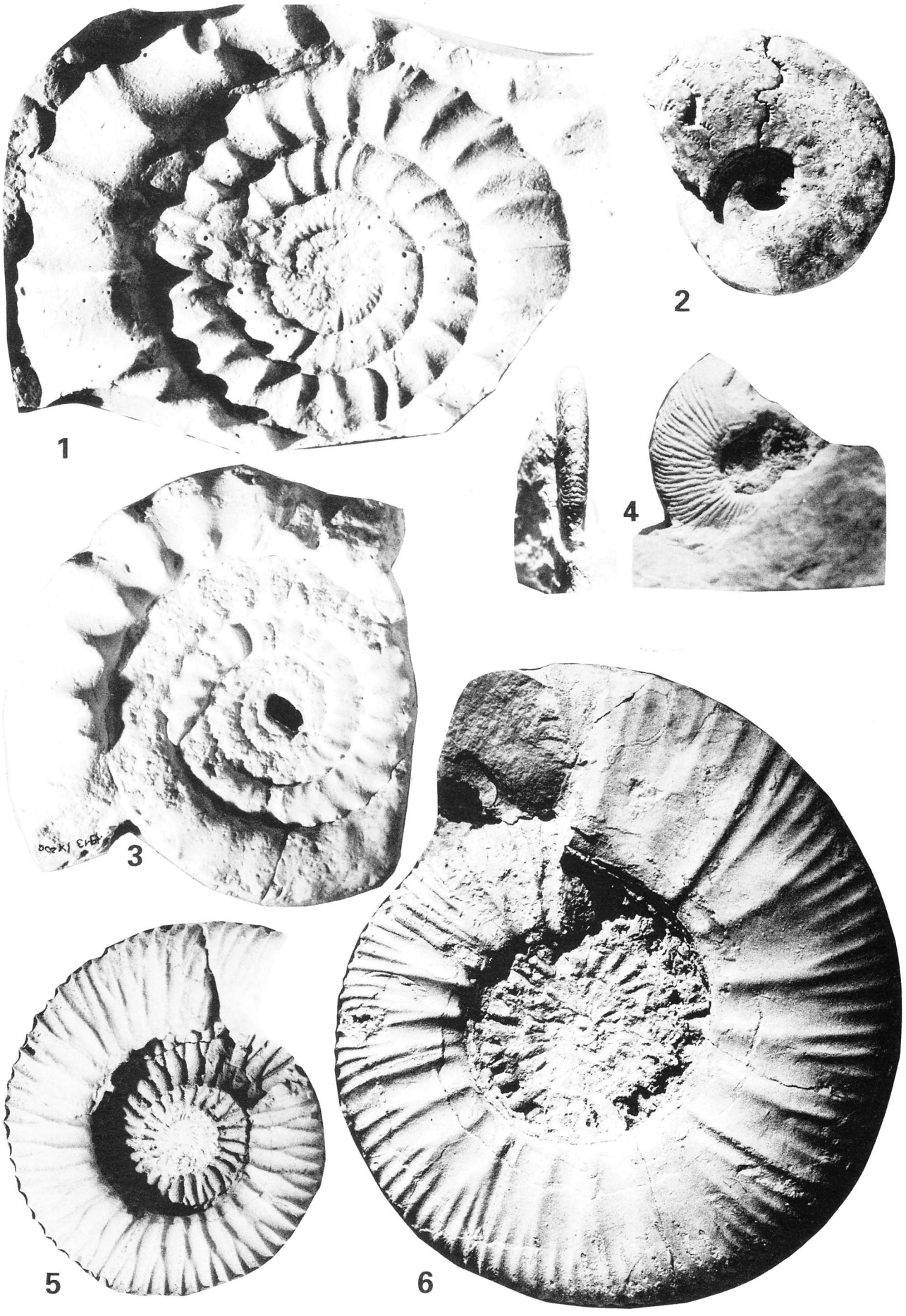

PLATE 1

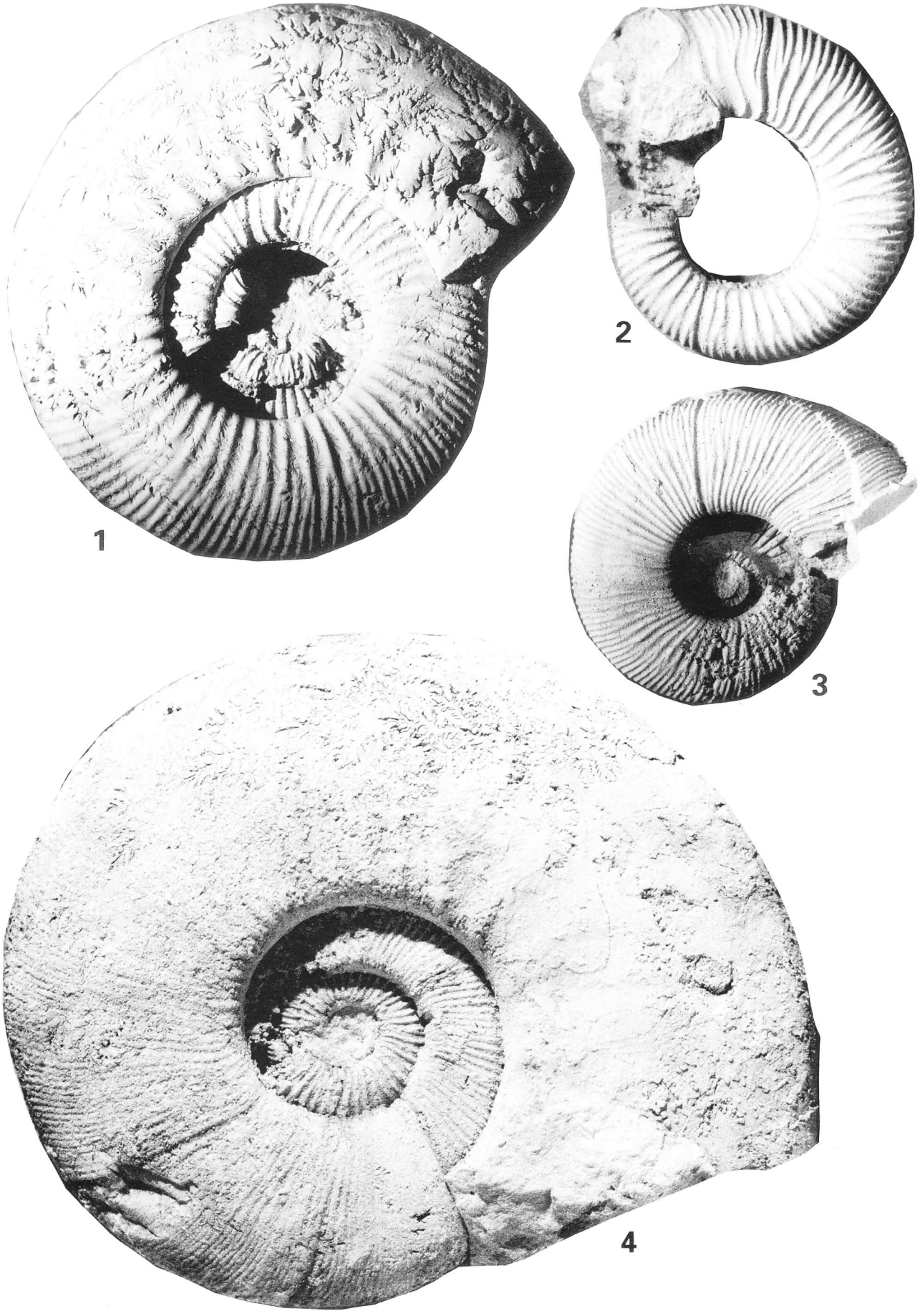

PLATE 2

REFERENCES

Barthel K.W. (1962) - Zur Ammonitenfauna und Stratigraphie der Neuburger Bankkalke. *Abh. Bayer. Akad. Wiss., math.-naturwiss. Kl., N. S.*, 105: 1-30, München.

Barthel K.W. (1964) - Die Verteilung der Cephalopoden in den Neuburger Bankkalken, ihr Vergleich mit der Ammonitenfauna von St-Concors und kurze Bemerkungen zum Zonenbegriff. Coll. Jurassique Luxembourg, 1962. *C.R. & Mem.*, 513-517, Luxembourg.

Barthel K.W. (1969) - Die obertithonische, regressive Flachwasser-Phase der Neuburger Folge in Bayern. Abh. Bayer. *Akad. Wiss., math.-naturwiss. Kl.*, N. F., 142: 1-174, München.

Barthel K.W. (1974) - *Isterites* gen. nov. (Ammonitina). *J. Paleont.*, 49: 426, Lawrence.

Barthel K.W. & Geyssant J.R. (1973) - Additional Tethydian ammonites from the lower Neuburg formation (Middle Tithonian, Bavaria). *N. Jb. Geol. Paläont. Mh.*, 1973: 18-36, Stuttgart.

Callomon J. H. (1995) - Time from fossils: S.S. Buckman and Jurassic high-resolution geochronology. In Le Bas, M.J. (Ed.): Milestones in geology. *Geol. Soc., Mem.*, 16: 127-150, London.

Caracuel J., Olóriz F. & Sarti C. (1998) - Updated biostratigraphy of the Kimmeridgian and Lower Tithonian at Lavarone (Trento Plateau, Italy). Correlation for epi-oceanic Western Tethys. *Geologica et Palaeontologica*, 32: 235-251, Marburg.

Cariou E. & Hantzpergue P. (coord.) (1997) - Biostratigraphie du Jurassique Ouest-Européen et Méditerranéen: Zonations parallèles et distribution des invertébrés et microfossiles. *Bull. Centre Rech. Elf Explor. Prod., Mém.*, 17: XIV + 440 pp., Pau.

Cecca F. (1986) - Le genre *Richterella* Avram (Ammonitina, Périsphinctidés) dans le Tithonique inférieur de la bordure ardéchoise (Sud-Est de la France): dimorphisme et variabilité. *Geobios*, 19: 33-44, Lyon.

Cecca F. (1988) - Ammonites méditerrannéennes du Tithonique inferieur de l`Ardèche: analyse des afflux téthysiens. *Geobios*, 21: 169-186, Lyon.

Cecca F. & Enay R. (1991) - Les ammonites des zones à Semiforme et à Fallauxi du Tithonique de l'Ardèche (Sud-Est de la France): stratigraphie, paléontologie, paléobiogéographie. *Palaeontographica, A*, 219: 1-87, Stuttgart.

Donze P. & Enay R. (1961) - Les Céphalopodes du Tithonique inférieur de la Croix-de-Saint-Concors près Chambéry (Savoie). *Trav. Lab. Géol. Lyon, (N. S.)*, 7: 1-236, Lyon.

Enay R. (1972) - Paléobiogéographie des Ammonites du Jurassique terminal (Tithonique/Volgien/Portlandien l.s.) et mobilité continentale. *Geobios*, 5: 355-407, Lyon.

Enay R. & Geyssant J. R. (1975) - Faunes tithoniques des chaînes bétiques (Espagne méridionale). Coll. Limite Jurassique-Crétacé, Lyon-Neuchâtel, 1973. *Mém. B.R.G.M.*, 86: 39-55, Paris.

Fözy I. (1988) - Tithonian ammonites (Oppeliidae, Haploceratidae and Simoceratidae) from the Transdanubian Central Range, Hungary. *Ann. Univ. Sci. Budapest, Sect. Geol.*, 28: 43-119, Budapest.

Fözy I. (1989) - Felsőjura ammonitesz biosztratigráfia a Bakony hegységben. *Foldtani Közlöny*, 119: 133-156, Budapest.

Fözy I. (1993) - Upper Jurassic ammonite biostratigraphy of the Mecsek Mts., southern Hungary. *Foldtani Közlöny*, 123: 195-205, Budapest.

Geyssant J. R. (1988) - Diversity in Mode and Tempo of Evolution within one Tithonian Ammonite Family, the Simoceratids. In Wiedmann J. & Kullmann J. (Eds.): Cephalopods – Present and Past. 79-88, Stuttgart (Schweizerbart).

Geyssant J. R. & Zeiss A. (1978) - Une nouvelle forme de *Virgatosimoceras* (Ammonitina, Simoceratinae) dans le Tithonique de Neuburg (Donau), en Bavière (Formation de Neuburg Inférieur). *Geobios*, 11: 175-187, Lyon.

Hantzpergue P., Baudin F., Mitta V., Olferiev A. & Zakharov V.A. (1998a) - Le Jurassique supérieur du bassin de la Volga: biostratigaphie des faunes d'ammonites et corrélations avec les zonations standards européennes. *C. R. Acad. Sc. Paris, Sci. terre plan.*, 326: 633-640, Paris.

Hantzpergue P., Baudin F., Mitta V., Olferiev A. & Zakharov V.A. (1998b) - The Upper Jurassic of the Volga Basin: ammonite biostratigraphy and occurrence of organic-carbon rich facies. Correlations between Boreal-Subboreal and Submediterranean Provinces. In Crasquin-Soleau S. & Barrier E. (Eds.): Epicratonic basins of Peri-Tethyan Platforms. Peri-Tethys Mémoir 4, *Mém. Mus. Nat. hist. Nat.*, 179: 9-33, Paris.

Jeletzky J.A. (1989) - Age of Neuburg Formation (Bavaria, Federal Republic of Germany) and its correlation with the Subboreal Volgian and Mediterranaean Tithonian. *Newsl. Stratigr.*, 20: 149-169, Berlin & Stuttgart.

Krantz F. (1928) - La Fauna del Titono superior y medio de la parte meridional de la provincia de Mendoza. *Act. Acad. Nac. Cienc. Rep. Argentina*, 10 (4): 1-57, Córdoba.

Kutek J. & Zeiss A. (1974) - Tithonian-Volgian ammonites from Brzostówka near Tomaszów Mazowiecki, Central Poland. *Acta geol. Pol.*, 24: 505-542, Warszawa.

Kutek J. & Zeiss A. (1988) - Further data on the correlation of the Middle/Upper Tithonian with the Lower/Middle Volgian Boundary. In Rocha R.B. & Soares A.F. (Eds.): 2nd Intern. Symposium on Jurassic Stratigraphy, 623-639, Lisboa.

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

Leanza H.A. (1980) - The Lower and Middle Tithonian ammonite fauna from Cerro Lotena, province of Neuquén, Argentina. *Zitteliana*, 5: 1-49, München.

Olóriz F. (1978) - Kimmeridgiense-Tithonico inferior en el Sector central de las Cordilleras Béticas (Zona Subbética). Paleontologia, Bioestratigrafia. Tesis Doctorales Univ. Granada, 184: 758 pp., Granada.

Olóriz F. & Tavera J.M. (1979) - El transito Tithonico inferior-Tithonica superior en las Cordilleras Béticas (Zona Subbética). *Tecniterrae*, 29: 1-10, Madrid.

Olóriz F., Villaseñor A.B., Gonzales-Arreola C. & Westermann G.E.G. (1999) - Ammonite biostratigraphy and correlations in the Upper Jurassic – Lowermost Cretaceous

Caja Formation of North-Central Mexico (Sierra de Catorce, San Luis Potosí. In Olóriz F. & Rodriguenz-Tovar F.J. (Eds.): Advancing research on living and fossil cephalopods: 463-492, Kluver Academic & Plenum Publishers, New York.

Oppel A. (1863) - Palaeontologische Mitteilungen. III. Ueber jurassische Cephalopoden. *Palaeont. Mitt. Mus. Bayer. Staat.*, 1: 163-266, Stuttgart.

Roman F. (1936) - Le Tithonique du Djurjura. Material pour la Carte géologique de l'Algerie, *1° ser., Paléont.*, 7: 1-43; Paris.

Rossi F. (1984) - Ammoniti del Kimmeridgiano superiore-Berrisiano inferiore del Passo del Furlo (Appennino Umbro-Marchigiano). *Mem. Soc. Ital. Sc. Nat.*, 23/3: 73-136, Milano.

Sapunov I.G. (1979) - Les fossiles de Bulgarie. III. 3. Jurassique supérieur, Ammonoidea. *Publ. Acad. Bulg. Sci.*: 1-263, Sofia.

Scherzinger A. & Schweigert G. (1999) - Die Ammoniten-Faunenhorizonte der Neuburg-Formation (Oberjura, Südliche Frankenalb) und ihre Beziehungen zum Volgium. *Mitt. Bayer. Staatsslg. Paläont. hist. Geol.*, 39: 3-12, München.

Schlosser M. (1882) - Die Fauna des Kelheimer Diceras-Kalkes. *Palaeontographica*, 28: 47-109, Kassel.

Schneid T. (1915) - Die Ammonitenfauna der obertithonischen Kalke von Neuburg a.D. *Geol. Palaeont. Abh., N. S.*, 13/5: 305-416, Jena.

Schneid T. (1916) - Die Geologie der fränkischen Alb zwischen Eichstätt und Neuburg a. D. *Geognost. Jh.*, 27 (1914): 59-172, München.

Schweigert G., Scherzinger A. & Parent H. (2002) - The *Volanoceras* lineage (Ammonoidea, Simoceratidae) – a tool for long-distance correlations in the Lower Tithonian. *Stuttgarter Beitr. Naturkde., B*, 326: 1-43, Stuttgart.

Spath L.F. (1925) - On the collection of fossils and rocks from Somaliland made by Messrs. B. K. W. Wyllie, B. Sc., F. G. S., and W. R. Smellie, D. Sc, F. R. S., part. VII. Ammonites and Aptychi. *Monogr. geol. Depart. Hunterian Mus.*, 1: 111-164, Glasgow.

Thieuloy J.P. (1963) - Nouveaux apports à la faune tithonique du col du Lauzon (Hautes-Alpes). *Trav. Lab. Géol. Fac. Sc. Grenoble*, 39: 283-302, Grenoble.

Vigh G. (1984) - Die Biostratigraphische Auswertung einiger Ammoniten-Faunen aus dem Tithon des Bakonygebirges sowie aus dem Tithon-Berrias des Gerecsegebirges. *Ann. Inst. Geol. Publ. Hungarica*, 67: 1-210, Budapest.

Villaseñor A.B., Olóriz F. & González-Arreola C. (2000) - Recent Advances in Upper Jurassic (Kimmeridgian – Tithonian Ammonite Biostratigraphy of North-Central Mexico Based on Recently Collected Ammonite Assemblages. In Hall R.L. &. Smith P.L. (Eds.): Advances in Jurassic Research 2000. *GeoResearch Forum*, 6: 249-261, Zürich.

Zeiss A. (1968) - Untersuchungen zur Paläontologie der Cephalopoden des Unter-Tithon der Südlichen Frankenalb. *Abh. Bayer. Akad. Wissensch., Math.-Naturwiss. Kl., N. S.*, 132: 1-191, München.

Zeiss A. (1977a) - Jurassic stratigraphy of Franconia. *Stuttgarter Beitr. Naturkde., B*, 31: 1-32, Stuttgart.

Zeiss A. (1977b) - Some ammonites of the Klentnice Beds (Upper Tithonian) and remarks on correlation of the uppermost Jurrasic. *Acta geol. Pol.*, 27: 369-386, Warszawa.

Zeiss A. (2001) - Die Ammonitenfauna der Tithonklippen von Ernstbrunn, Niederösterreich. *N. Denkschr. Naturhist. Mus. Wien*, 6: 114 pp., Wien.

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