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Ammonite biostratigraphy as a tool for dating Upper Jurassic lithographic limestones from South Germany – first results and open questions

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With 5 figures and 1 table

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Abstract: Although the Upper Jurassic lithographic limestones of Franconia and Swabia belong to the worldwide most famous fossil sites ('Fossil Lagerstätten'), a detailed biostratigraphical analysis was missing. Often the various fossiliferous localities, distributed over an area of several hundreds of square kilometres, were summarized as 'Solnhofen', and an early Tithonian age was traditionally assumed for most of them, with few exceptions. This is the first comprehensive attempt for a high-resolution biostratigraphy based on ammonite biohorizons. The different ages of laminated limestones obtained by this method, ranging from the Kimmeridgian Pseudomutabilis Zone to the Tithonian Ciliata Zone – a duration of ca. 4 Ma – provide a basis for future high time-resolution correlations, environmental reconstructions, and deposition-modelling.

Key words: Ammonites, laminated limestones, Solnhofen, biohorizons, high resolution datings, Kimmeridgian, Tithonian.

1. Introduction – previous work

The occurrence of lithographic limestones in Franconia and Swabia is long known due to their former economical usage for lithography or roof tiles. During the quarrying spectacular fossils in excellent preservation, like fishes, pterosaurs, crocodiles, arthropods, etc. were recovered but only little attention was drawn to ammonites. Jurassic ammonites are known to be excellent indicators for age determinations due to their rapid evolution. Thus they are often used as guide fossils, and standard chronostratigraphy in the Jurassic is consequently based on ammonite biostratigraphy. However, the stratigraphic value of ammonites occurring in lithographic limestones (including plattenkalks and similar laminated limestones) was often neglected in the past because of their often poor preservation due to compaction and distortion. Since the early descriptions of some ammonite species by QUENSTEDT (1887-1888) and OPPEL (1863) for a long time only very little material was studied, except of the monograph of SCHNEID (1916).

The Tithonian stage was preliminarily introduced by OPPEL (1865) without giving a clear definition. He listed several localities all over Europe yielding typical faunas, among them the lithographic limestones of Solnhofen, Eichstätt, and Nusplingen. The

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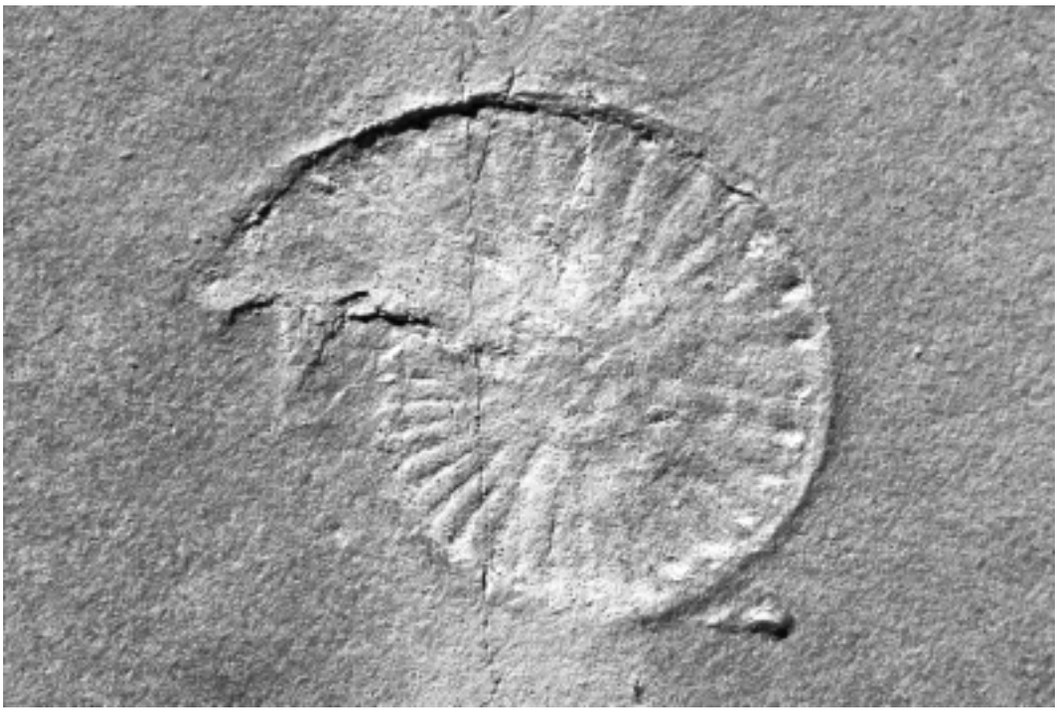

Fig. 1. *Aulacostephanus eudoxus* (D'ORBIGNY). Wattendorf Member, Wattendorf, northern Franconia; Upper Kimmeridgian, Pseudomutabilis Zone; Naturkundemuseum Bamberg, no. Watt. E 144 (diameter of specimen: 50 mm).

latter localities originally represent part of the "Weißjura zeta" of QUENSTEDT (1856-1858) but this unit spans a very large stratigraphical range, and some of OPPEL's original determinations and correlations were incorrect. In Swabia and Franconia the "Weißjura zeta" was independently subdivided, mainly according to the lithological successions in different areas, but also with some biostratigraphic implications. This mixture of litho- and biostratigraphic terminology is highly misleading and should be abandoned, although it is still very popular. Alternatively, ZEISS (1977) proposed a new lithostratigraphic frame for the Upper Jurassic of Franconia, which should be the basis for all future work. It is important that there is a complex differentiation of lithofacies in neighbouring areas of Franconia, which made the introduction of many new lithostratigraphic units indispensable instead of QUENSTEDT's alphabetic numbering. The correlation between these units, however, was only preliminary. During the last decade it became obvious that severe problems exist concerning correlation of Upper Jurassic strata between Swabia and Franconia (SCHWEIGERT & ZEISS 1994), and several newly collected ammonite faunas were studied, including material from lithographic limestones (SCHWEIGERT et al. 1996; SCHWEIGERT 1998, 2000; SCHWEIGERT & ZEISS 1998, 1999; ZEISS 1992, 2001). The correlations between Swabia and Franconia and also within the Franconian Upper Jurassic proposed by ROLL (1933, 1940) are responsible for other confusions. It became clear that, like in the Lower and Middle Jurassic, also in the Upper Jurassic a high-resolution biostratigraphic frame based on ammonite faunal horizons is necessary for precise correlations and datings.

2. The Kimmeridgian/Tithonian boundary

At present there is a general agreement that the Tithonian Stage should start with the Hybonotum Zone. The Hybonotum Zone has been subdivided into three subzones (see ZEISS 1968) and, more recently, into several ammonite faunal horizons (SCHWEIGERT 2000), but no GSSP has been defined yet by international plenary ratification, and the exact position of the Kimmeridgian/Tithonian boundary is still a case of debate (SCHWEIGERT & ATROPS 2006). For this reason the age of many of the lithographic limestones

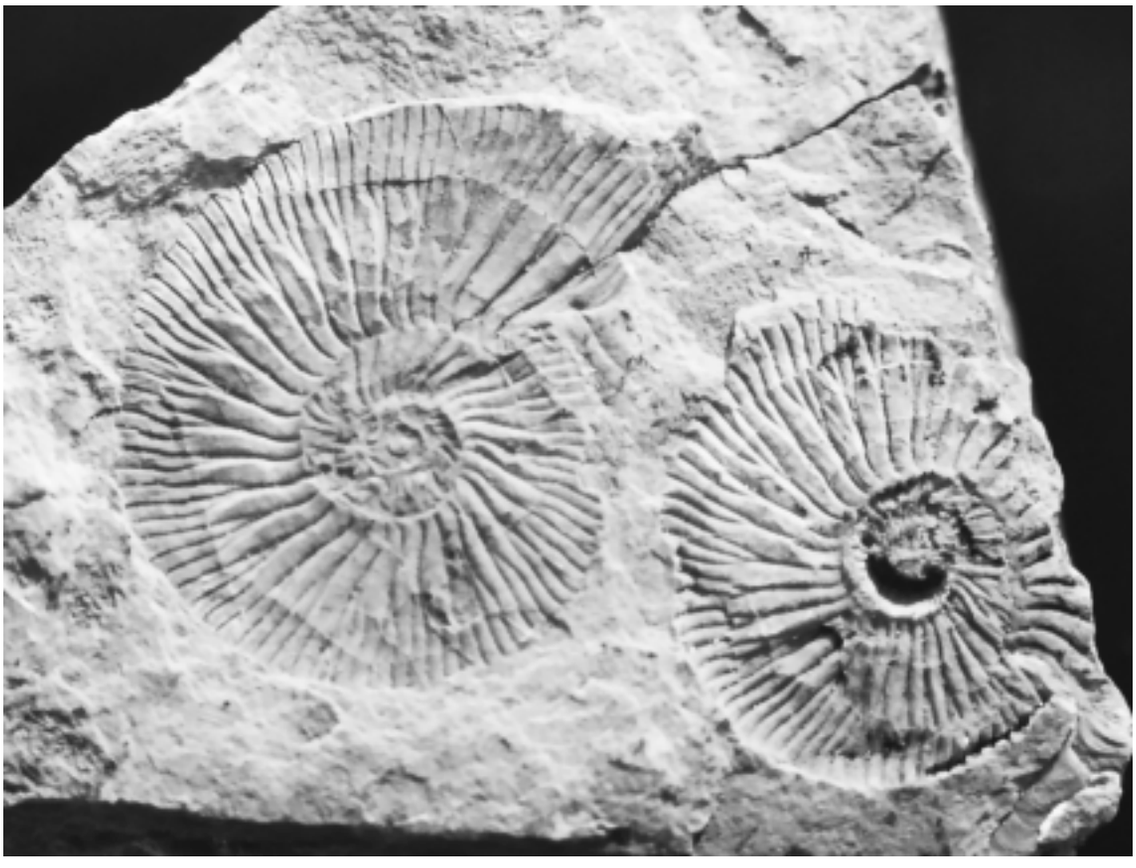

Fig. 2. *Virgataxioceras setatum* (SCHNEID), counterplate of SCHNEID 1916: pl. 6, fig. 4. Arnstorf Member, Dörndorf near Beilngries, Franconia, Upper Kimmeridgian, Beckeri Zone, Setatum Subzone, *ornatum* horizon; Jura-Museum Eichstätt, without no. (diameter of left specimen: 53 mm)

can be dated with some accuracy but it is possible that in near future the lower boundary of the Tithonian may be drawn deeper or, more likely, even higher in the section, with an inclusion of the Riedense Subzone (sensu ZEISS 1968, 1977) into the Kimmeridgian. Of course this would be in some conflict with tradition going back as far as to the times of OPPEL.

Differences in the specific faunal composition of some Franconian outcrops were previously thought to have primarily ecological reasons (ZEISS 1968). Comparisons with independently obtained stratigraphical successions of ammonite faunas from other areas and lithologies showed that these differences in faunal compositions are mostly caused by different ages. Only very few sites of laminated limestones in South Germany have not yet proliferated any ammonites and are thus not directly biostratigraphically dateable.

3. Ages of lithographic limestones in South Germany

In Franconia, according to their ammonite faunas included, lithographic limestones in general become younger from the East to the West and from the North to the South. The oldest, just recently recovered intercalation of laminated limestones occurs far in the North at Wattendorf (N Franconia, see FÜRSICH et al. 2007). It belongs to the late Kimmeridgian Pseudomutabilis Zone (time equivalent of lower part of French Eudoxus Zone) as indicated by the presence of *Aulacostephanus eudoxus* (D'ORBIGNY) (Fig. 1) and *Streblites levipictus* (FONTANNES). Another locality in the southeast of Bavaria, Ebenwies in the Naabtal valley near Regensburg, has not yet proliferated ammonites, but the thin intercalations of siliceous laminates occurring there are overlain by micritic

Fig. 3. *Lithacoceras eigeltingense* (OHMERT & ZEISS). Zandt Member, Zandt, Lower Tithonian, Hybonotum Zone, *eigeltingense* horizon; Staatliches Museum für Naturkunde Stuttgart, no. 66075 (diameter of specimen: 160 mm).

limestones dated into the Subeumela Subzone of the Beckeri Zone. Other occurrences in the same area higher up in the section are dated still within the lower part of the Beckeri Zone (Brunn: Beckeri Zone, Subeumela Subzone, RÖPER et al. 1996; RÖPER & ROTHGAENGER 1998b).

To date, laminated limestones of the Setatum Subzone are only poorly studied. Some ammonite-bearing sites occur in the vicinity of Beilngries which contain ammonites of the *supinum* and *ornatum* horizons (with *Virgataxioceras supinum* = "*subsetatum*" and *V. setatum* published by SCHNEID 1916; Fig. 2). At the boundary between the late Kimmeridgian Setatum Subzone and the Ulmense Subzone a major tectonic event with a shallowing trend is recognizable throughout South Germany, with disconformities in Swabia (SCHWEIGERT & FRANZ 2004) or a thin laminated marly limestone interval followed by a stratigraphic gap in W Franconia. This gap comprises the youngest Setatum Subzone and the oldest biohorizon of the Ulmense Subzone. The ammonites of the "Rote Lage" in the Torleite section near Dollnstein – one of three small intercalations of reddish weathering marly laminated limestones – are very badly preserved and most likely correspond to the *uracensis* horizon of Swabia.

In SW Swabia, the Plattenkalk at the unique Fossil Lagerstätte Nusplingen yields abundant ammonites of the middle part of the Ulmense Subzone, indicated by the index *Lithaoceras ulmense* and accompanying species (SCHWEIGERT 1998). Siliceous levels have yielded also a rich moderately preserved radiolarian fauna (ZÜGEL et al. 1998). In Franconia no lithographic limestones of this age occur. However, little younger ammonite faunas come from the localities of Painten, Schamhaupten, and Öchselberg near Breitenhill. These ammonite faunas are characterized by several still undescribed perisphinctids besides *Silicisphinctes* ex gr. *russi* SCHWEIGERT, *Sutneria bracheri* BERCKHEMER, *Metahaploceras* aff. *acallopistum* (BERCKHEMER & HÖLDER), *Taramelliceras rebouletianum* (FONTANNES), and, extremely rare, *Hybonoticeras kamicense* (SCHOPEN). The same ammonite assemblage occurs in the quarry district of Pfalzpaint (Walting), famous for its abundance of fossil jellyfishes and limulid trackways (RÖPER et al. 1999). Since the Kimmeridgian/Tithonian boundary has not been fixed, it is impossible to locate it

Fig. 4. *Gravesia gigas* (ZIETEN). Hienheim Formation, Ried near Hienheim, Lower Tithonian, Hybonotum Zone, *riedlingensis* horizon; Bürgermeister-Müller-Museum Solnhofen, without no. (diameters of specimens: 130 and 160 mm).

precisely within the Upper Jurassic succession of southern Germany. A specimen of *Lithacoceras eigeltingense* OHMERT & ZEISS (Fig. 3) was obtained from the lithographic limestones of Zandt. This taxon is typical of the lowermost Tithonian biohorizon according to present usage. The lithographic limestones of Zandt (Zandt Member) correlate with the micritic lithographic limestones in the upper part of the Painten section (the lower part of this section was studied by LINK & FÜRSICH 2001), which are famous for their ammonite rolling marks (SEILACHER 1963).

The micritic limestones of the "Teufelskopfkalke", which overly the Zandt Member (see BAUSCH 1963), have yielded numerous specimens of *Gravesia gigas* (ZIETEN) and other perisphinctids of the *riedlingensis* horizon (index: "*Subplanites*" *riedlingensis* OHMERT & ZEISS). This level is easy to correlate and occurs even in southeastern France, in the section of Canjuers (Département Var). More to the south of Franconia laminated limestones of this age occur at Hienheim, Ried, Eining, and close to Kelheim (Goldberg), proven by the frequent occurrence of *Gravesia gigas* (Fig. 4). These *Gravesia* findings are often strongly crushed and were therefore formerly misidentified as *Gravesia gravesiana* (D'ORBBIGNY) (ZEISS 1968; SCHWEIGERT 1993; RÖPER & ROTHGAENGER 1998a), a species of much younger age which occurs in the *laisackerensis* horizon of Swabia and Franconia (e.g., coral reef of Laisacker near Neuburg a.d. Donau, BARTHEL 1959).

The 'classical' outcrops of Tithonian lithographic limestones – those in the vicinity of Eichstätt (Schernfeld, Wintershof, Blumenberg, see RÖPER et al. 2000) and, on the other hand, those of Solnhofen and Langenaltheim – have been formerly assigned to the same lithological member and they were thus assumed to be coeval. However, their ammonite faunas are strikingly distinct, thus indicating a difference in age. According to the ammonite fauna included the "Oberer Schiefer" Member of Solnhofen – with the early Tithonian index *Hybonoticeras hybonotum* (OPPEL) besides *Neochetoceras steraspis* (OPPEL), *Paralingulaticeras lithographicum* (OPPEL), *Fontannesiella prolithographica* (FONTANNES) (Fig. 5), *Lingulaticeras percevali* (FONTANNES) and others – is significantly younger than the "Oberer Schiefer" Member in the vicinity of Eichstätt in which these ammonite taxa are all missing. This has important consequences for palaeogeographic reconstructions

Fig. 5. *Fontannesiella prolithographica* (FONTANNES), specimen with preserved jaw apparatus. Mörnsheim Formation, Daiting, Lower Tithonian, Hybonotum Zone, *moernsheimensis* horizon; Staatliches Museum für Naturkunde Stuttgart, no. 66076 (diameter of specimen: 75 mm).

and correlations in the area. The exact position of the lithographic limestones of Eichstätt is still problematic. The very common occurrence of the smooth oppeliid *Neochetoceras bous* (OPPEL) and the complete absence of *Fontannesiella* or *Paralingulaticeras* points to an age older than the *riedlingensis* horizon.

Few sites of lithographic or laminated limestones in South Germany have not yielded determinable ammonites and are therefore not exactly datable. This is the case with the site of Ettling (Markt Pförring, southern Franconia), recently known for its content of excellently preserved fishes. Probably the palaeoenvironment was too shallow and thus unfavourable for ammonites. Similarly the Kolbingen Plattenkalk in southwestern Swabia (TEMMLER 1966; SCHWEIGERT et al. 2005) yields neither ammonites nor any other guide fossils. However, the Kolbingen Plattenkalk overlies bedded limestones and sponge-microbial mounds with typical ammonites of the early Ulmense Subzone (*zio-wepferi* horizon β).

In southern Franconia laminated limestones also occur higher in the section, like in the Mörnsheim Formation of Mörnsheim and Daiting and in the Usseltal Formation of Gansheim and Störzelmühle. Silica-rich levels within the Mörnsheim Formation have been successfully etched out for radiolarians, which allow a correlation between early Tithonian ammonite and radiolarian biozonations (ZÜGEL 1998; DUMITRICA & ZÜGEL 2003). The youngest laminated limestones, which occur at the transition between the Rennertshofen and Neuburg formations, crop out in a small area northwest of Neuburg a.d. Donau, at Ellenbrunn (for localities see ZEISS 1968).

4. Conclusions

Many laminated limestones from the Upper Jurassic of southern Germany yield age-diagnostic ammonite faunas (summarized in Table 1) also recognizable in other lithologies or in neighbouring areas. The wide range of ages obtained from these ammonite faunas shows the complexity of coexisting environments and facies patterns. A precise dating of the various depositions is crucial for palaeogeographic reconstructions, deposition-modelling and correlations at a high time-resolution.

Table 1. Ages of lithographic limestones in South Germany. The succession of ammonite faunal horizons may be still incomplete. Modified and updated from SCHWEIGERT (2000) and SCHERZINGER & SCHWEIGERT (2003). For localities see ZEISS (1968: fig. 1) and FÜRSICH et al. (2007: fig. 1).

Stage	Zone	Subzone	horizon	localities
Tithonian	Palmatus		*palmatus*	
			scoparius	
	Ciliata		*callodiscus*	
			ciliata	
			penicillatum	Ellenbrunn
	Vimineus		*vimineus*	
	Mucronatum		*levicostatum*	
			franconicum	Gansheim, Störzelmühle
	Hybonotum	Moernsheimensis	*laisackerensis*	
			moernsheimensis	Mörnsheim, Daiting
		Rueppellianus	*rueppellianus*	Solnhofen, Langenaltheim
			riedlingensis	Hienheim, Ried, Kelheim (Goldberg)
		Riedense	(still unnamed)	Eichstätt (Schernfeld, Wintershof, Blumenberg)
			eigeltingense	Painten (upper part), Zandt
Kimmeridgian	Beckeri	Ulmense	*rebouletianum*	Painten, Schamhaupten, Öchselberg, Walting
			hoelderi	Nusplingen
			zio-wepferi β	Nusplingen (Großer Kirchbühl)
			zio-wepferi α	
		Setatum	*siliceus*	
			uracensis	Dollnstein (Torleite)
			ornatum	vicinity of Beilngries
			supinum	vicinity of Beilngries
			minutum	
		Subeumela	*fischeri*	
			subsidens	
			kiderleni	Brunn
			pedinopleura	
	Pseudo-mutabilis	Pseudomutabilis	*semicostatum*	
			not yet studied in detail	Wattendorf

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