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First record of the Mediterranean zonal index *Mesosimoceras cavouri* (Gemmellaro, 1872) in the Upper Jurassic (Pseudomutabilis Zone, *semicostatum* γ horizon) of SW Germany and its stratigraphical significance

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Key words: ammonites, Late Kimmeridgian, biostratigraphy, correlation, Germany, Spain.

Abstract. The ammonite species *Mesosimoceras cavouri* (Gemmellaro), the index of the Mediterranean Cavouri Zone, is recorded for the first time from the Submediterranean Upper Jurassic of SW Germany. It occurs in the Untere-Felsenkalke Formation, within a rich ammonite association of the late Pseudomutabilis Zone characterized by fine-ribbed variants of *Aulacostephanus pseudomutabilis* (de Loriol) and a still undescribed flexuous-ribbed variant of *Aulacostephanus eudoxus* (d'Orbigny). This ammonite association represents the here newly introduced *Lingulaticeras semicostatum* γ horizon. The record of *Mesosimoceras cavouri* (Gemmellaro) confirms at least a partial correlation of the Mediterranean Cavouri Zone with the Submediterranen Pseudomutabilis Zone and the Subboreal Eudoxus Zone.

INTRODUCTION

Although the Upper Kimmeridgian of the Untere-Felsenkalke Formation (=Weißjura Delta) of Swabia has been discussed in numerous publications (Aldinger, 1945; Ziegler, 1955a, b, 1957, 1958a, b, c, 1959a, b, 1962; Seeger, 1958, 1961), our present knowledge of the ammonites and the succession of ammonite faunas within this formation is still very incomplete.

The Mediterranean ammonite genus *Mesosimoceras* Spath, 1925 is very rare within the ammonite faunas of SW Germany, and only a few specimens exist in public collections. Schneid (1914) described *Simoceras risgoviensis*, a form which is morphologically close to *M. cavouri* (Gemmellaro), from the Treuchtlingen Formation of Franconia; the type locality of this taxon is situated at the eastern margin of the Miocene Ries impact crater. According to Schneid (1914) the monotypic holotype was associated with *Pseudhimalayites uhlandi* (Oppel), hence the type horizon of *Mesosimoceras risgoviensis* (Schneid) lies within the Early Kimmeridgian Divisum Zone. Wegele (1929, p. 38) discussed this taxon in his monograph on the Oxfordian and Kimmeridgian ammonite fauna of Middle Franconia and mentioned a few more specimens. Since he did not illustrate any of them, it is not certain whether these determinations were correct or not. Ziegler (1959b) interpreted *Mesosimoceras* as a subgenus of *Nebrodites*. He illustrated several specimens, which were later excluded from *Mesosimoceras* by Sarti (1990) and assigned to another genus, *Presimoceras*, like *Presimoceras teres* (Neumayr) from basal parts of

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the Untere-Felsenkalke Formation of Salmendingen (Ziegler 1959b, pl. 1, fig. 19). Moreover, "*Presimoceras*" *heteromorphum* (Quenstedt), erroneously interpreted as *Nebrodites* (*Mesosimoceras*) *herbichi* (von Hauer) by Ziegler (1959b, pl. 1, fig. 21), is the macroconch corresponding to *Berckhemeria scherzingeri* Schweigert & Zeiss, 1998. Its type horizon is located at the base of the Tithonian. Concerning *Mesosimoceras cavouri*, Ziegler (1959b, p. 44, 53) stated that this taxon was exclusively known from the Mediterranean and that in the Swabian Upper Jurassic the genus *Mesosimoceras* – including the forms now assigned to *Presimoceras* – ranges only up to the member "δ1" of the Untere-Felsenkalke Formation. This member corresponds to the Acanthicum Zone. During new sampling activities in the area of the Swabian Alb by one of us (A.S), among *ca.* 1.500 ammonites one specimen of *Mesosimoceras cavouri* (Gemmellaro) and one of *Mesosimoceras* sp. have been recorded now from the uppermost part of the Untere-Felsenkalke Formation (member "δ4"). We discuss below these finds and their correlation potential between neighboring faunal provinces within different zonal schemes.

MATERIAL

During the last few years, numerous ammonites from the higher part of the Untere-Felsenkalke Formation (Pseudomutabilis Zone) of the middle and western Swabian Alb have been collected bed-by-bed. The specimen of *Mesosimoceras cavouri* (Gemmellaro) and that of *Mesosimoceras* sp. were found in an abandoned quarry in the Rabental Valley, *ca.* 2 km SE of Möhringen an der Donau (Fig. 1). In this quarry a *ca.* 4 metres thick section of bright yellowish micritic limestone is exposed. Due to their exposure over a period of decades, the rocks are strongly weathered and split easily into platy pieces. From the same section *ca.* 300 other fossils have been collected, most of them being ammonites. Besides ammonites (see list of taxa below) a few bivalves, brachiopods and decapod crustaceans were found. Apart from fossils a unique quartz pebble with a diameter of *ca.* 1.5 cm was found. Most likely this exotic pebble was brought in within the roots of driftwood. Biostratigraphically, the entire section exposed in the Rabental Quarry yields a single ammonite biohorizon, here termed the *Lingulaticeras semicostatum* γ horizon.

The illustrated specimens are housed in the collection of the Staatliches Museum für Naturkunde, Stuttgart, Germany (SMNS).

SYSTEMATIC PALAEONTOLOGY

Family **Perisphinctidae** Steinmann, 1890

Subfamily **Idoceratinae** Spath, 1924

Genus ***Mesosimoceras*** Spath, 1925

Mesosimoceras cavouri (Gemmellaro, 1872)

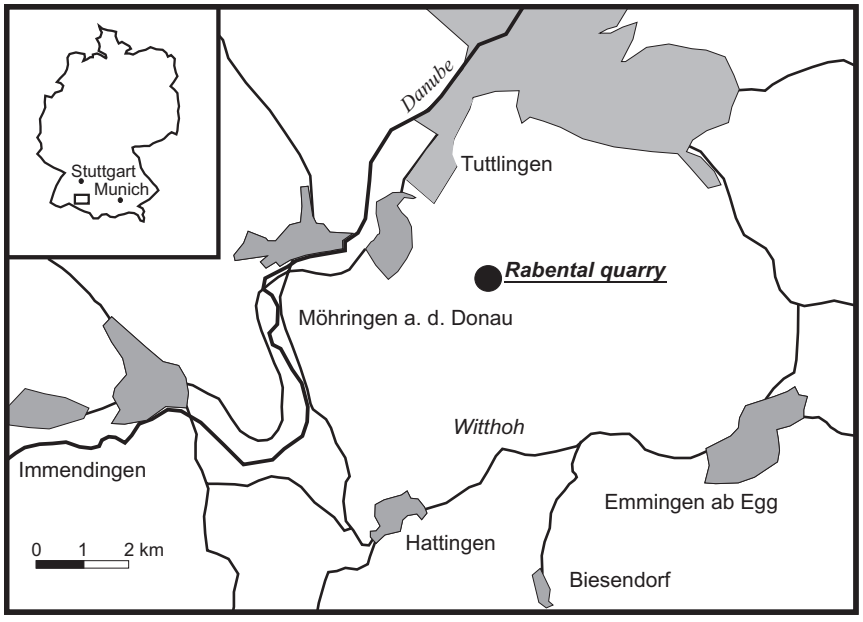

Fig. 1. Studied locality

1872. *Simoceras Cavouri* Gemm. – Gemmellaro, p. 44, pl. 7, figs 3, 4.

1898. *Simoceras Cavouri* Gemm. – Canavari, p. 229, pl. 15, fig. 1 (? fig. 2).

1936. *Simoceras* (*Mesosimoceras*) *cavouri* Gemmellaro – Roman, p. 20, pl. 1, fig. 5.

1978. *Nebrodites* (*Mesosimoceras*) *cavouri* (Gemmellaro) – Olóriz, p. 175, pl. 15, fig. 5.

1978. *Nebrodites* (*Mesosimoceras*) *risgoviensis* (Schneid) – Olóriz, p. 180, pl. 15, figs 3, 4.

1988. *Nebrodites* (*Mesosimoceras*) *risgoviensis* (Schneid) – Fezer & Geyer, p. 210, pl. 7, fig. 3.

1990. *Mesosimoceras cavouri* (Gemmellaro) – Sarti, p. 40, fig. 6A.

1992. *Nebrodites* (*Mesosimoceras*) *risgoviensis* (Schneid, 1914) – Finkel, p. 233.

1998. *Mesosimoceras cavouri* (Gemmellaro) – Caracuel *et al*., p. 240, pl. 1, fig. 2.

2002. *Mesosimoceras cavouri* (Gemmellaro, 1872) – Sarti, p. 297, fig. 199.

2011. *Nebrodites cavouri* (Gemmellaro) – Főzy *et al.,* p. 415, fig. 4.1, 4.2.

2013. *Mesosimoceras cavouri* (Gemmellaro) – Főzy & Scherzinger, p. 176, pl. 3, fig. 8.

Description. – The rather well-preserved specimen of *Mesosimoceras cavouri* (Gemmellaro) is an uncompressed fragment 110 mm in size, showing about one third of an extremely evolute outer whorl (SMNS 70337/1; Fig. 2) with the strongly crushed remains of the preceding whorl. In the outer whorl fragment, the whorl section is high-rectangular. Originally this ammonite must have had a diameter of at least 150 mm. Its ribbing consists of radiate or slightly prorsiradiate simple ribs which are interrupted on the venter by a broad smooth band. Along the ventromarginal edges the strong ribs end abruptly thus suggesting a spiny appearance

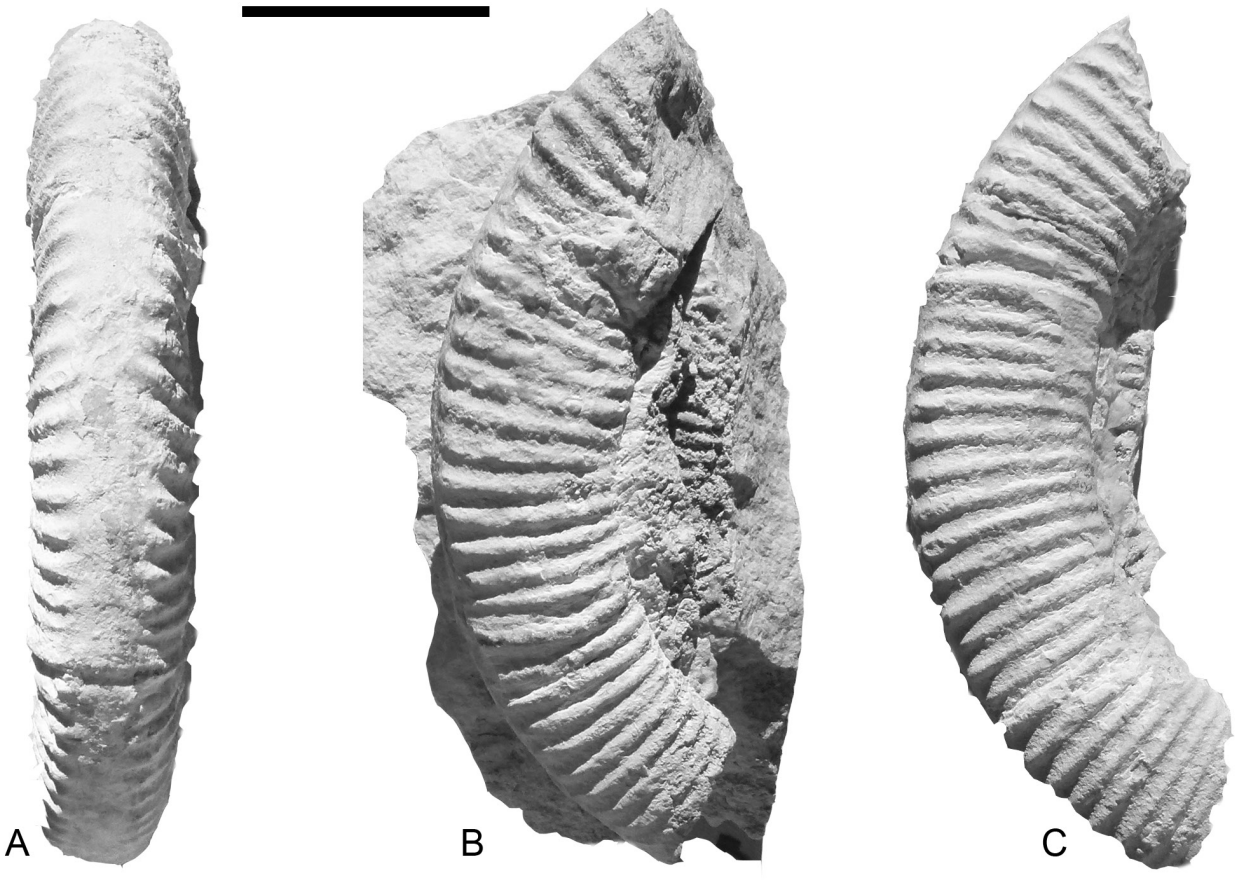

Fig. 2. *Mesosimoceras cavouri* (Gemmellaro)

Specimen SMNS 70337/1 in ventral (**A**) and lateral views (**B, C**). Möhringen an der Donau, Rabental quarry, SW Germany; Untere-Felsenkalke Formation, Upper Kimmeridgian, Pseudomutabils Zone, *semicostatum* γ horizon. Scale bar = 20 mm

of the original shell. This ribbing is laterally interrupted by a constriction, which deeply crosses the venter.

Discussion. – Sarti (1990) distinguished two morphotypes of *Mesosimoceras, M. cavouri* (Gemmellaro) and *M. risgoviensis* (Schneid); the first one is densely ribbed in all ontogenetic stages, whereas in the second one the ribbing of the adult whorls becomes wider-spaced. *M. cavouri* (Gemmellaro) differs from the stratigraphically older *M. risgoviensis* (Schneid) mainly in its denser ribbing as well as in a more depressed and rounded whorl section. Our fragmentary, but well-preserved specimen (Fig. 2) corresponds perfectly in its coiling, ribbing density and ventral aspects to the lectotype of *Mesosimoceras cavouri* (Gemmellaro) from Sicily (*cf.* Sarti, 2002). Probably there is some variation of rib density and coiling within this taxon, hence some specimens still keep a more involute coiling as seen in *Mesosimoceras risgoviensis* (Schneid), (*e.g.* the specimens illustrated by Olóriz, 1978), and Olóriz (1978) mentioned both taxa from the Cavouri Zone of Spain.

Remarks. – This newly discovered material is not the first record of *Mesosimoceras cavouri* (Gemmellaro) from the Submediterranean Province. A specimen from the Calanda section of eastern Spain illustrated by Fezer and Geyer (1988, pl. 7, fig. 3) as *Nebrodites* (*Mesosimoceras*) *risgoviensis* clearly represents *M. cavouri* (Gemmellaro) as well. Unfortunately, the ammonites collected from a thicker rock unit high in that section have either not been collected bed-by-bed or merged together later, resulting in a faunal list with Late Kimmeridgian and Early Tithonian taxa. The rock matrix of the *Mesosimoceras* differs from that of all other ammonites from the same rock unit in that collection. Therefore, the sole *cavouri* specimen is the only proof for the presence of the Cavouri Zone somewhere in the Calanda section; its exact horizon is untraceable.

Mesosimoceras sp.

The specimen, *Mesosimoceras* sp. (SMNS 70337/2; Fig. 3), is an incompletely preserved and strongly crushed mould with a diameter of *ca.* 50 mm. The inner whorls of this specimen exhibit an equally dense and simple ribbing style as seen in the outer whorl in the previous specimen, but the coiling appears to be more involute than in the latter.

PALAEOGEOGRAPHIC DISTRIBUTION OF *MESOSIMOCERAS CAVOURI*

Mesosimoceras cavouri (Gemmellaro) is widely distributed in the Tethyan Realm. It is recorded from Tunisia (Boughdiri *et al.*, 2005, not illustrated), Morocco (Roman, 1936), Sicily (Gemmellaro, 1872; Floridia, 1931), Southern Alps (Sarti, 1988, 1990; Caracuel *et al.*, 1998), Apennines (Canavari, 1898; Cecca *et al.*, 1990), Bulgaria (Sapunov, 1979), eastern Serbia (Andelkovic, 1966), southern Spain (Olóriz, 1978), eastern Spain (Fezer, Geyer, 1988), Bakony and Gerecse Mountains of Hungary (Főzy *et al.*, 2011; Főzy, Scherzinger, 2013), and even from Baluchistan, Pakistan (Fatmi, Zeiss, 1999). This wide distribution makes it a perfect guide fossil. Olóriz (1978) therefore used this species as a zonal index for the interval between the Kimmeridgian Acanthicum and Beckeri zones within the Mediterranean zonation.

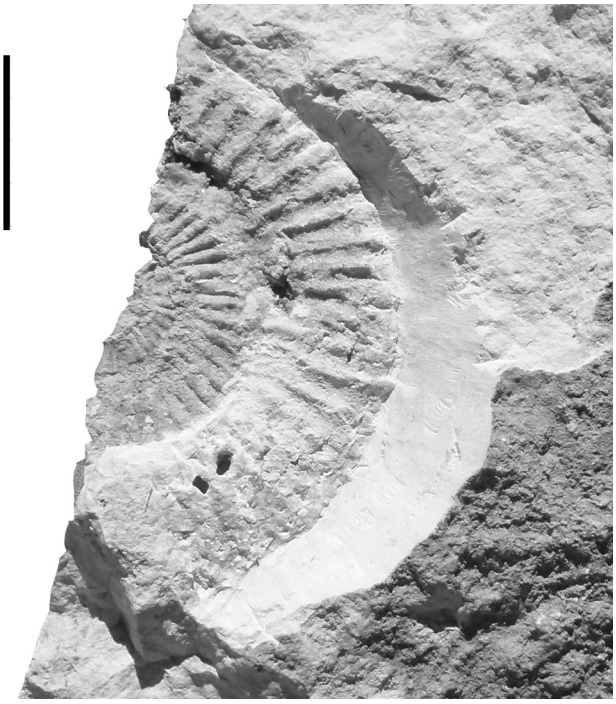

Fig. 3. *Mesosimoceras* sp.

Specimen SMNS 70337/2. Möhringen an der Donau, Rabental quarry, SW Germany; Untere-Felsenkalke Formation, Upper Kimmeridgian, Pseudomutabils Zone, semicostatum γ horizon. Scale bar = 20 mm.

AMMONITE FAUNA OF THE *SEMICOSTATUM* γ HORIZON

In 1996, Schweigert *et al.* provided a high-resolution biostratigraphic subdivision of the late Kimmeridgian Beckeri Zone of SW Germany into ammonite biohorizons. At that time, knowledge on the biostratigraphy of the underlying rocks was still very scarce. Schweigert (2007: table 1) later modified this subdivision and informally introduced

the term "*semicostatum* horizon" for the ammonite fauna immediately below the Beckeri Zone. This unit was distinguished by the striking abundance of *Lingulaticeras semicostatum* (Berckhemer) in sections of the Untere-Felsenkalke Formation in the area of the Upper Danube Valley of Swabia. Meanwhile it became obvious that this species is not restricted to a single biohorizon; hence this interval can be further subdivided.

The main difference between the *semicostatum* α and β horizons below and the *semicostatum* γ horizon above is a significant increase in diversity, with taxa of Mediterranean, Submediterranean and Subboreal origin. Otherwise these ammonite faunas share numerous taxa, *e.g.*, *Lingulaticeras semicostatum* (Berckhemer), *Sutneria eumela* (d'Orbigny), *Taramelliceras* cf. *compsum* (Oppel), *Taramelliceras intersistens* Hölder, and *Aulacostephanus pseudomutabilis* (de Loriol). After a long gap comprising the beds above the basal biohorizons of the Pseudomutabilis Zone (*prominens-hoelderi* α and β horizons of Fig. 4), in the *semicostatum* γ horizon perisphinctids become abundant again

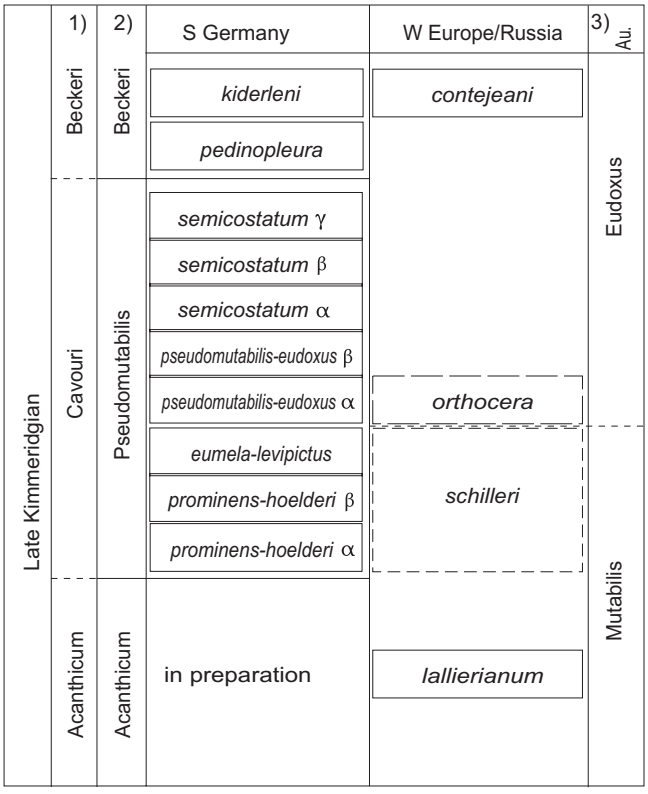

Fig. 4. Correlation table between different European zonal schemes

1) Mediterranean Province. **2)** Submediterranean Province. **3)** Subboreal Province. Correlation table after Hantzpergue (1989), Hantzpergue *et al.* (1998a, b), Schweigert *et al.* (1996) – modified – and Scherzinger (in preparation). Younger biohorizons of the Beckeri and Eudoxus zones are not shown in this scheme

("*Progeronia*" cf. *subdolus* (Fontannes), "*Crussoliceras*" ex gr. *atavum* (Schneid)). Within the *semicostatum* γ horizon, the Submediterranean zonal index *Aulacostephanus pseudomutabilis* (de Loriol) is characterized by variants showing a very fine and flexuous ribbing, which corresponds well to the equally fine-ribbed microconchs, for which Seeger (1958) used the manuscript name "*gracilis*" in his unpublished thesis. Physodoceratids show a much stronger ornamentation than in the beds below, where morphotypes with more delicate and irregularly spaced spines predominate.

The ammonite fauna of the *semicostatum* γ horizon yields the following taxa:

Mesosimoceras cavouri (Gemmellaro) [M], *Physodoceras* cf. *longispinum* (Sowerby) [M], *Sutneria eumela* (d'Orbigny) [m], *Aulacostephanus pseudomutabilis* (de Loriol) [M], *Aulacostephanus eudoxus* "*gracilis*" Seeger mscr. [m], *Taramelliceras* cf. *compsum* (Oppel) [M], *Lingulaticeras modestum* Ziegler [m], *Taramelliceras intersistens* Hölder [M], *Taramelliceras klettgovianum* (Würtenberger) [M], *Lingulaticeras semicostatum* (Berckhemer) [m], *Taramelliceras* ex gr. *pugile* (Neumayr) [M], *Granulochetoceras* cf. *undulatum* Höroldt [M], "*Progeronia*" cf. *subdolus* (Fontannes) [M + m], "*Crussoliceras*" ex gr. *atavum* (Schneid) [M + m].

HISTORY AND USAGE OF THE PSEUDOMUTABILIS ZONE

Loriol (1876) realized that *Ammonites mutabilis* illustrated by d'Orbigny differs from Sowerby's *Ammonites mutabilis*. Therefore, he introduced a new name for d'Orbigny's species, *Perisphinctes pseudomutabilis*.

Von Ammon (1875, p. 50) introduced the biostratigraphic term "Stufe des *Perisphinctes pseudomutabilis*" for Upper Jurassic deposits in eastern Bavaria intercalated between the "Zone der *Oppelia tenuilobata*" and overlying dolomitic rocks. Later, he modified this term into the "Stufe des *Ammonites* (*Reineckia*) *eudoxus* und (*Reineckeia*) *pseudomutabilis*" (von Ammon in Gümbel, 1891).

Finally, von Ammon (1899, p. 15, 36, 50) used the biostratigraphic terms "Stufe des *Perisphinctes pseudomutabilis*", "Stufe der *Reineckeia pseudomutabilis*" or "*Pseudomutabilis*-Schichten" in the Upper Jurassic of entire Franconia. It is worth noting that he mentioned that the diagnostic ammonite species *Aulacostephanus eudoxus* (Sowerby) as well as *Aulacostephanus pseudomutabilis* (de Loriol) are restricted to the higher part of this unit.

Haizmann (1902) was the first to use the term "Zone des *Ammonites pseudomutabilis*" in the Upper Jurassic of Swabia; later he was followed by Salfeld (1913). Subsequently,

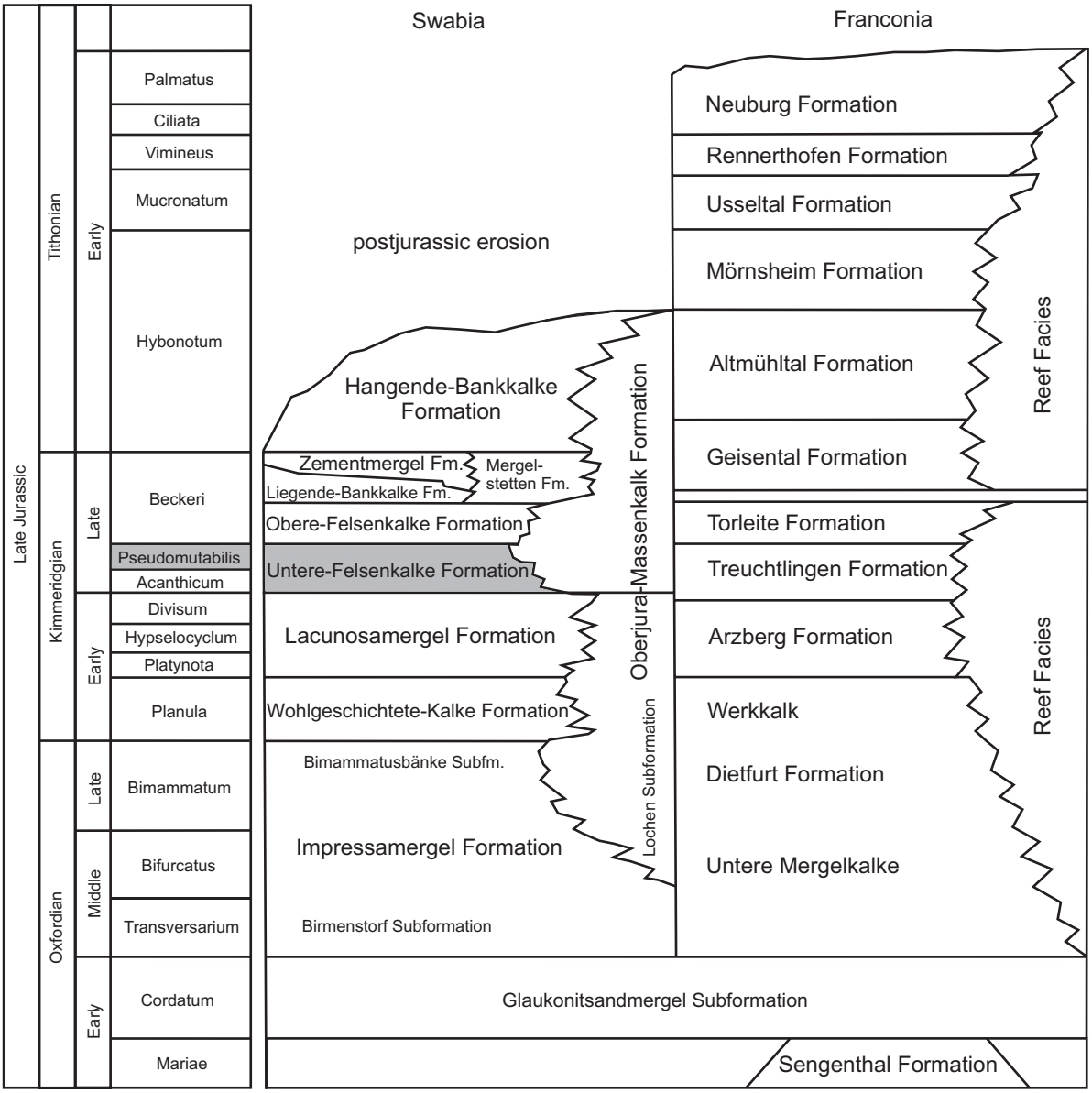

Fig. 5. Lithostratigraphic units of the Upper Jurassic in SW Germany (Swabia/Franconia)

The interval studied is shaded

Schneid (1914) provided many lithological and palaeontological details of the "Pseudomutabilis-Zone" in southern Franconia and described several ammonite taxa typical of this zone. Ziegler (1962) suggested the use of the term "Pseudomutabilis-Zone" for the higher part of the Untere-Felsenkalke Formation in Swabia. For lithostratigraphic terminology of Swabia and Franconia see Figure 5. This Pseudomutabilis Zone of Ziegler (1962), however, has a shorter range than the Pseudomutabilis Zone sensu Salfeld (1913), because the Autissiodorensis Zone of the latest Kimmeridgian was not separated in Salfeld's times.

More recently, Hantzpergue *et al.* (1997) gave a brief summary of the Kimmeridgian biozonation and ammonite faunas in the Submediterranean Province. Due to the wide palaeogeographic range of *Aulacostephanus eudoxus* (Sowerby) these authors preferred the usage of the Eudoxus Zone, and suppressed the Pseudomutabilis Zone as a synonym. Zeiss (2003) still used the term Eudoxus Zone for the zonal

subdivision of the Upper Jurassic in the Submediterranean Province.

In contrast, Baier and Schweigert (2001, p. 190) suggested the revalidation of the Pseudomutabilis Zone. In the Upper Jurassic of Swabia *Aulacostephanus contejeani* (Thurmann) and *Aulacostephanus yo* (d'Orbigny) have been recorded in the Subeumela and Setatum subzones, respectively, of the Beckeri Zone (Baier, Schweigert, 2001; Schweigert, Vallon, 2005). These two taxa are diagnostic for the upper part of the Eudoxus Zone of central Russia, southern England, western France, northern Switzerland and adjacent France (Hantzpergue, 1989; Hantzpergue *et al.*, 1998a, b; Comment *et al.*, 2015; Gallois *et al.*, 2015). Therefore, the "Eudoxus Zone" of southern Germany – the interval between the Acanthicum and Beckeri zones – has a significantly shorter duration than in western France, southern England, or central Russia. Baudouin *et al.* (2011, fig. 3) followed this view; however, these authors still included basal parts of the Pseudomutabilis Zone in the Crussol section of SE France in the Acanthicum Zone, contrary to Hölder and Ziegler (1959). Since the lower and upper boundaries of the Subboreal Eudoxus Zone are not fully isochronous with those of the Submediterranean Pseudomutabilis Zone, their usage must be restricted to their areas. A further biostratigraphical subdivision of the Pseudomutabilis Zone into subzones and biohorizons is in progress (A.S). Therefore, we here present only a preliminary correlation table (Fig. 4).

DISCUSSION AND CONCLUSIONS

In SW Germany the Mediterranean ammonite index species *Mesosimoceras cavouri* (Gemmellaro) occurs in the uppermost Pseudomutabilis Zone, *semicostatum* γ horizon. Within the accompanying ammonite taxa of the newly introduced *semicostatum* γ horizon, *Aulacostephanus pseudomutabilis* (de Loriol) and *Aulacostephanus eudoxus* "*gracilis*" Seeger (mscr.) underline the correlation between the Submediterranean Pseudomutabilis Zone (and parts of the Subboreal Eudoxus Zone) with the Mediterranean Cavouri Zone. In the Upper Jurassic of the SW Swabian Alb the *pedinopleura* horizon of the Beckeri Zone follows just a few metres above the horizon containing *Mesosimoceras cavouri* (Gemmellaro) (*cf.* Seeger, 1958, 1961).

At the base of the Mediterranean Cavouri Zone (Olóriz, 1978 = Interval Zone no. 1 *in* Sarti, 1985 and Cavouri Zone *in* Sarti, 1993) the index species *Mesosimoceras cavouri* (Gemmellaro) is accompanied by *Taramelliceras pseudoflexuosum* (Favre) and last representatives of *Physodoceras acanthicum* (Oppel) (Sarti, 1985, 1986a, b). However, in the Upper Jurassic of SW Germany, typical *Physodoceras acanthicum* (Oppel) do not range up into the Pseudomutabilis Zone. It is questionable whether the *Physodoceras* species reported from the basal part of the Cavouri Zone, the specimens illustrated from the Crussol section (Baudouin *et al.*, 2011), and newly collected specimens of *Physodoceras* from the basal beds of the Pseudomutabilis Zone of Swabia should be included in *Physodoceras acanthicum* (Oppel). In SW Germany and SE France *Taramelliceras pseudoflexuosum* (Favre) ranges up into the basal beds of the Pseudomutabilis Zone and is then abruptly replaced by *Taramelliceras klettgovianum* (Würtenberger), (*e.g.* Ziegler, 1958c; Hölder, Ziegler, 1959; Schmidt-Kaler, 1962). Hence, the duration of the Cavouri Zone of Olóriz, 1978 seems to correspond almost exactly with that of the Submediterranean Pseudomutabilis Zone as underlined already by Olóriz (1978).

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