Stratigraphy of the Kahlenberg near Ringsheim (Upper Rhine Valley, SW Germany) with emphasis on the Laeviuscula and Sauzei zones (Lower Bajocian, Middle Jurassic)

Volker Dietze, Michael Kutz, Matthias Franz & Klaus Bosch

In memoriam Gottfried Knopf (1931–2001)

Abstract

The lithological succession, ammonite faunas, and chrono-/biostratigraphy of the former iron-mine at the Kahlenberg near Ringsheim (Upper Rhine Valley) are described with emphasis on strata of the Laeviuscula and Sauzei zones (Lower Bajocian). Two new ammonite faunal horizons are recognized in the Laeviuscula Zone, that of *Pelekodites macer* (Trigonalis Subzone) and *Witchellia glauca* (Laeviuscula Subzone). Between them is the faunal horizon of *Pseudoshirbuirnia stephani* which is also known from Swabia (Trigonalis Subzone). In the Sauzei Zone one new faunal horizon is described, that of *Emileia pseudocontrahens*, between that of *Otoites dilatus* below and *Stephanoceras macrum* above. The "γ-Tone" at Gingen/Fils (Eastern Swabian Alb) include the faunal horizon of *Witchellia spinifera*. The faunal horizons of the Laeviuscula and Sauzei zones of southern Germany and southern England are correlated. The microfauna is briefly described.

Keywords: Ammonites, lithostratigraphy, chronostratigraphy, ammonite faunal horizons, Southern Germany, Southern England, Laeviuscula Zone, Sauzei Zone, correlation.

Zusammenfassung

Schichtenfolge, Ammonitenführung sowie Chrono- und Biostratigraphie im ehemaligen Eisenerz-Tagebau am Kahlenberg bei Ringsheim (Oberrhein) werden unter besonderer Berücksichtigung der Laeviuscula- und der Sauzei-Zone (Unter-Bajocium) dargestellt. In der Laeviuscula-Zone werden zwei neue Ammonitenfaunen-Horizonte, der Faunen-Horizont des *Pelekodites macer* (Trigonalis-Subzone) und der Faunen-Horizont der *Witchellia glauca* (Laeviuscula-Subzone) beschrieben. Zwischen diesen beiden Faunen-Horizonten liegt am Kahlenberg der schon aus Schwaben bekannte Faunenhorizont der *Pseudoshirbuirnia stephani* (Laeviuscula-Subzone). Aus der Sauzei-Zone wird der Faunenhorizont der *Emileia pseudocontrahens* neu aufgestellt. Dieser liegt unterhalb des Faunen-Horizonts des *Stephanoceras macrum* und über demjenigen des *Otoites dilatus*. Die „γ-Tone" von Gingen an der Fils (östliche Schwäbische Alb) enthalten den Faunen-Horizont der *Witchellia spinifera*. Die süddeutschen Ammoniten-Faunenhorizonte von der Laeviuscula- bis zur Sauzei-Zone werden mit denjenigen Südenglands korreliert. Die Mikrofauna wird kurz beschrieben.

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1. Introduction

The Kahlenberg near Ringsheim is situated some 30 km north of Freiburg im Breisgau in the eastern foothills of the Upper Rhine valley (Fig. 1), the formation of which has had a marked influence on the Jurassic outcrop at the Kahlenberg. The area is tectonically disjointed such that the thickness of individual layers varies locally.

Former iron-mining between 1937/38 to 1969 exposed strata of the Middle Jurassic Upper Aalenian and Lower Bajocian in a manner unique to the area. From 1973 to the present the mining area has been exploited for landfill and recently the domestic waste there has been converted to fuel by an innovative technique. Extensive recycling has employed the use of earth moving machinery with renewed excellent opportunities for collecting fossils bed by bed.

We present new results on the stratigraphy from the 3. Erzband to the „Blaukalk" with strata ranging the Laeviuscula to Sauzei zones of the Lower Bajocian. Ammonite names are used in a morphospecific sense if not otherwise indicated.

The Laeviuscula Subzone is poorly represented in Southern Germany, until now recorded only from the Eastern Swabian Alb (Dietze et al. 2005) and Ringsheim itself (Geologisches Landesamt Baden-Württemberg 1997); therefore these new data broaden the knowledge of this interval considerably. Investigation of the ammonites and stratigraphy of the Sauzei Zone at this locality will enrich the understanding of ammonite diversity and the temporal succession of ammonite faunal horizons in this zone in Southern Germany, allowing improved correlation with other areas in Southern Germany and further afield including Southern England where many important exposures have been recorded and from which a number of important types come.

Figured specimens, mostly collected by the authors M.K. and K.B., are deposited in the collection of the SMNS, if not otherwise indicated. The species of the faunal lists are ammonites only unless otherwise stated.

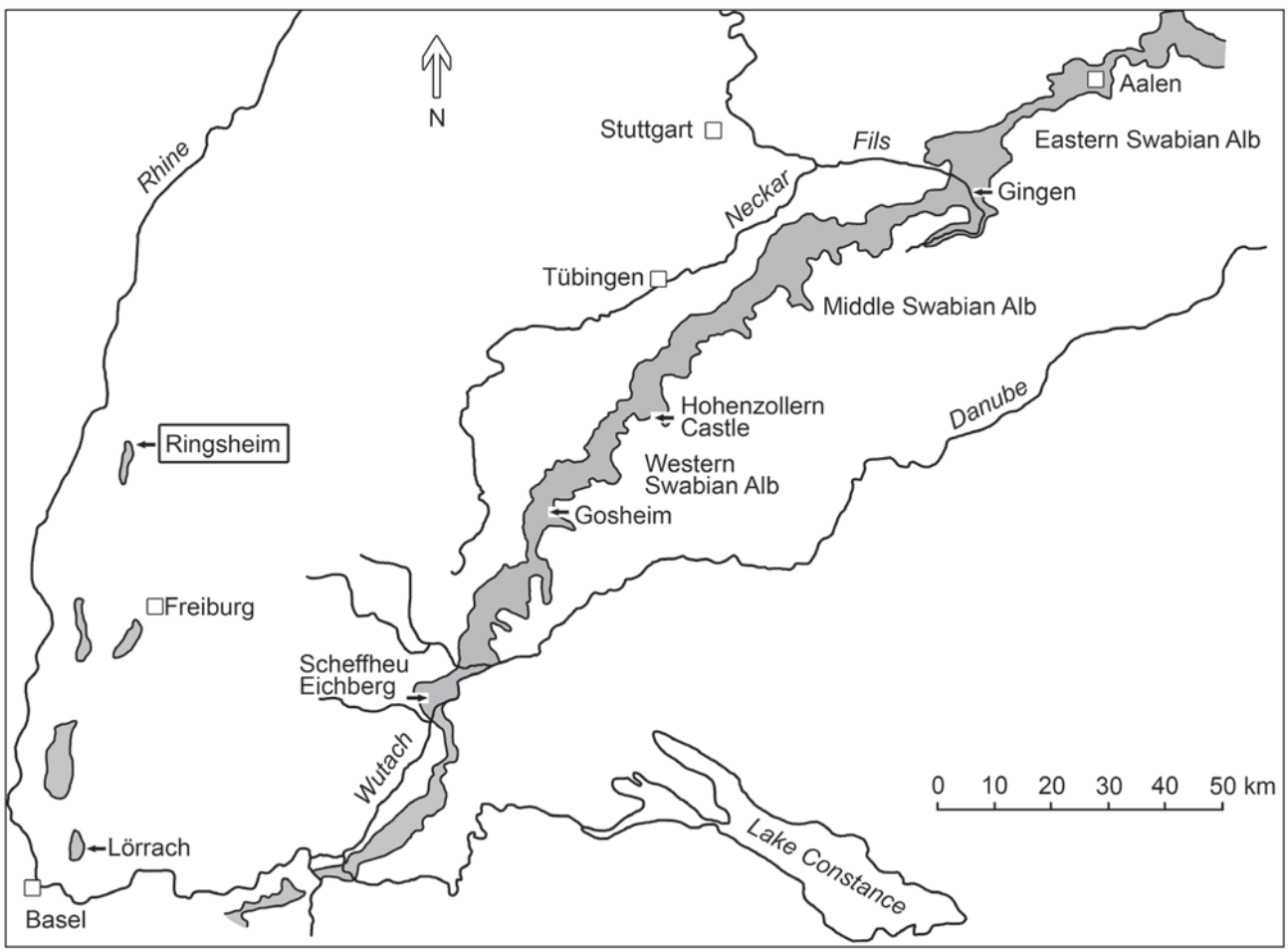

Fig. 1. Outcrop of the Middle Jurassic in SW Germany, with locations cited in the text (modified after Ohmert 1990, fig. 1 and Dietze et al. 2008, fig. 3).

Abbreviations

[m]	microconch ammonite dimorph
[M]	macroconch ammonite dimorph
OW	"Oberer Wedelsandstein"
BL	"Blaukalk"
LGRB	Landesamt für Geologie, Rohstoffe und Bergbau Baden-Württemberg im Regierungspräsidium Baden-Württemberg, Freiburg im Breisgau, Germany
SMNS	Staatliches Museum für Naturkunde Stuttgart, Germany

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2. The section at the Kahlenberg near Ringsheim

2.1. Research history

Sauer (1948) described the section with particular reference to the open mine at the so called Erzlager, then Urban (1966) gave a profile from the *opalinum*-Ton to the beds above the Hauptrogenstein. Bayer (1970) was first to describe the biostratigraphy in modern terms in contrast to Sauer & Simon (1975), who employed Quenstedts obsolete classification. Ohmert (1981, 1988a, 2004), Gassmann & Mattes (1984) and Dietze et al. (2005) refined the biostratigraphy. Many ammonites from the Kahlenberg were figured in Reichenbach (1998) and Bosch (2006).

We allocate strata described here in to Standard chronozones and -subzones (modified after Contini et al. 1997 and Rioult et al. 1997) and include six ammonite faunal horizons in the Laeviuscula and Sauzei Zones. The use of the term faunal horizon or for brevity horizon indicates usage in the sense of an ammonite faunal horizon as of Callomon (1995).

2.2. Description of the section from the 3. Erzband to the "Blaukalk"

A detailed description of the beds and their ammonite fauna is given below for strata from the 3. Erzband to the top of the "Blaukalk". The stratigraphy and ammonite faunas of beds below the 3. Erzband and above the "Blaukalk" will be given in future work. Details of the Opalinuston Formation (Opalinuston), Murchisonae-Oolith Formation (Liegende Sandkalke to Concavasandstein) and Wedelsandstein Formation (Unteres Erzband to Rimsingen Ton) can be seen in Fig. 2. The information is based upon cited literature and the private collections of M. Kutz and K. Bosch.

3. Erzband (~0.15–0.4 m)

Variable, occasionally absent or reduced to a thin conglomerate (Reichenbach 1998, fig. 93).

– Hard, nodular limestone with scarce iron ooids, ammonites preserved with test (0.1–0.2 m locally).

Witchellia jugifera (Waagen) [M] (Fig. 3)
W. cf. *jugifera* (Waagen) [M] (Fig. 10, 11)
W. pseudoromanoides (Dietze, Chandler & Schweigert) [M] (Figs. 4, 7)
Pelekodites macer (Buckman) [m] (Figs. 8, 9)
Sonninia sp. [M] (Figs. 5, 6)
S. ex gr. *adicra* (Waagen) [M] (Figs. 12, 13)

– Impersistent soft, ironshot calcareous mudstone (0.1 m max).

Pseudoshirbuirnia stephani (Buckman) [M] (Fig. 16)
Pelekodites sp. [m]

– Sandy marls (0.15 m)
– Sandy and rusty bed lacking iron ooids (0.1 m)

Pseudoshirbuirnia fastigata (Buckman) [M] (Fig. 14)

Ammonites listed below come from the upper part of the 3. Erzband, above the basic iron oolitic bed (0.1–0.2 m); their exact position in the upper part is unknown.

Witchellia sp. [M] (Fig. 18)
Pelekodites cf. *schlumbergeri* (Haug) [m] (Figs. 15, 20)
P. cf. *spatians* (Buckman) [m] (Fig. 19)
P. boweri (Buckman) [m] (Fig. 17)
Sonninia sp. [M]

Unterer Tonhorizont (~0.05–1.0 m)

Marl, highly variable in thickness, a single ammonite occurred a few centimetres above the 3. Erzband.

?*Sonninia* sp. [M]

Unterer Wedelsandstein (~0.4–1.4 m)

Limestone bed with characteristic ichnofossil *Zoophycos*. No ammonites.

Tonhorizont im Wedelsandstein (~4.5–6 m)

Black marls with reddish limestone nodules up to 0.10 m. About 0.5–1 m above the Unterer Wedelsandstein small pyritized ammonites occur.

Witchellia laeviuscula (Sowerby) [M] (Figs. 21, 22, 26)
W. cf. *laeviuscula* (Sowerby) [M] (Fig. 27)
W. glauca Buckman [M] (Figs. 23–25, 28, 29)
Pelekodites cf. *spatians* (Buckman) [m] (Figs. 30, 31)
Sonninia sp. [M] (Figs. 32, 33)

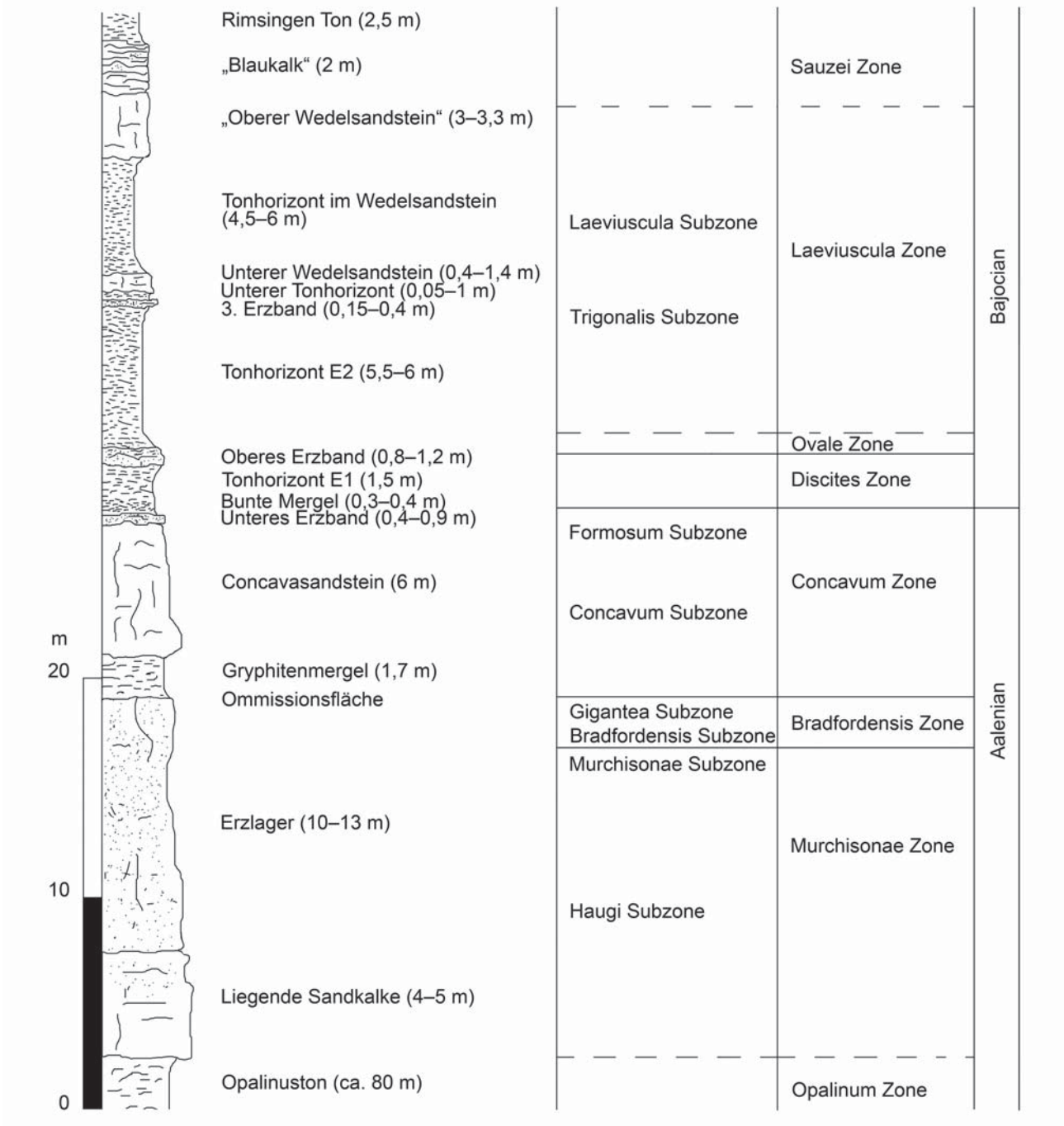
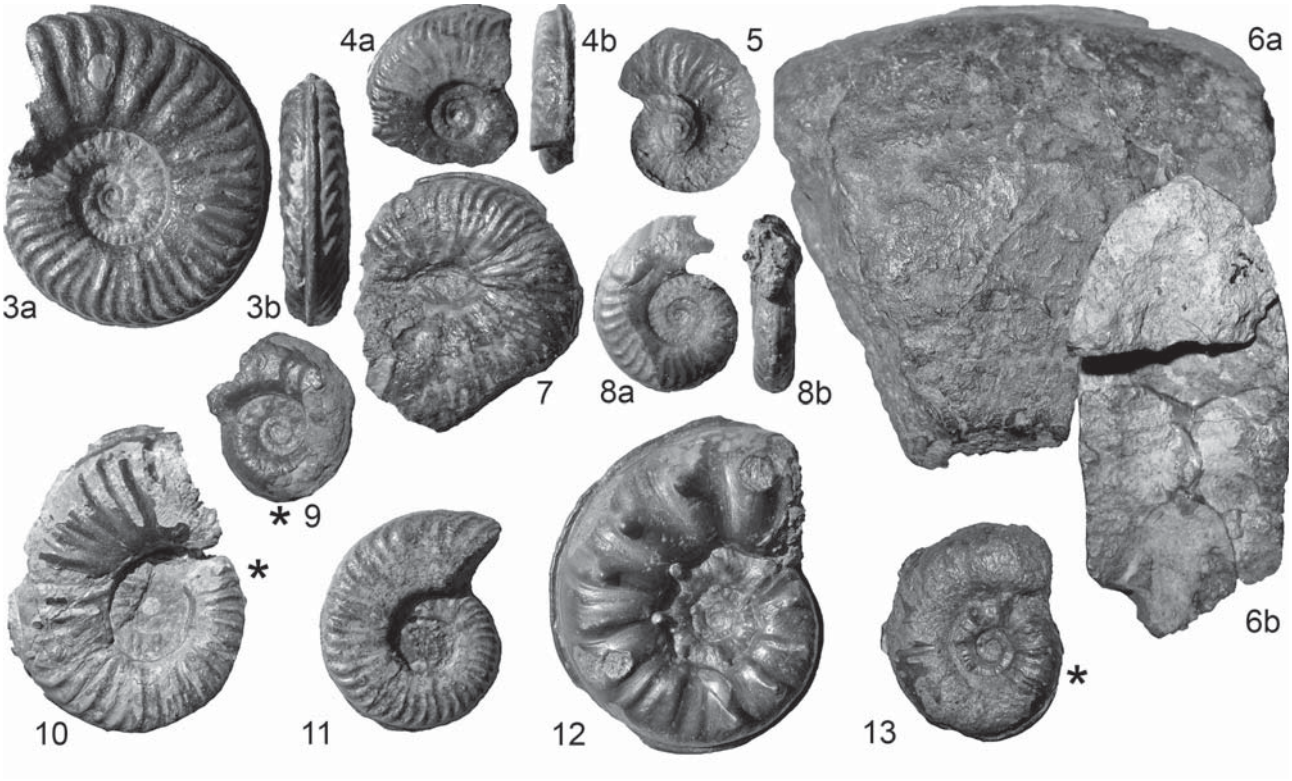


Fig. 2. Chrono- and lithostratigraphical subdivision of the Middle Jurassic of the Kahlenberg from the top of the Opalinuston to the Rimsingen Ton. An dashed line indicates that the exact boundary between (sub)zones is unknown. Opalinuston Formation: Opalinuston; Murchisonae-Oolith Formation: Liegende Sandkalke to Concavasandstein; Wedelsandstein Formation: Unteres Erzband to Rimsingen Ton (adopted from Sauer 1948, Urban 1966, Bayer 1970, Sauer & Simon 1975, Ohmert 1981, 2004, Gassmann & Mattes 1984 and own observations; chronostratigraphy modified from Contini et al. 1997, Rioult et al. 1997).

“Oberer Wedelsandstein” (~3–3.3 m)

– Bed OW-1: Mainly undulating, irregular, fresh blue-grey, weathered yellow-brown coloured, partly dolomitic, with fine-sandy marlstones; surfaces burrowed with phosphatic nodules. Fossils scarce, ammonites extremely rare, fragmentary or crushed (~2.8–3 m).

Sonninia sp. [M] (Pl. 1, Fig. 1)



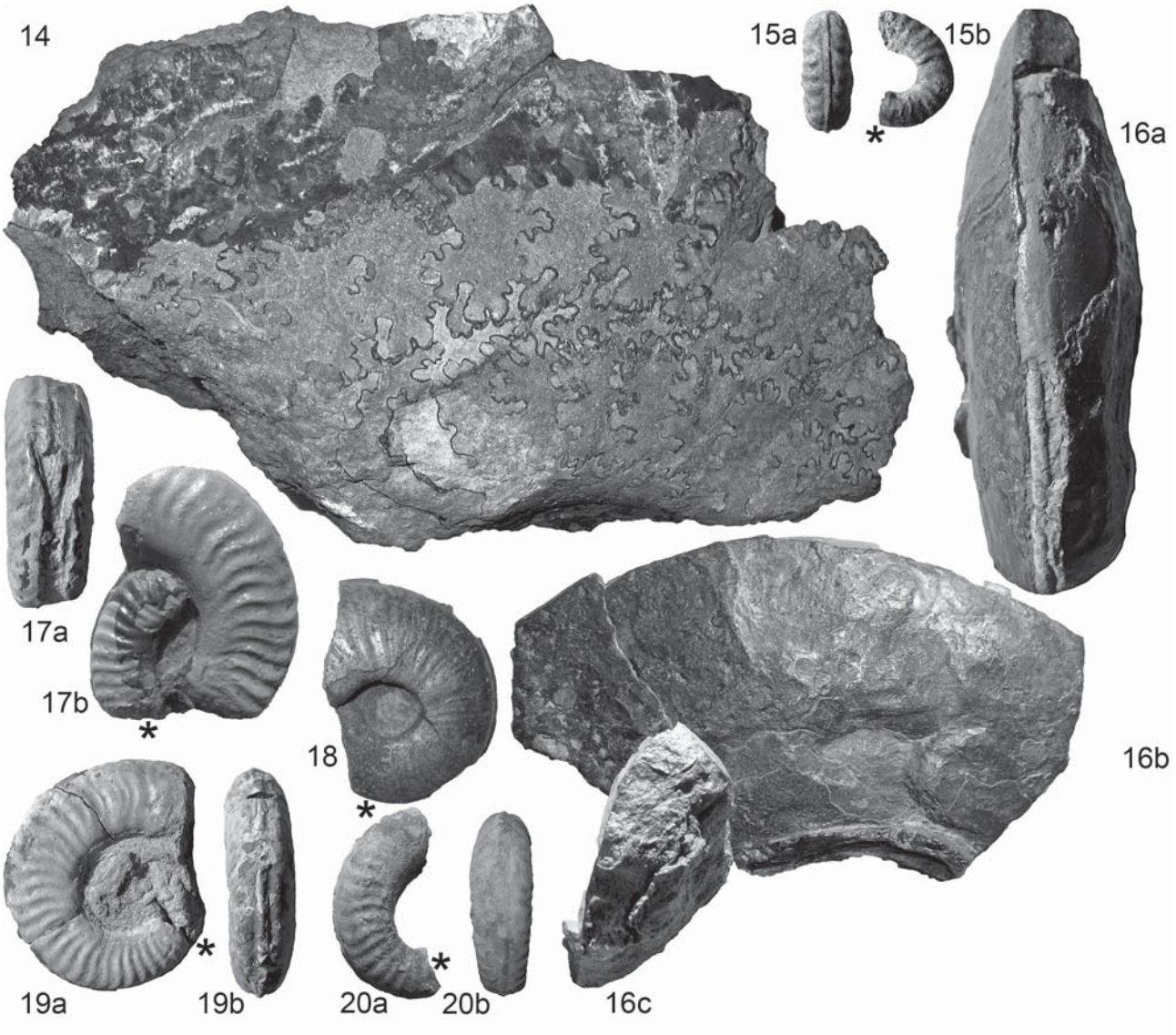
Figs. 3–13. Specimens from the *macer* horizon (Trigonalis Subzone, Laevisucula Zone), lower part of the 3. Erzband, Kahlenberg. – **3**. *Witchellia jugifera* (Waagen) [M], coll. Kutz, cast in LGRB, without number); **a**. Lateral view, **b**. Ventral view. **4**, **7**. *Witchellia pseudoromanoides* (Dietze, Chandler & Schweigert) [M]; **4**. SMNS 67458; **a**. Lateral view, **b**. Ventral view; **7**. SMNS 67459. **5**, **6**. *Sonninia* sp. [M]; **5**. SMNS 67457; **6**. SMNS 67488; **a**. Lateral view, **b**. Section. **8**, **9**. *Pelekodites macer* (Buckman) [m]; **8**. SMNS 67461; **a**. Lateral view, **b**. Ventral view; **9**. SMNS 67462. **10**, **11**. *Witchellia* cf. *jugifera* (Waagen) [M]; **10**. SMNS 67489; **11**. SMNS 67460. **12**, **13**. *Sonninia* ex gr. *adicra* (Waagen) [M]; **12**. Slg. Kutz, cast in LGRB, without number); **13**. SMNS 67490. – All figures in natural size. Beginning of body chamber is marked by an asterisk.

S. strigoceroides Dorn [M] (Pl. 1, Fig. 2)
?*Stephanoceras* sp. [M] (Pl. 1, Fig. 4)
Kumatostephanus sp. [M] (coll. Kutz)

– Bed OW-2: Sandy marls (0.25 m).
Emileia lotharingica Maubeuge [M] (Pl. 2, Fig. 2)
Kumatostephanus triplicatus (Renz) [M] (Pl. 1, Fig. 3)
Otoites dilatus Westermann [m] (Pl. 2, Fig. 3)
O. fortis Westermann [m] (Pl. 2, Fig. 1)

"Blaukalk" (~2 m) – Here we retain the conventional usage of the term "Blaukalk" (Reichenbach 1998, pictures 90, 97; Fig. 34).

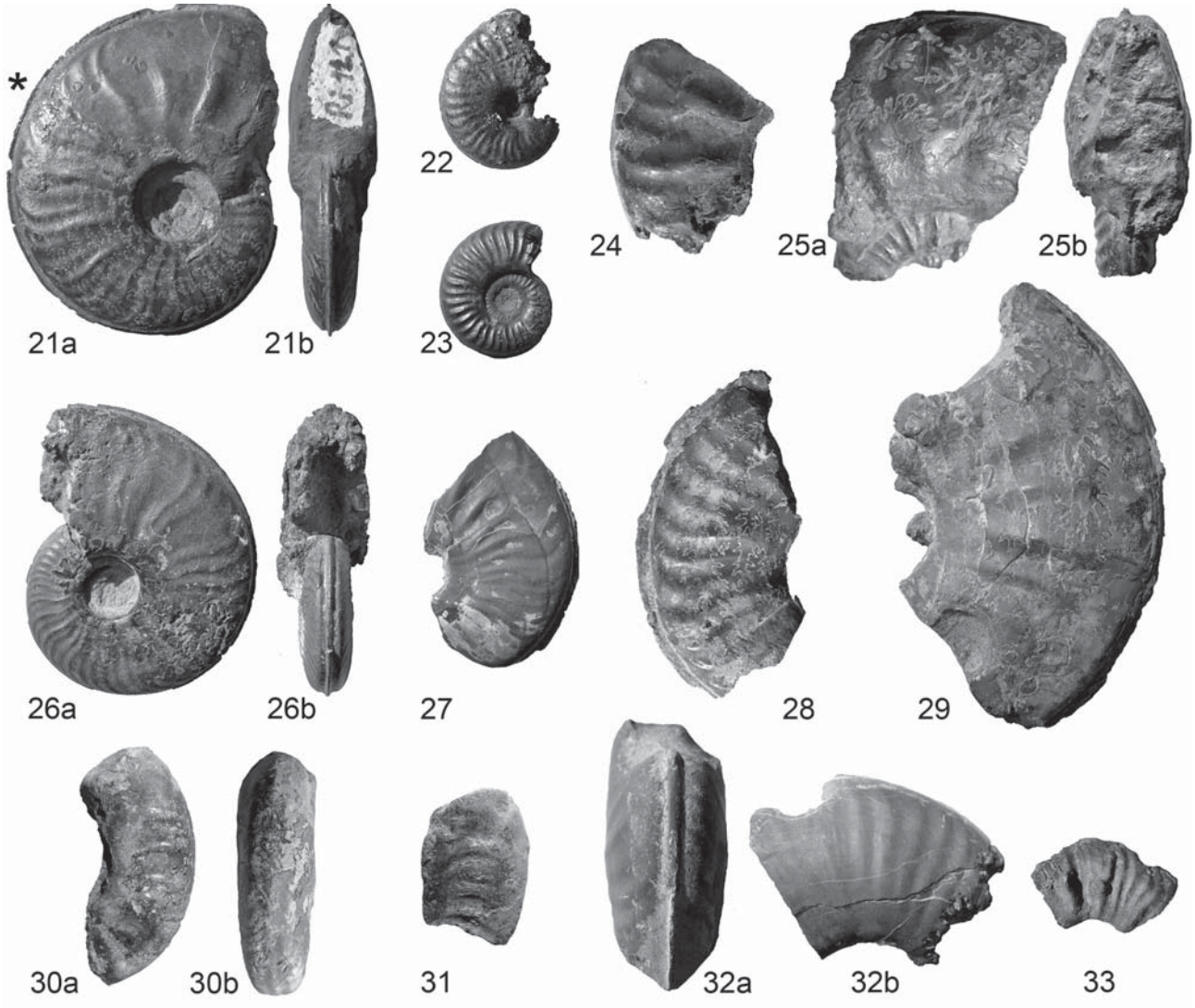
– Bed BL-1: Sparitic calcarenite, bio-detrital, composed mainly of derived echinodermal debris coated by brown hematite. Abundant shell debris and a few serpulids (0.12 m).
– Bed BL-2: Marls, occasionally with nodules (peloidal limestones), densely overgrown with bryozoans and serpulids (0.05 m).
– Beds BL-3–5: Bed BL-3 (0.3 m) is a yellowish-red calcarenite with dark brown, ironrich parts, fine biodetrital echinoderm debris encrusted with hematite in a fine-grained matrix and scarce limonitic ooids. Shells, e. g. *Ctenostreon* sp. single serpulids, bryozoans, ammonites and rare small sponges. Bed BL-4 (0.05 m) is a marl, sometimes absent. Bed BL-5 (0.3–0.4 m) is a yellow-reddish, calcarentic limestone, partly microsparitic, with hematite encrusted echinodermal debris in a fine grained matrix. As in bed BL-3 iron rich bands of a dark brown colour occur. Ammonite fauna, rich and diverse, *Sarcinella plexus* [= „*Serpula socialis*"], detached urchin spines, bivalves. Eroded surface with perfect corals up to 0.5 m, absent in places. Beds BL-3 and BL-5 yield most of the ammonites found in the "Blaukalk" of the Kahlenberg. A nodule found in



Figs. 14–20. Specimens from the *stephani* horizon (Trigonalis Subzone, Laeviuscula Zone), upper part of the 3. Erzband, Kahlenberg. – **14**. *Pseudoshirbuirnia fastigata* (Buckman) [M], SMNS 67491. **15**, **20**. *Pelekodites* cf. *schlumbergeri* (Haug) [m]; **15**. SMNS 67456; **a**. Ventral view, **b**. Lateral view; **20**. SMNS 67492; **a**. Lateral view, **b**. Ventral view. **16**. *Pseudoshirbuirnia stephani* (Buckman) [M], SMNS 67455; **a**. Ventral view, **b**. Lateral view, **c**. Section. **17**. *Pelekodites boweri* (Buckman) [m], SMNS 67454; **a**. Ventral view, **b**. Lateral view. **18**. *Witchellia* sp. [M], SMNS 67493. **19**. *Pelekodites* cf. *spatians* (Buckman) [m], SMNS 67463; **a**. Lateral view, **b**. Ventral view; – All figures in natural size. Beginning of body chamber is marked by an asterisk.

bed BL-5 with bivalve borings suggests the possibility of a depositional interruption within the bed too short to be discernable by biostratigraphical methods.

Emileia pseudocontrahens Maubeuge [M] (Pl. 3, Fig. 1–3)
E. vagabunda Buckman [M] (Pl. 5, Fig. 1)
E. cf. *arkelli* Maubeuge [M] (coll. Kutz)
E. cf. *bulligera* Buckman [M] (Pl. 4, Fig. 6)
Otoites cf. *seitzi* Westermann [m] (Pl. 5, Fig. 3)
O. cf. *pauper* Westermann [m] (Pl. 12, Fig. 3)
O. contractus (Sowerby) [m] (Pl. 12, Fig. 4)
O. cf. *contractus* (Sowerby) [m] (Pl. 6. Fig. 1)
Praeoppelia gracilobata (Vacek) [M] (Pl. 4, Fig. 2)



Figs. 21–33. Specimens from the *glauca* horizon (Laeviuscula Subzone, Laeviuscula Zone), "Tonhorizont im Wedelsandstein", Kahlenberg. – **21, 22, 26**. *Witchellia laeviuscula* (Sowerby) [M]; **21**. coll. Kutz, cast in LGRB, without number [First illustration: Geologisches Landesamt Baden-Württemberg (1997), fig. 18]; **a**. Lateral view, **b**. Ventral view; **22**. SMNS 67477; **26**. SMNS 67476; **a**. Lateral view, **b**. Ventral view. **23–25, 28, 29**. *Witchellia glauca* (Buckman); **23**. SMNS 67478; **24**. SMNS 67479; **25**. SMNS 67480; **a**. Lateral view, **b**. Ventral view; **28**. SMNS 67482; **29**. SMNS 67483. **27**. *W.* cf. *laeviuscula* (Sowerby) [M], SMNS 67481. **30, 31**. *Pelekodites* cf. *spatians* (Buckman) [m]; **30**. SMNS 67484; **a**. Lateral view, **b**. Ventral view; **31**. SMNS 67485. **32, 33**. *Sonninia* sp. [M]; **32**. SMNS 67486; **a**. Ventral view, **b**. Lateral view. **33**. SMNS 67487. – All figures in natural size. Beginning of body chamber is marked by an asterisk.

Strigoceras languidum (Buckman) [M] (Pl. 12, Figs. 1, 2)
Kumatostephanus aff. *turgidulus* (Quenstedt) [M] (Pl. 11, Figs. 1, 2)
Sonninia propinquans (Bayle) [M] (Pl. 9, Fig. 2; Taf. 10, Fig. 7)
S. cf. *propinquans* (Bayle) [M] (Pl. 9, Fig. 1; Pl. 11, Fig. 4)
S. cf. *patella* (Waagen) [M] (Pl. 9, Fig. 5; Pl. 7, Fig. 1)
Sonninia ["*Sonninites*"] aff. *felix* (Buckman) [M] (Pl. 8, Figs. 1–4; Pl. 11, Fig. 3)
Pelekodites moisyi (Brasil) [m] (Pl. 10, Figs. 1–6)

– Bed BL-6: Reddish marls, frequent iron ooids (~0.05 m).
Otoites fortis Westermann [m] (Pl. 5, Fig. 2)
Strigoceras languidum (Buckman) [M] (coll. Bosch)

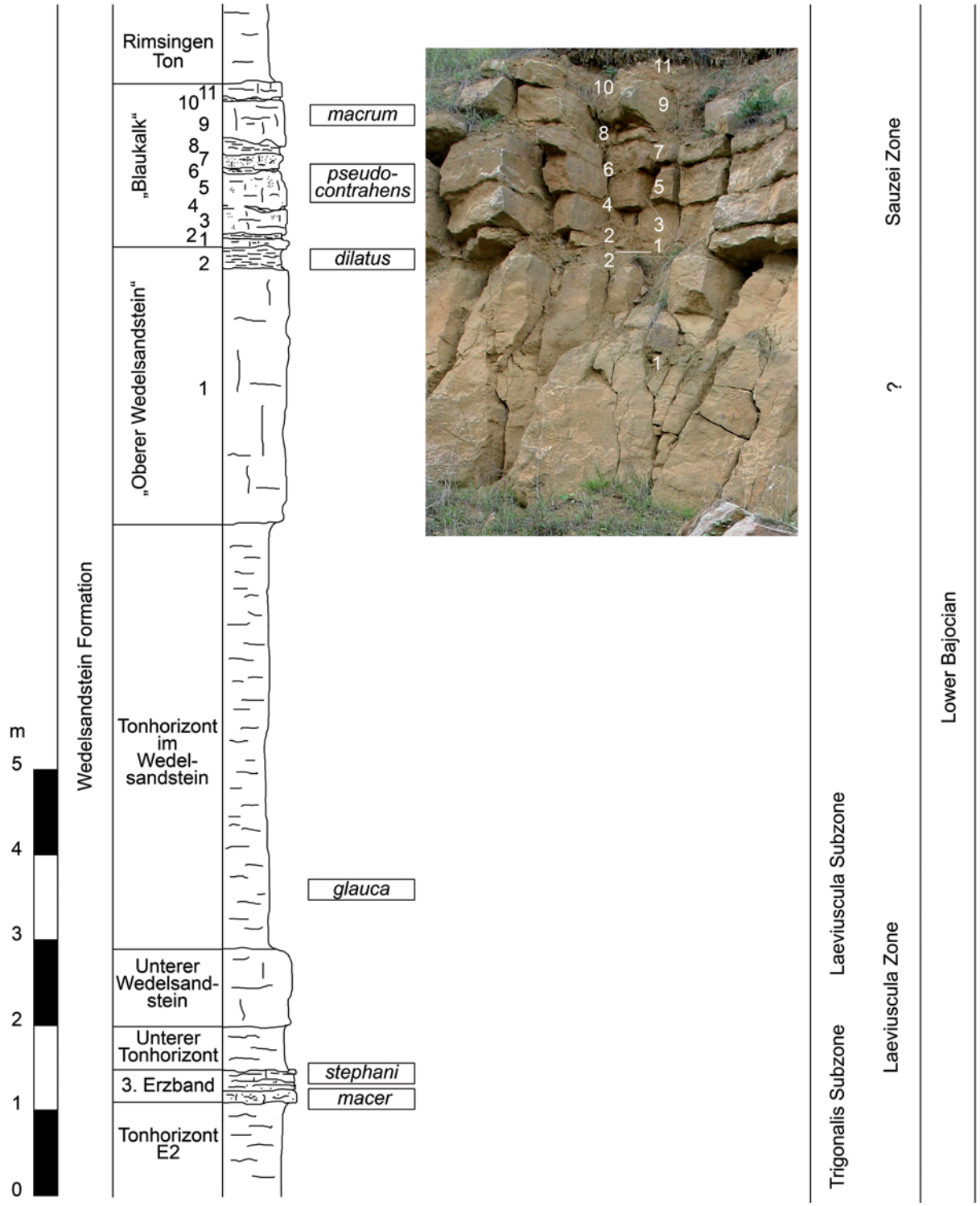


Fig. 34. Detailed section from the 3. Erzband to the base of the Rimsingen Ton. The photograph of the “Oberer Wedelsandstein” and the “Blaukalk” was taken in 2008.

Pelekodites moisyi (BRASIL) [m] (Pl. 4, Fig. 3)
P. sulcatus (BUCKMAN) [m] (Pl. 4, Fig. 4)
Nannina cf. *deltafalcata* (QUENSTEDT) [m] (Pl. 9, Fig. 3)
Bradfordia amblys (BUCKMAN) [M] (Pl. 4, Fig. 1)
B. etheridgii (BUCKMAN) [M] (Pl. 4, Fig. 5)

– Bed BL-7: Lithology as for bed BL-5, but yellow to red in colour (0.15 m).
Emileia vagabunda BUCKMAN [M] (Pl. 6, Fig. 2)
E. aff. *vagabunda* BUCKMAN [M] (coll. KUTZ)
Sonninia cf. *patella* (WAAGEN) [M] (coll. KUTZ)

– Bed BL-8: Marls with abundant oysters (0.02 m).
Stephanoceras macrum (QUENSTEDT) [M] (Pl. 12, Fig. 6)

– Bed BL-9: Yellow calcarenite, partly microsparitic, bio-detrital limestone (derived, partly with hematite encrusted echinoderms fragments in fine-grained matrix) with many bivalves, including pectinids, and single echinoderm spines (0.4 m).
Stephanoceras macrum (QUENSTEDT) [M] (Pl. 13)
Emileia fuellinsdorfense MAUBEUGE [M] (Pl. 14)

– Beds BL-10–11: Marl bed of 0.05 m (BL-10), then 0.15 m bio-detrital sandy marlstone finer than below (BL-11) with rare bivalves.
Stephanoceras macrum (QUENSTEDT) [M] (Pl. 12, Fig. 5)
?*Sonninia* sp.

2.3. Chrono- and biostratigraphy of the Laeviuscula and Sauzei zones

The chrono- and biostratigraphy of the Lower Bajocian (Fig. 2) is based on RIOULT et al. (1997); but modified after OHMERT (1988a, 1990, 2004), OHMERT et al. (1995) and DIETZE et al. (2005, 2008).

2.3.1. Laeviuscula Zone

2.3.1.1. Trigonalis Subzone

Horizon of *Pelekodites macer* (here newly introduced). – The 3. Erzband has in its lower, oolitic part a small, but typical fauna, characterised by a *Witchellia* fauna intermediate between the morphospecies *Witchellia jugifera* and *W. pseudoromanoides*. There are occasional specimens of *Sonninia*, mainly of the *S. adicra* group. *Fissilobiceras ovale* has not been recorded. The genus *Fissilobiceras* is a predominant faunal element in the older *oechslei* horizon of the Ovale Zone (DIETZE et al. 2005). Conversely there is no evidence of *Shirbuirnia gingensis*, characteristic of the *adicra α* and *adicra β* horizons of Eastern Swabia. For these reasons we position the *macer* horizon, index species *Pelekodites macer* BUCKMAN, at the base of the Trigonalis Subzone, between the *oechslei* and the *adicra α* horizons.

RIOULT et al. (1997) erected a 'horizon à Jugifera' – labelled with '*Sonninia*' [recte *Witchellia*] *jugifera* – for strata at the base of the Laeviuscula Subzone. To avoid confusion we refrain from the usage of *Witchellia jugifera* as the index for this horizon at the base of the Trigonalis Subzone.

Horizon of *Pseudoshirbuirnia stephani*. – The upper part of the 3. Erzband yields an ammonite fauna of the *stephani* horizon – index species *Pseudoshirbuirnia stephani* (BUCKMAN) – including the highly characteristic morphologies of *Pseudoshirbuirnia stephani* and *Ps. fastigata* that are unmistakable. The fauna of the genus *Pelekodites* is less diagnostic. A single example of *Witchellia* fits well with finds from the *stephani* horizon of Eastern Swabia.

2.3.1.2. Laeviuscula-Subzone

Laeviuscula Subzone strata are so far only recorded in Southern Germany from the Kahlenberg (Geologisches Landesamt Baden-Württemberg 1997) and the "γ-Tone" of Eastern Swabia (DIETZE et al. 2005). Examples of the species *Witchellia spinifera* found in the 19th century in "γ-Tone" of Gingen/Fils are more evolute compared to the *Witchellia laeviuscula* assemblage from the Kahlenberg and from Dundry Hill (CHANDLER et al. 2006); hence the "γ-Tone" of Gingen/Fils represent the faunal horizon of *Witchellia spinifera* (CHANDLER et al. 2006), first introduced in Southern England.

Horizon of *Witchellia glauca* (here newly introduced). – The ammonites now described from the Kahlenberg increase the faunal spectrum of the Laeviuscula Subzone in Southern Germany. We have selected *W. glauca* BUCKMAN as index species to avoid confusion with the *W. laeviuscula* Zone and Subzone. At Frogden Quarry near Oborne (Southern England), the type locality of *W. glauca*, the species occurs in the *spinifera* and in the *micracanthica* horizons (CHANDLER et al. 2006; pers. communication R. B. CHANDLER 2006). The type horizon is bed 3a of the "green grained marl" at Frogden Quarry. We have not recorded the typical morphogenera '*Prepapillites* BUCKMAN' and '*Papilliceras* BUCKMAN' – both belonging

to *Sonninia* Bayle (Dietze et al. 2005; Callomon & Chandler 2006). We have therefore refrained from the use of *Sonninia micracanthica* as a nominal label as used in Southern England.

The exact stratigraphic biostratigraphic position of the few, badly preserved ammonites (Pl. 1, Figs. 1, 2, 4) from the basal bed of the „Oberer Wedelsandstein" (OW-1) is unclear. This bed belongs either to the topmost Laeviuscula or the lowermost Sauzei Zone. It is possible, that it belongs in the *glauca* horizon of the Laeviuscula Zone. In Southern England *Witchellia laeviuscula* and *W. glauca* co-occur with sonniniids similar to our finds from bed OW-1 (Fig. 36).

2.3.2. Sauzei Zone

We refrain from subdividing the Sauzei Zone into subzones until further research is concluded in Southern Germany and Southern England. To date three faunal horizons can be resolved in the Sauzei Zone of Kahlenberg.

Horizon of *Otoites dilatus*. – Characteristic ammonites of the *dilatus* horizon of the area around the Hohenzollern castle in the Western Swabian Alb (Dietze et al. 2008) are relative common *Kumatostephanus* with broad whorl sections and highly variable representatives of *Otoites* including large inflated morphs. *Emileia* is highly variable; predominantly specimens with broad whorl sections and adult diameters for complete specimens of less than 20 cm, including *E. quenstedti*, occur. The occurrence of *Kumatostephanus triplicatus*, *Emileia lotharingica*, *Otoites dilatus* Westermann and *O. fortis* in bed OW-2 of the Oberer Wedelsandstein in the Kahlenberg section correlate well with known species of the *dilatus* horizon.

Horizon of *Emileia pseudocontrahens* (here newly introduced). – The ammonites of this faunal horizon (BL-3–7) have a unique and still undescribed record, distinguished primarily by *Emileia pseudocontrahens* Maubeuge/*E. vagabunda* Buckman and a sonniniid fauna with a high variability ranging from forms ornamented by nodes, *Sonninia propinquans* to smooth *S.* aff. *felix* [= *Sonninites* Buckman]/*S.* cf. *patella* (Waagen). *Pelekodites moisyi* (Brasil) is also characteristic.

Horizon of *Stephanoceras macrum*. – The uppermost 0.8 m of the "Blaukalk" (beds BL-8–11) constitute the *macrum* horizon at Ringsheim, erected by Dietze et al. (2008) for the beds from 1.5 to 3.0 m above the base of the Humphriesioolith in Gosheim (western Swabian Alb). Large, very evolute *Stephanoceras* [= *Skirroceras* auct.] *macrum* (Quenstedt) with rounded whorl-sections and small spines on the flanks is characteristic.

The single example of an *Emileia fuellinsdorfense* (Pl. 14) from bed Bl-9 is the first specimen with precise stratigraphical provenance for a member of the Otoitidae from the *macrum* horizon and thus the hitherto youngest record of this family at all. Two ex-situ specimens from the Kahlenberg (*Emileia arkelli* in coll. Knopf † and *Otoites* sp. in coll. Kutz) are by matrix neither from the *dilatus* nor from the *pseudocontrahens* horizons, but their source as *macrum* horizon is conjecture.

3. Remarks on the ammonite fauna of the Laeviuscula and Sauzei zones

3.1. Oppeliidae Douvillé, 1890

The figured examples from the Sauzei Zone are, with the exception of a *Bradfordia* sp. from the basal Laeviuscula Zone of the Breitenbach section near Reutlingen (Ohmert 2004), the oldest examples of Oppeliidae in Germany. The specimen illustrated on Pl. 4, Fig. 1 lies within the variability of *Bradfordia amblys* (Buckman), as compared with numerous new, unpublished topotypes from the type locality Sandford Lane (Dorset, Southern England). The typical furrow running parallel to the umbilical margin (Dietze et al. 2007), characteristic of *Bradfordia* Buckman, 1910 is clearly visible. The determination of the small fragment (Pl. 4, Fig. 5) as *Bradfordia etheridgii* is in a purely morphological sense. *Praeoppelia gracilobata* (Vacek) on Pl. 4, Fig. 2 has no furrows. The morphospecies *P. gracilobata* ranges from the Aalenian to the Sauzei Zone of the Bajocian (Sapunov 1971; Sadki 1988; Callomon et al. 1994).

3.2. Stephanoceratidae Neumayr, 1875

The genera *Stephanoceras* Waagen, 1869 and *Kumatostephanus* Buckman, 1922 occur in the Sauzei Zone of Southern Germany.

The first records of *Stephanoceras* are from the Upper Aalenian of the Tethys (Dietze et al. 2007). The roots of the genus can be traced from the genus *Erycites* Gemmellaro, 1886. Presently only single specimens are recorded from strata older than the *macrum* horizon of Southern Germany. One published example comes from the topmost Ovale or the lowermost Laeviuscula zones of the Wutach area (Dietze et al. 2001), another one was figured by Dietl & Haag (1980) from the *stephani* horizon of the Trigonalis Subzone of Eastern Swabia. A fragment, possibly affiliated to *Stephanoceras,* was found in bed OW-1 (Pl. 1, Fig. 4). The genus dominates with the species *S. macrum* in the *macrum* horizon of the Sauzei Zone of Southern Germany, reflecting the opening of a passage through which these Tethyan migrants arrived.

The palaeogeographic roots of *Kumatostephanus* are unknown, but may lie somewhere in the Jurassic Pacific. The oldest representatives known from the Tethys come from the uppermost Laeviuscula Subzone (CHANDLER et al. 2006). Initially GALÁCZ (1988) proposed to define the beginning of the Sauzei Zone with the first occurrence of *Kumatostephanus* [M] and its dimorphic counterpart *Gerzenites* [m]. CHANDLER et al. (2006) have discovered that *Witchellia laeviuscula*, the index-species of the zone, occurs at its type locality, Dundry Hill (near Bristol, Southern England) together with the earliest *Kumatostephanus*, thus it was desirable, to re-position the base of the Sauzei Zone to a slightly later horizon to retain the integrity of the Laeviuscula Zone.

K. triplicatus (Pl. 1, Fig. 3) is a common, characteristic faunal element of the *dilatus* horizon. Nearly identical specimens of the species come from the uppermost bed of the Blaukalk in Gosheim and from near Hohenzollern castle (DIETZE et al. 2008). *K.* aff. *turgidulus* in the *pseudocontrahens* horizon (Pl. 11, Figs. 1–2) of Ringsheim exhibits a more rounded and less compressed whorl section compared to *K. triplicatus*.

3.3. Otoitidae MASCKE, 1907

The first recorded specimens to date occur as the dimorphic pair *Docidoceras* BUCKMAN [M]/*Trilobiticeras* BUCKMAN [m] in the Discites Zone. The oldest *Emileia* BUCKMAN [M]/*Otoites* MASCKE [m] occur as extreme rarities in the Ovale Zone and increase in frequency nearly until the end of the Sauzei Zone (DIETZE & CHANDLER 2008). In contrast to those areas lying more to the west of the Tethyan shelf (Southern England, Spain, Morocco), in Southern Germany both *Emileia* and *Otoites* are very uncommon in strata earlier than the Laeviuscula/Sauzei zonal boundary. The importance of the Ringsheim specimens is that they demonstrate for the first time the variability of the (bio-)species within one faunal horizon (*pseudocontrahens* horizon). The hitherto youngest known *Emileia* (Pl. 14) comes from the *macrum* horizon of Ringsheim.

A single *Emileia lotharingica* MAUBEUGE (Pl. 2, Fig. 2), two *Otoites dilatus* WESTERMANN (Pl. 2, Fig. 3) and one *O. fortis* WESTERMANN (Pl. 2, Fig. 1) have been found in the *dilatus* horizon. *E. lotharingica* and *O. dilatus* have a relatively broad, inflated whorl section and comparable specimens have been found in the *dilatus* horizon of the Hohenzollern area (Western Swabian Alb).

The *pseudocontrahens* horizon has produced 25 specimens of *Emileia*, mostly fragments and nuclei and about 10 *Otoites* (colls. KUTZ and BOSCH). The ribbing of the *Emileia* population is rather dense. The variability ranges between the morphospecies *E. pseudocontrahens* MAUBEUGE (Pl. 3, Figs. 1–3) and *E. vagabunda* BUCKMAN (Pl. 5, Fig. 1; Pl. 6, Fig. 2) [?synonym: *E. pseudomultifida* MAUBEUGE]. In contrast, *E. pseudocontrahens* is extremely finely ribbed and involute on the innermost whorls. Specimens of *E. vagabunda* are more evolute on the inner whorls and less densely ribbed. The specimen figured on Pl. 5, Fig. 1 is completely septate. Its complete size with body chamber would be in excess of 30 cm. In Southern England *Emileia* of this size occur no earlier than in the *kalum* horizon (Bj-11a; Fig. 36). Additional elements of the *Emileia* population in the *pseudocontrahens* horizon are *E.* cf. *arkelli* (coll. KUTZ), *E.* aff. *vagabunda* (coll. KUTZ) and *E.* cf. *bulligera* (Pl. 4, Fig. 6).

The specimen of *E. fuellinsdorfense* MAUBEUGE (Pl. 14) from the *macrum* horizon is still more densely ribbed as the finds from the *pseudocontrahens* horizon.

The *Otoites* fauna of the *pseudocontrahens* horizon like that of *Emileia* and the *Sonninia* display a unique character, hence we use 'cf.' in our identifications. The most coarsely ribbed specimen (Pl. 12, Fig. 3) matches with *O. pauper* WESTERMANN, apart from a slightly broader whorl section. A specimen identified as *O. contractus* BUCKMAN (Pl. 12, Fig. 4) is, apart from its denser ribbing, very similar to the specimen on Pl. 12, Fig. 4. Very close to that figured as Pl. 12, Fig. 3 is a specimen with a narrower whorl section (Pl. 6, Fig. 1) and can be best identified as *O.* cf. *contractus* BUCKMAN. *Otoites* cf. *seitzi* (Pl. 5, Fig. 3) shows a minute umbilicus and very delicate tubercles at the dividing points of the ribs. The morphospecies *O. fortis* WESTERMANN (Pl. 5, Fig. 2) is just a micromorphic *O. contractus*.

3.4. Sonniniidae BUCKMAN, 1892

DIETZE et al. (2005) and CALLOMON & CHANDLER (2006) have recently studied the Sonniniidae in detail. With the specimens from the Kahlenberg the phylogeny of this family can be described for the first time in the upper part of the Sauzei Zone. Presently our knowledge of sonniniid evolution in the Sauzei Zone and basal Humphriesianum Zone is highly incomplete. Many nominal taxa are described from these strata, however, their exact stratigraphical provenience is rarely known. Here we provide adequate details of the fauna to serve as a basis for a future monograph of the family.

3.4.1. Witchelliinae CALLOMON & CHANDLER, 2006

The oldest *Witchellia* from the Kahlenberg occur in the the *macer* horizon of the 3. Erzband with a variability ranging between evolute *Witchellia jugifera* (Fig. 3) and allied morphs labelled as *W.* cf. *jugifera* (Figs. 10, 11) to *W. pseudoromanoides* (Figs. 4, 7). Morphological overlap ex-

ists between the *Witchellia* faunas of the younger *adicra α* and *adicra β* horizons of the Eastern Swabian Alb, where the trend to a coarser ribbing is already more marked. The small *Pelekodites* of the *macer* horizon belong to *Pelekodites macer* (Buckman) (Figs. 8–9).

The *stephani* horizon yielded a finely ribbed *Witchellia* sp. (Fig. 18), matching well with a specimen figured by Dietze et al. (2005, fig. 34c) from the *stephani* horizon of Eastern Swabia. The *Pelekodites* fauna is fragmentary and poorly preserved and included in *P.* cf. *schlumbergeri* (Haug) (Figs. 15, 20) with its constant ribbing style. Specimens of *P.* cf. *spatians* (Buckman) (Fig. 19) and *P. boweri* (Buckman) (Fig. 17) are relatively large.

The *glauca* horizon of the Kahlenberg yields a *Witchellia* fauna identical in variability to the *micracanthica* horizon (Bj-10b; Fig. 36) of the Laeviuscula Subzone of Southern England, but there is a trend in the Kahlenberg specimens to be more evolute than those from the *spinifera* horizon (Bj-10a) of Southern England. Scarce, but diagnostic specimens from the Kahlenberg centre on *W. laeviuscula* (Figs. 21, 22, 26), a finer ribbed variety *W.* cf. *laeviuscula* (Fig. 27) and the coarsely ribbed and more evolute *Witchellia glauca* (Figs. 23–25, 28–29). We regard *W. falcata* Buckman and *W. actinophora* Buckman as subjective junior synonyms of *W. glauca*. *W. spinifera* Buckman differs from *W. glauca* by possessing slightly spinose inner whorls. We have not observed this feature in any of the Kahlenberg specimens. The entire range of morphology seen in the *Witchellia* specimens of the *glauca* horizon are almost certainly members of a single palaeobiospecies (Callomon & Chandler 2006). Callomon & Chandler (2006) regarded *Pelekodites spatians* as the microconch counterpart of the genus *Witchellia*. The *P.* cf. *spatians* (Figs. 30–31) of this study show finer ribbing than the holotype, but otherwise match well.

Pelekodites of the *pseudocontrahens* horizon are characterised by a sub-quadrate whorl section already resembling the extreme morphology of *Pelekodites hannoverana* and *P. westfalica* of the Pinguis Subzone, but lacking the very broad whorl section. We place most of the specimens in *Pelekodites moisyi* (Brasil) (Pl. 4, Fig. 3; Pl. 10, Figs. 1–6) as differences in the ribbing and whorl section fall within the variability of this species. Only the more involute *P. sulcatus* (Buckman) (Pl. 4, Fig. 4), with its rounded venter differs significantly. The total absence of the genus *Witchellia,* the presumed sexual dimorph of *Pelekodites* (Callomon & Chandler 2006) in the *pseudocontrahens* horizon indicates the possibility that *Pelekodites* is a polyphyletic genus.

3.4.2. Sonniniinae Buckman, 1892

Two specimens of *Pseudoshirbuirnia* from the *stephani* horizon in the upper part of the 3. Erzband belong to *Ps. fastigata* (Fig. 14) and *Ps. stephani* (Fig. 16).

Three specimens of *Sonninia* in the *macer* horizon are the inner whorls of juveniles identifiable only as *S.* ex gr. *adicra* (Figs. 12–13). Figs. 5–6 lack ornament and are identified only as *Sonninia* sp., as two similar fragments (Figs. 32–33) from the *glauca* horizon. The genus is proved in the *stephani* horizon by two small, indeterminable fragments of juvenile specimens.

Comparable specimens to ammonites figured on Pl. 1, Figs. 1–2 from the bottom layer of the Oberer Wedelsandstein (OW-1) occur in Southern England (Dundry Hill, Frogden Quarry near Sherborne) around the boundary of the Laeviuscula/Sauzei zones. Dorn (1935) has figured similar specimens from Oberleinleiter (Northern Franconian Alb).

The *Sonninia* fauna of the *pseudocontrahens* horizon has a range of variability between two extreme end-members with all intermediate morphologies present.

Relatively evolute specimens, strongly sculptured on the inner whorls are placed in *Sonninia propinquans* (Pl. 9, Fig. 2; Pl. 10, Fig. 7). These are almost identical to specimens figured by Bayle (1878, pl. 84, figs. 1–6) as *Waagenia propinquans* from the Sauzei Zone [= Propinquans Zone auct.] of Les Moutiers near Caen (Normandy). The large morphological variability within *Sonninia propinquans* prompted Gillet (1937) to erect several varieties. One of these, *S. propinquans* var. *hussigniensis*, occurs at the Kahlenberg. We also consider *S. hussigniensis* to be a variant of *S. propinquans* and therefore include it in the latter.

The lectotype of *S. propinquans* is the specimen figured by Bayle (1878, pl. 84, fig. 1), not the specimen given as pl. 84, figs. 3, 4 erroneously used by Westermann & Riccardi (1972) and Schlegelmilch (1985). Prior to Roman (1938), Gillet (1937: 30) had designated Bayle's fig. 1 as 'le type'. This is a valid lectotype designation (J. H. Callomon in litt. 2006).

At the opposite extreme of variability are specimens that can be determined as *Sonninites* Buckman. These are characterised by compressed shells with high whorl sections, ornamented only with growth lines. The inner and middle whorls are relatively involute and weakly sculptured. The specimens exhibit radial, often straight primary ribs, rarely with tiny nodes. The sharp umbilical walls, which may overhang slightly, become in later ontogenetic stages slightly rounded with a pronounced flattening of the whorl flank. The variability of the Kahlenberg specimens is slightly different compared to the variability of topotypes of *Sonninites felix* Buckman from Sandford Lane Quarry, Sherborne, Dorset, UK (Sauzei Zone). We identify our examples as *S.* aff. *felix* (Pl. 8, Figs. 1–4; Pl. 11, Fig. 3). The Dorset specimens have slightly broader whorl sections and a more evolute trend with more defined

ventral shoulders. This is the opposite of specimens from Ringsheim where the overhanging umbilical edge persists later than in the topotypes. The complex suture line of the specimens from Ringsheim is of typical sonniniid style (Pl. 11, Fig. 3).

Between end members are specimens with a variety of intermediate morphological features including evolute specimens (Pl. 7, Fig. 1) with marked regular, primary ribs on the inner whorls, in some sporadically bunched at the base, but lacking marked nodes as in *S. propinquans*. Apart from having slightly less developed nodes and sculpture, which becomes smooth later, they can be matched with *Sonninia patella* (Waagen). We identify these specimens as *S.* cf. *patella* and include the example from Pl. 9, Fig. 5, which is more involute with weaker sculpture and delicate spines on the inner whorls compared to the lectotype (Waagen 1867, pl. 25, fig. 2; Dietze et al. 2005). *S.* cf. *propinquans* (Pl. 9, Fig. 1; Pl. 11, Fig. 4) has a broader, higher whorl section with coarse, more or less straight primary ribbing. These specimens are close to ammonites figured by Morton (1975, pl. 16, figs. 1–2; pl. 17, figs. 3–4) from the Hebridica Subzone of the Isle of Skye (Scotland) as *Sonninia* aff. *furticarinata*. Callomon & Chandler (2006) assigned these ammonites to the genus *Sonninites*.

Concerning the intergrading morphology between the *S. propinquans* and the *S.* aff. *felix*/cf. *patella* groups, we consider all specimens from the *pseudocontrahens* horizon to belong to one palaeo-biospecies to be placed in *Sonninia*.

Some of our figured specimens of *S.* cf. *patella* and *S.* aff. *felix* resemble ammonites figured by Buckman (1892) as *Dorsetensia liostraca*, *D. subtecta* and *D. tecta* from the Romani Subzone (Humphriesianum Zone) of Frogden Quarry (Oborne, Southern England). It is possible that the sonniniid fauna from the *pseudocontrahens* horizon is the evolute forerunner of these taxa, however, this requires the complex sonniniid suture line to become simplified within a short time between the Sauzei Zone and the Romani Subzone. The macroconch *Dorsetensia* of the Romani Subzone compared to *Sonninia* [*Sonninites*] possesses a much simplified suture line (Huf 1968), resembling that of *Pseudoshirbuirnia*, the latter, however, lacks the high, sharp keel typical of these *Dorsetensia.*

A specimen of *Nannina* cf. *deltafalcata* [m] (Pl. 9, Fig. 3) has been recovered from the *pseudocontrahens* horizon of the Sauzei Zone at the Kahlenberg. The acme of the species *N. deltafalcata* in Southern Germany is in the Pinguis and Romani subzones but the specimens are larger (Ohmert 1990; Ohmert et al. 1995; Pl. 9, Fig. 4 = lectotype of *Nannina deltafalcata* (Quenstedt)). Huf (1968, pl. 11) figured specimens from the "Mittel-Bajocium" of Gerzen (Northern Germany), which are comparable with our specimen. Huf's specimens probably come from around the Pinguis-/Romani subzonal boundary. The faunal horizon of *Nannina evoluta* (Bj-11b) in Southern England lies within the Sauzei Zone (Fig. 36). Pavia (1983) has also cited the genus *Nannina* from the Sauzei Zone of Southeastern France.

3.5. Strigoceratidae Buckman, 1924

The Strigoceratidae were recently revised by Schweigert et al. (2007) using the chronospecies concept. By this treatment all strigoceratids from the Sauzei Zone can be placed in *Strigoceras languidum* (Buckman).

4. Correlation within Southern Germany and with Southern England

4.1. Southern Germany

L a e v i u s c u l a Z o n e . – Three faunal horizons can be recognised at the Kahlenberg:

The *macer* horizon in the bottom part of the 3. Erzband is slightly younger than the *oechslei* horizon of the Ovale Zone. This is clear at the Kahlenberg, where the 3. Erzband rests some meters above the *oechslei* horizon (oolitic marl bed on the top of the Oberes Erzband). The ammonite faunas of both horizons differ by the absence of *Pseudoshirbuirnia oechslei* and *Fissilobiceras ovale* in the *macer* horizon, whereas both species are typical of the *oechslei* horizon. There is considerable similarity in *Witchellia* from both horizons with *W. jugifera* common in both and *W. pseudoromanoides* suggestive of *adicra α*/*β* horizon morphs. *Shirbuirnia gingensis*, very characteristic of the *adicra α* and *adicra β* horizons (Dietze et al. 2005), is absent from the *macer* horizon (Fig. 35).

The correlation of the *stephani* horizon by the occurrence of *Pseudoshirbuirnia stephani* and *Ps. fastigata* at the Kahlenberg with that of Eastern Swabia is effortless (Fig. 35).

The *glauca* horizon in the Tonhorizont im Wedelsandstein of Ringsheim yields for the first time a reasonable ammonite fauna from the Laeviuscula Subzone of Southern Germany. The only evidence from Gingen an der Fils (Eastern Swabia) is restricted to few ammonites from the "γ-Tone" (Dietze et al. 2005). It can be assigned now to the faunal horizon of *Witchellia spinifera* (Chandler et al. 2006; Fig. 35). In keeping with the evidence in Southern England we date the *spinifera* horizon as slightly older than that of the *glauca* horizon. The Blaukalk of Gingen an der Fils with *S. mesacantha* (type locality) is younger than the subjacent "γ-Tone" with the *spinifera* horizon. Of similar age and near the Laeviuscula/Sauzei zonal boundary is bed OW-1 at the Kahlenberg.

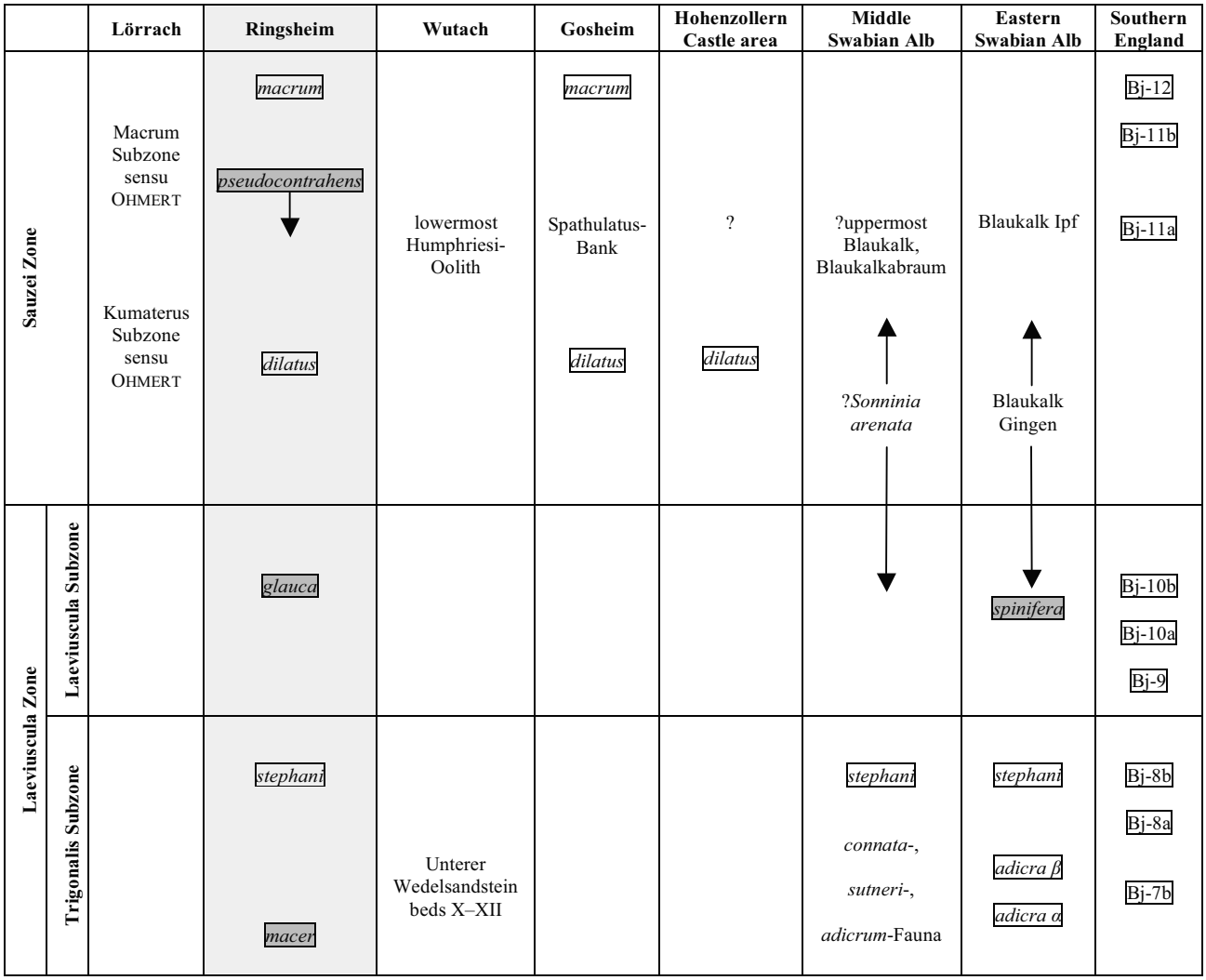


Fig. 35. Correlation of the Kahlenberg section with other sections in Southern Germany and the faunal horizons described from Southern England in the Laeviuscula and Sauzei zones (Lower Bajocian). New horizons are in grey colour. An arrow indicates that the relative stratigraphical position is still unclear (modified from Dietze et al. 2008).

S a u z e i - Z o n e . – Three faunal horizons can be recognised at the Kahlenberg:

The first evidence of the *dilatus* horizon was found in the top layer of the Blaukalk near the Hohenzollern Castle (Western Swabian Alb; Dietze et al. 2008; Fig. 35). At Gosheim the *dilatus* horizon lies in a similar position, directly below the Humphriesi-Oolith.

The best stratigraphically controlled bed-by-bed collections of ammonite fauna from the Sauzei Zone in Southern Germany come from the *pseudocontrahens* horizon of Ringsheim. The basal Humphriesi-Oolith of the Wutach area (Dietze et al. 2008) can be correlated approximately with the *pseudocontrahens* horizon. The *Emileia* fauna of the basal Humphriesi-Oolith of Gosheim is distinguished from that of the *pseudocontrahens* horizon and is probably slightly older. The investigations of the beds above the *dilatus* horizon around the Hohenzollern Castle are still incomplete. There is at least one further faunal horizon between the *dilatus* and the *ohmerti* horizon of that area (Dietze et al. 2008). It yields besides *Sonninia propinquans* typical large, smooth "*Sonninites*" and relative common *Strigoceras languidum*. Further investigations should clarify if this horizon is older or of the same age as the *pseudocontrahens* horizon. Unresolved, similar problems remain regarding the relative stratigraphical position of the Oberer Blaukalk and the Blaukalkabraum of the Middle Swabian Alb. Abundant specimens in old collections of *Emileia polyschides* and *S.*

		Southern Germany	Southern England
Sauzei Zone		*Stephanoceras macrum* *Emileia pseudocontrahens* ? *Otoites dilatus*	*Stephanoceras rhytum*; Bj-12 *Nannina evoluta*; Bj-11b *Stephanoceras kalum*; Bj-11a
Laeviuscula Zone	Laeviuscula Subzone	*Witchellia glauca* *Witchellia spinifera*	*Sonninia micracanthica*; Bj-10b *Witchellia spinifera*; Bj-10a *Witchellia rubra*; Bj-9
	Trigonalis Subzone	*Pseudoshirbuirnia stephani* *Sonninia adicra β* *Sonninia adicra α* *Pelekodites macer*	*Shirbuirnia trigonalis*; Bj-8b *Euhoploceras nodatipingue*; Bj-8a *Witchellia pseudoromanoides*; Bj-7b

Fig. 36. Correlation of the published faunal horizons between Southern Germany and Southern England in the Laeviuscula and Sauzei zones (Lower Bajocian).

[*Prepapillites*] *arenata* from the Middle Swabian Alb (Balzholz near Neuffen to Reutlingen) indicate an older horizon than *pseudocontrahens* lying near the boundary of the Laeviuscula and Sauzei zones.

At the Kahlenberg directly above the uppermost bed of the *pseudocontrahens* horizon (BL-7) the *macrum* horizon (BL-8) is found. This indicates that the *pseudocontrahens* horizon is probably the youngest faunal horizon below that of *macrum*. The stephanoceratid ammonite faunas of the beds containing the *macrum* horizons of Ringsheim and Gosheim (Fig. 35) are identical (DIETZE et al. 2008).

4.2. Southern England

L a e v i u s c u l a Z o n e . – The *macer* horizon of the Trigonalis Subzone (Fig. 36) lies between the faunal horizons of *Witchellia gelasina* (Bj-7a) of the uppermost Ovale Zone and *Witchellia pseudoromanoides* (Bj-7b) of the lowermost Laeviuscula Zone. Unpublished specimens from Bruton (coll. R. B. CHANDLER) indicate that the *Witchellia* fauna of Bj-7a is relatively less ornamented with most of them still resembling *W. romanoides*. In contrast the *Witchellia* fauna of Bj-7b possesses more strongly ribbed morphs, centred on *W. pseudoromanoides*.

The *stephani* horizon approximates in age to the faunal horizon of *Shirbuirnia trigonalis* (Bj-8b), and the *glauca* horizon of Ringsheim matches with the *Sonninia micracanthica* (Bj-10b) horizon.

S a u z e i Z o n e . – The faunal horizon of *Stephanoceras kalum* (Bj-11a), the oldest faunal horizon of the Sauzei Zone of Southern England, is younger than the *dilatus* horizon of Ringsheim (Fig. 36). Both, the *Emileia*/*Otoites* and the *Sonninia* faunas in the *kalum* horizon are further developed. The *pseudocontrahens* horizon appears to be younger.

In Southern England the faunal horizon of *Nannina evoluta* (Bj-11b) has yielded rare representatives of the genus *Emileia*. It contains typical *Sonninia alsatica* and is

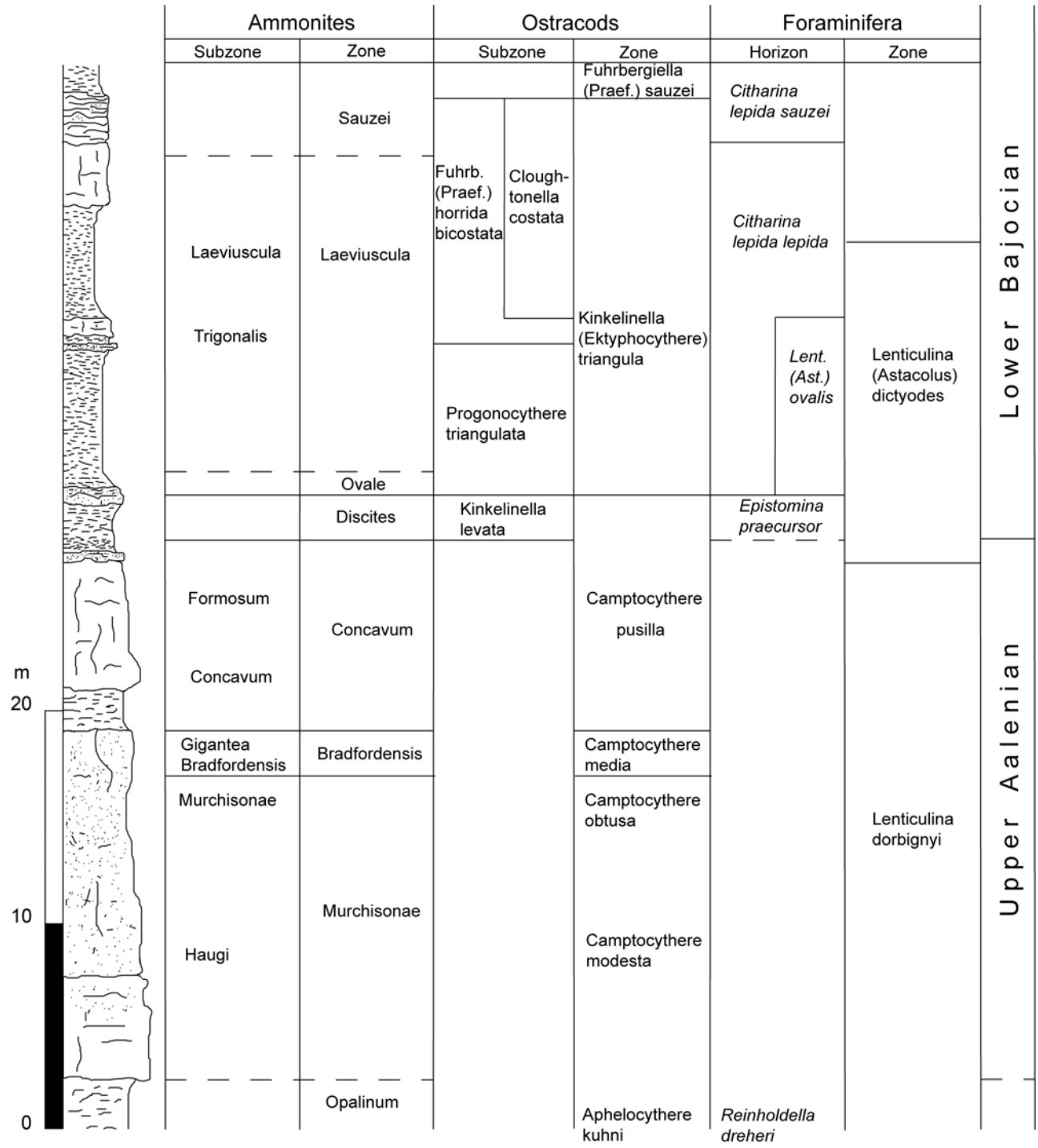


Fig. 37. Correlation of the ammonite-, ostracoda- and foraminifera-stratigraphy at the Kahlenberg (microfaunal zonation from OHMERT 2004).

younger than the *pseudocontrahens* horizon. The *Sonninia* fauna of the *pseudocontrahens* horizon shows typical *Sonninia propinquans*, also common in the *kalum* horizon, but absent in the *evoluta* horizon (J. H. CALLOMON and R. B. CHANDLER, unpublished). Specimens of *Sonninia* with straight radial ribs are typical for both levels. The faunal horizon of *Stephanoceras rhytum* (Bj-12) in Dorset and the *macrum* horizon in Southern Germany yield ex-

tremely large stephanoceratids ["*Skirroceras*" auct.], however, the faunas are not identical. Both horizons yielded very rare Otoitidae (R. B. Chandler collection from the Red Bed of Burton Bradstock). They are of similar age, and the differences in the *Stephanoceras* faunas of the *macrum* and the *rhytum* horizons may also have ecological or palaeogeographic reasons.

5. Remarks on the microfauna

The microfauna of the Aalenian and Bajocian was described by Brand & Ohmert (1992), Braun (1958), Buck et al. (1966), Dilger (1963), and particularly Ohmert (1988a, b, 1996, 2004), to which we refer for further details. Ohmert (2004: 73) subdivided the layers into zones, subzones, and ostracoda (O) and foraminifera (F) microfaunal horizons. Details of the microfauna and stratigraphy of strata below the 3. Erzband and above the Blaukalk and its correlation with the ammonite stratigraphy is given in Fig. 37.

Progonocythere triangulata Subzone (O), *Lenticulina (Astacolus) ovalis* horizon (F). – Strata from the upper part of the Oberes Erzband to the 3. Erzband are characterised by the occurrence of *Kinkelinella (Ektyphocythere) triangula* (Brand) and *Progonocythere triangulata* Braun in Ohmert. *Pleurocythere* cf. *kirtonensis* persists from below. The foraminifera *Citharina lepida lepida* (Schwager) and *Lenticulina (Astacolus) ovalis* (Brand & Ohmert) have their first appearances.

Some 1–1.5 m above the Oberes Erzband there is an interruption in the occurrence of *Kinkelinella (Ektyphocythere) triangula*. *Citharina lepida lepida*, *Lophodentina*? *ultima* (Braun) occurs rarely for the first time. The sudden mass occurrence of large-sized foraminifera *Haplophragmium coprolithiforme* (Schwager) is worthy of mentioning.

Fuhrbergiella (Praefuhrb.) horrida bicostata Subzone (O), *Citharina lepida lepida* horizon (F). – Above the 3. Erzband is the first occurrence of *Fuhrbergiella (Praefuhrbergiella) horrida bicostata* Brand & Malz, whereas *Progonocythere triangulata* becomes extinct.

The interval from the top of the Unterer Wedelsandstein to the top of the Oberer Wedelsandstein is characterised by *Cloughtonella costata* Braun in Ohmert (*Cloughtonella costata* horizon) and *Lophodentina*? *ultima*, which is especially abundant. *Kinkelinella (Ekt.) triangula* reappears.

Fuhrbergiella (Praefuhrb.) sauzei Zone (O), *Citharina lepida sauzei* horizon (F). – New results prove *Fuhrbergiella (Praef.) sauzei* Brand & Malz and *Citharina lepida sauzei* Ohmert in the Blaukalk of Ringsheim. The lower boundary of the Sauzei Subzone/*sauzei* horizon was preliminary drawn with the first occurrences of the species (Fig. 37). Additionally *Lenticulina* cf. *quenstedti*, *Lenticulina* spp., *Dentalina* sp., *Nodosaria* sp., *Spirillina tenuissima* were recorded. In bed BL-10 *Haplophragmium coprolithiforme* and *Reophax* sp. were found. *Praeschuleridea subtrigona* (Jones & Sherborn) and *Kinkelinella (Ekt.) triangula* occur throughout the Blaukalk. *Lophodentina*? *ultima* remains common in bed OW-2 but is rare in beds BL-4 and 6 together with *Pleurocythere laticosta* Braun in Dilger, *Fuhrbergiella (Praef.) sauzei* and *Cytherelloidea fullonica* Jones & Sherborn which are scarcely recorded in bed BL-10.

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Adresses of the authors:

VOLKER DIETZE, Benzstr. 9, 73469 Riesbürg-Pflaumloch, Germany
E-mail: v.dietze@enmail.de

MICHAEL KUTZ, 8 rue haute, 67390 Mackenheim, France
E-mail: michael.kutz@orange.fr

Dr. MATTHIAS FRANZ, Regierungspräsidium Freiburg, Landesamt für Geologie, Rohstoffe und Bergbau, Albertstrasse 5, 79104 Freiburg im Breisgau, Germany
E-mail: matthias.franz@rpf.bwl.de

KLAUS BOSCH, Sonnhalde 13, 77975 Ringsheim, Germany
E-mail: klaus-bosch@web.de

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Plate 1

Specimens from around the boundary Laevisucula/Sauzei zones and from the *dilatus* horizon (Sauzei Zone), "Oberer Wedelsandstein", Kahlenberg.

Fig. 1. *Sonninia* sp. [M]; Bed OW-1, boundary Laeviuscula/Sauzei zones; SMNS 67440.

Fig. 2. *Sonninia strigoceroides* Dorn [M]; Bed OW-1, boundary Laeviuscula/Sauzei zones; SMNS 67420.

Fig. 3. *Kumatostephanus triplicatus* (Renz) [M]; Bed OW-2, *dilatus* horizon; SMNS 67429; **a**. Ventral view, **b**. Lateral view.

Fig. 4. ?*Stephanoceras* sp. [M]; Bed OW-1, boundary Laeviuscula/Sauzei zones; SMNS 67441.

All figures in natural size; beginning of body chamber is marked by an asterisk.


1
2
3a
3b
*
4

Plate 2

Specimens from the *dilatus* horizon (Sauzei Zone), "Oberer Wedelsandstein", bed OW-2, Kahlenberg.

Fig. 1. *Otoites fortis* Westermann [m]; SMNS 67473; **a**. Lateral view, **b** Ventral view.
Fig. 2. *Emileia lotharingica* Maubeuge [M]; SMNS 67426; **a**. Ventral view, **b**. Lateral view.
Fig. 3. *Otoites dilatus* Westermann [m]; SMNS 67439; **a**. Lateral view, **b**. Ventral view.

All figures in natural size; beginning of body chamber is marked by an asterisk.

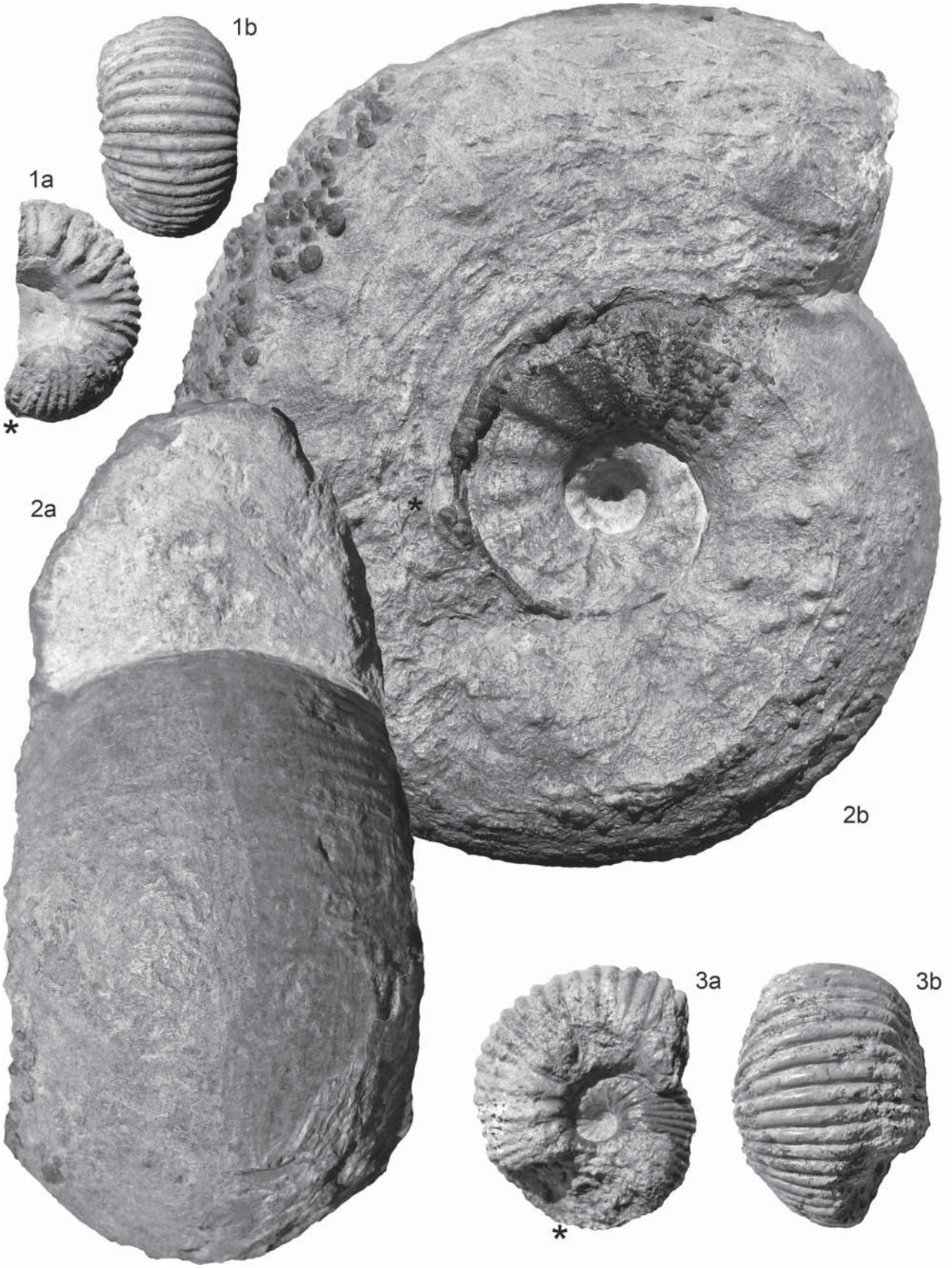
1b
1a
*
2a
*
2b
3a
3b
*

Plate 3

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Beds BL-3–5, Kahlenberg.

Fig. 1. *Emileia pseudocontrahens* Maubeuge [M]; SMNS 67435; **a**. Lateral view, **b**. Ventral view.
Fig. 2. *Emileia pseudocontrahens* Maubeuge [M]; SMNS 674421.
Fig. 3. *Emileia pseudocontrahens* Maubeuge [M]; SMNS 67428; **a**. Lateral view, **b**. Ventral view.

All figures in natural size.


1a
1b
2
3a
3b

Plate 4

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Kahlenberg.

Fig. 1. *Bradfordia amblys* (Buckman) [M]; Bed BL-6; SMNS 67474; **a**. Ventral view, **b**. Lateral view.

Fig. 2. *Praeoppelia gracilobata* (Vacek) [M]; Beds BL-3–5; SMNS 67475; **a**. Ventral view, **b**. Lateral view.

Fig. 3. *Pelekodites moisyi* (Brasil) [m], complete with body chamber; Bed BL-6; SMNS 67465; **a**. Lateral view, **b**. Ventral view.

Fig. 4. *Pelekodites sulcatus* (Buckman) [m], complete with body chamber; Bed BL-6; SMNS 67464; **a**. Lateral view, **b**. Ventral view.

Fig. 5. *Bradfordia etheridgii* (Buckman) [M]; Bed BL-6; SMNS 67448; **a**. Lateral view, **b**. Ventral view.

Fig. 6. *Emileia* cf. *bulligera* Buckman [M], complete internal mould with the casts of a serpulid on the inner side of the former shell; Beds BL-3–5; SMNS 67425.

All figures in natural size; beginning of body chamber is marked by an asterisk.


1a
1b
2a
2b
3a
3b
4a
4b
5a
5b
6

Plate 5

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Kahlenberg.

Fig. 1. *Emileia vagabunda* Buckman [M], ?complete phragmocone; Beds BL-3–5; SMNS 67427; **a**. Lateral view, **b**. Ventral view.
Fig. 2. *Otoites fortis* Westermann [m]; body chamber; Bed BL-6; SMNS 67442.
Fig. 3. *Otoites* cf. *seitzi* Westermann [m]; Beds BL-3–5; SMNS 67465.

All figures in natural size; beginning of body chamber is marked by an asterisk.

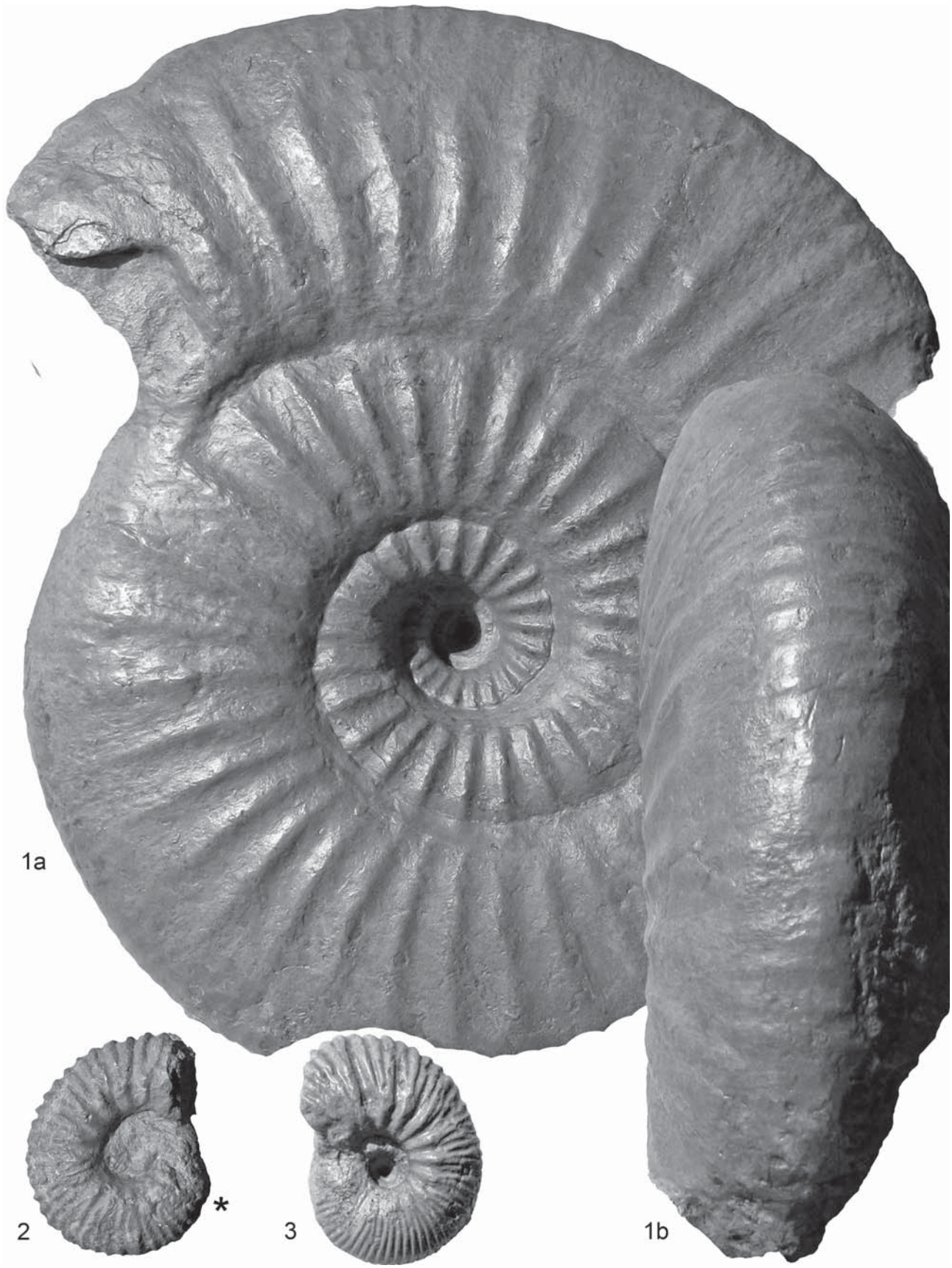
1a
1b
2
*
3

Plate 6

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Kahlenberg.

Fig. 1. *Otoites* cf. *contractus* (Sowerby) [m], complete with lappets; Beds BL-3–5; Collection Kutz; **a**. Ventral view, **b**. Lateral view.

Fig. 2. *Emileia vagabunda* Buckman [M]; Bed BL-7; SMNS 67452; **a**. Lateral view, **b**. Whorl section.

All figures in natural size.

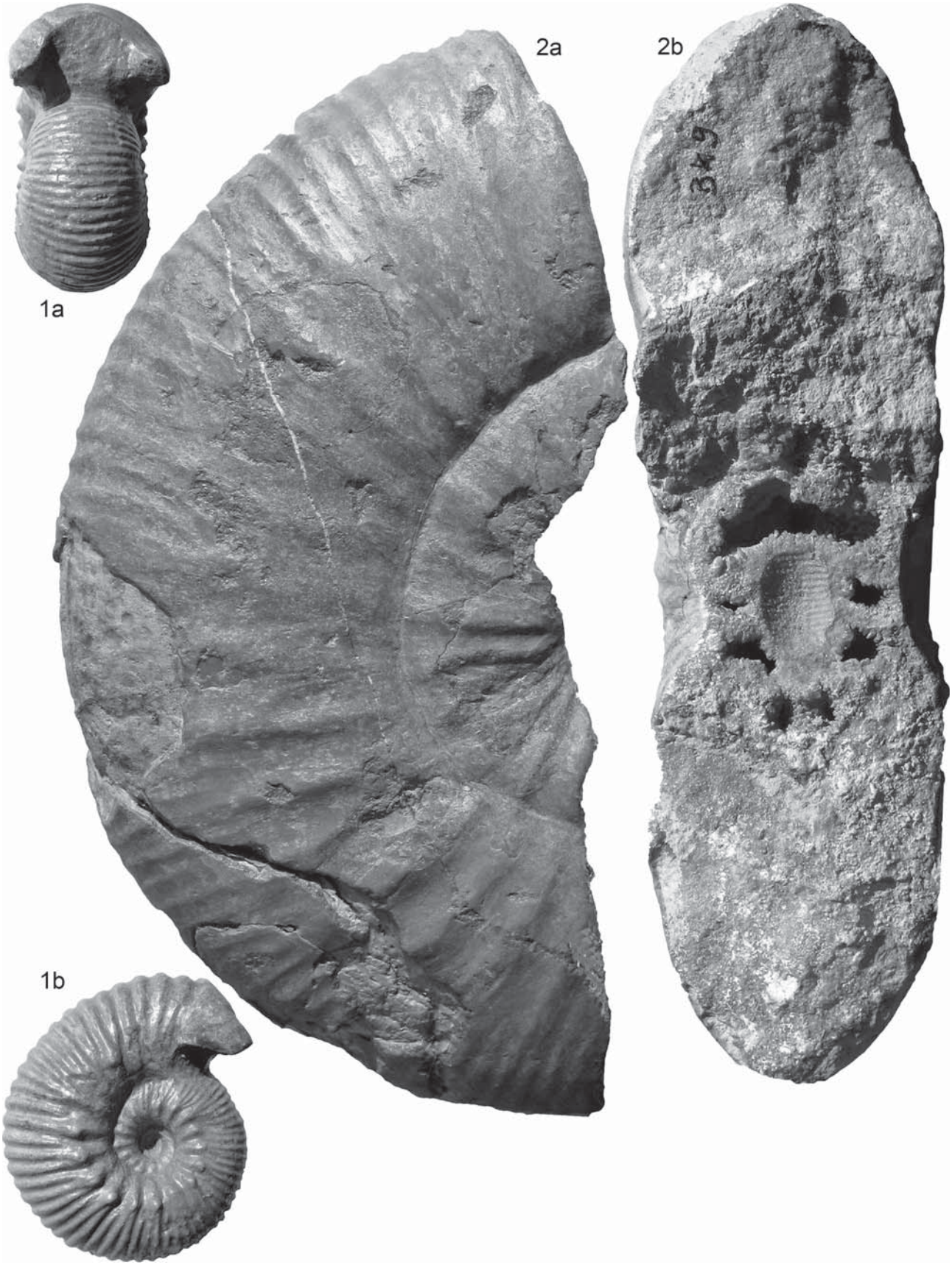
1a
2a
2b
1b

Plate 7

Fig. 1. *Sonninia* cf. *patella* (WAAGEN) [M], ?complete phragmocone; *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Beds BL-3–5, Kahlenberg; SMNS 67430; **a**. Lateral view, **b**. Ventral view. – Natural size.


1a
1b

Plate 8

Sonninia ["*Sonninites*"] aff. *felix* (BUCKMAN) [M]; *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Beds BL-3–5, Kahlenberg.

Fig. 1. SMNS 67436; **a**. Ventral view, **b**. Lateral view.

Fig. 2. SMNS 67443.

Fig. 3. SMNS 67444.

Fig. 4. Collection BOSCH.

All figures in natural size; beginning of body chamber is marked by an asterisk.


1a
2
3
4
*
1b

Plate 9

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Kahlenberg (except Fig. 4).

Fig. 1. *Sonninia* cf. *propinquans* (Bayle) [M]; Beds BL-3–5; SMNS 67431.

Fig. 2. *Sonninia propinquans* (Bayle) [M]; Beds BL-3–5; SMNS 67437.

Fig. 3. *Nannina* cf. *deltafalcata* (Quenstedt) [m]; complete with body chamber; Beds BL-3–5; SMNS 67449; **a**. Ventral view, **b**. Lateral view.

Fig. 4. *Nannina deltafalcata* (Quenstedt) [m]; Lectotype; Giganteus-Ton, Lower Humphriesianum Zone, Öschingen (Middle Swabian Alb); Institut für Geowissenschaften der Universität Tübingen, without number; **a**. Ventral view, **b**. Lateral view.

Fig. 5. *Sonninia* cf. *patella* (Waagen) [M]; Bed BL-6; SMNS 67423; **a**. Ventral view, **b**. Lateral view.

All figures in natural size; beginning of body chamber is marked by an asterisk.


1
2
3a
3b
*
4a
4b
*
5a
5b

Plate 10

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Beds BL-3–5, Kahlenberg.

Fig. 1. *Pelekodites moisyi* (Brasil) [m]; SMNS 67469.
Fig. 2. *Pelekodites moisyi* (Brasil) [m]; collection Kutz.
Fig. 3. *Pelekodites moisyi* (Brasil) [m]; SMNS 67466.
Fig. 4. *Pelekodites moisyi* (Brasil) [m]; SMNS 67472 ; **a**. Lateral view, **b**. Ventral view.
Fig. 5. *Pelekodites moisyi* (Brasil) [m]; SMNS 67470.
Fig. 6. *Pelekodites moisyi* (Brasil) [m]; SMNS 67467; **a**. Ventral view, **b**. Lateral view.
Fig. 7. *Sonninia propinquans* (Bayle) [M]; SMNS 67422; **a**. Ventral view, **b**. Lateral view.

All figures in natural size; beginning of body chamber is marked by an asterisk.


1
2
3
4a
4b
5
6a
6b
7a
7b

Plate 11

Specimens from the *pseudocontrahens* horizon (Sauzei Zone), "Blaukalk", Beds BL-3–5, Kahlenberg.

Fig. 1. *Kumatostephanus* aff. *turgidulus* (Quenstedt) [M]; SMNS 67450; **a**. Lateral view, **b**. Ventral view.

Fig. 2. *Kumatostephanus* aff. *turgidulus* (Quenstedt) [M]; SMNS 67438.

Fig. 3. *Sonninia* ["*Sonninites*"] aff. *felix* (Buckman) [M], with relatively complex suture line typical for the genus *Sonninia* in contrary to the more simplified sutures of the genus *Dorsetensia*; SMNS 67451.

Fig. 4. *Sonninia* cf. *propinquans* (Bayle) [M]; SMNS 67424; **a**. Lateral view, **b**. Ventral view.

All figures in natural size.


1a
1b
2
3
4a
4b

Plate 12

Specimens from the "Blaukalk" (Sauzei Zone), Kahlenberg.

Fig. 1. *Strigoceras languidum* (Buckman) [M]; Bed BK-5–7, *pseudocontrahens* horizon; SMNS 67469.

Fig. 2. *Strigoceras languidum* (Buckman) [M]; Bed BK-5–7, *pseudocontrahens* horizon; SMNS 67433; **a**. Front side, **b**. Back side.

Fig. 3. *Otoites* cf. *pauper* Westermann [m]; Beds BL-3–5, *pseudocontrahens* horizon; collection Kutz.

Fig. 4. *Otoites contractus* (Sowerby) [m]; Beds BL-3–5, *pseudocontrahens* horizon; collection Bosch; **a**. Ventral view, **b**. Lateral view.

Fig. 5. *Stephanoceras macrum* (Quenstedt) [M]; Bed BL-11, *macrum* horizon; SMNS 67453.

Fig. 6. *Stephanoceras macrum* (Quenstedt) [M]; Bed BL-8, *macrum* horizon; SMNS 67446.

All figures in natural size.


1
2a
3
2b
4a
4b
5
6

Plate 13

Stephanoceras macrum (QUENSTEDT) [M], with compressed last part of body chamber; *macrum* horizon (Sauzei Zone), "Blaukalk", Bed BL-9, Kahlenberg; SMNS 67447.

Scale: 5 cm.

Plate 14

Emileia fuellinsdorfense MAUBEUGE [M], compressed specimen complete to the mouth border; *macrum* horizon (Sauzei Zone), "Blaukalk", Bed BL-9, Kahlenberg; SMNS 67504.

Scale: 5 cm; beginning of body chamber is marked by an asterisk.