



Biostratigraphy of the Aalener Flöz (“Oberes Flöz”) at the type locality of the Eisensandstein Formation (Upper Aalenian, Middle Jurassic) at Aalen-Wasseraufingen (E Swabian Alb, SW Germany)

Authors: Dietze, Volker, Chandler, Robert B., and Schweigert, Günter

Source: Palaeodiversity, 15(1) : 91-109

Published By: Stuttgart State Museum of Natural History

URL: <https://doi.org/10.18476/pale.v15.a7>

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Biostratigraphy of the Aalener Flöz (“Oberes Flöz”) at the type locality of the Eisensandstein Formation (Upper Aalenian, Middle Jurassic) at Aalen-Wasseralffingen (E Swabian Alb, SW Germany)

VOLKER DIETZE, ROBERT B. CHANDLER & GÜNTER SCHWEIGERT

Abstract

The biostratigraphical position of the Aalener Flöz (= Oberes Flöz) within the Eisensandstein Formation of Aalen-Wasseralffingen (E Swabian Alb) is discussed and revised. It lies in the herein newly introduced *falcifera* biohorizon of the *Gigantea* Subzone (Upper Aalenian, Bradfordensis Zone) and not in the Bradfordensis Subzone as stated in literature. With the exception of the Concavum Zone, all other zones and subzones of the Upper Aalenian can be identified in the Eisensandstein Formation at Aalen-Wasseralffingen.

Keywords: Bradfordensis Zone, *falcifera* biohorizon, SW Germany, Upper Aalenian.

1. Introduction

In the Eastern Swabian Alb (Fig. 1) and adjacent Franconian Alb large “Minette type” iron ore lenses occur as seams and are typical of the Upper Aalenian of this area (QUENSTEDT 1843; QUENSTEDT 1856–1857; FREYBERG 1951; WILD 1951; WEBER 1967; DIETL & ETZOLD 1977; ETZOLD 1980; FRANZ & NITSCH 2009). They are located within the Middle Jurassic Eisensandstein Formation (GÜMBEL 1864), whose type locality is at Aalen-Wasseralffingen (FRANZ & NITSCH 2009). The lithostratigraphy of the Eisensandstein Formation was recently revised by FRANZ & NITSCH (2009). The latest biostratigraphical subdivisions of the Eisensandstein Formation of the Upper Aalenian of the area around Aalen are by WEBER (1964) and DIETL & ETZOLD (1977).

Since iron mining in the Aalen area has ended, the ore seams are no longer worked and collecting underground in the galleries is no longer possible. Practically, it is now extremely difficult to collect ammonites there and certainly not in quantity by bed-by-bed. Ammonites originating from the Unteres Flöz of the Aalen mines located in old collections can be identified in nearly all cases by their characteristic preservation. This is more difficult with the ammonites from the iron ore seams lying higher in the section.

With the exception of the two thickest iron ore seams in the Aalen-Wasseralffingen area (Unteres Flöz and Aalener Flöz), which are relatively evenly formed, the other ore seams are considerably thinner and are reported to wedge out over short distances (SCHULER 1865, fig. 1). This increases the difficulty in assigning historical ammonite specimens to specific layers, although it is the case that the bulk of the ammonites have their origins from either the Unteres Flöz or in the case of most examples from the

Aalener Flöz. Some ammonites likely originate from the Geislinger Flöz (Figs. 2, 3). Fortunately, a small collection of ammonites collected from the Aalener Flöz (formerly: Oberes Flöz) from Aalen-Wasseralffingen is preserved. The specimens were sampled by the fossil collector HANS SCHÖNE (see MAYER 2010), who donated his collection to the Tübingen University. The ammonites have been determined by HANS RIEBER (Esslingen, Switzerland) as part of his PhD thesis (RIEBER 1963) as “*Ludwigia bradfordensis* (BUCKMAN)” and “*Ludwigia murchisonae falcifera* (ALTHOFF)”; this is confirmed by a label written by himself that survived along with the specimens (pers. communication H.R. to V.D., May 2022). These ammonites had been the basis of the determinations of ammonites from the Aalener Flöz (= Oberes Flöz) in DIETL & ETZOLD (1977; Fig. 3), since it was H. RIEBER, who determined the ammonites of the Braunjura β in this publication (DIETL & ETZOLD 1977: 10).

The SCHÖNE collection consists of twelve ammonites from the Aalener Flöz (= Oberes Flöz) of Aalen-Wasseralffingen. Since the collector H. SCHÖNE had moved to the nearby town of Schwäbisch Gmünd at the beginning of the 1930s, the examples almost certainly come from the gallery “Süßes Löchle”, which was first opened in 1924, and finished in the same year in the “Oberes Flöz”. This confirms the location of the specimens as from the northern part of the Braunenberg hill in Aalen-Wasseralffingen. Mining resumed there in 1932–1933, but stopped again in 1939 after the opening of the “Faber-du-Faur Stollen” in Aalen (BAUER 1982). With the help of the ammonites of the SCHÖNE collection it was possible to identify and assign additional ammonites in the collection of the Staatliches Museum für Naturkunde Stuttgart (SMNS) to the Aalener Flöz since they show exactly the same preservation and matrix.

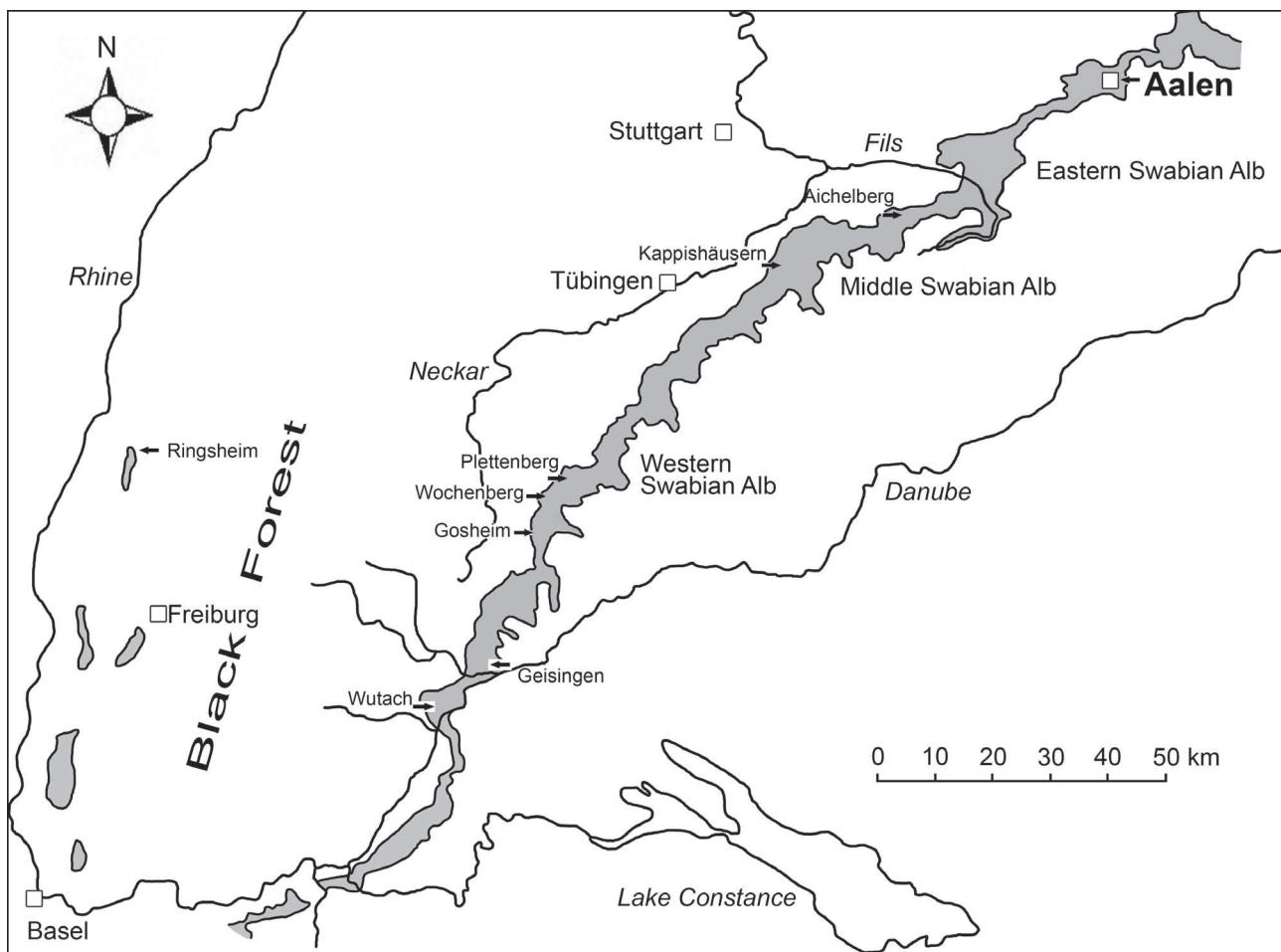


Fig. 1. Location map. The outcrops of the Middle Jurassic are marked in gray.

The ammonites of the SCHÖNE collection are kept in the Palaeontological Collection of Eberhard-Karls-Universität Tübingen (GPIT). The further ammonites under investigation are stored in the collection of the SMNS.

A b b r e v i a t i o n s : [M] = macroconch; [m] = microconch.

2. Origin of the Aalener Flöz (= Oberes Flöz) and description of the section

Based on measurements by the mining inspector SCHULER (SCHULER 1865; FRAAS 1871; SCHLEH 1927), the Aalener (= Oberes) Flöz at the Braunenberg Hill in Wasseralfingen is approx. 1.1 m thick. SCHLEH (1927) measured 1.3 m. The Aalener Flöz is an ore lens of several kilometers in extent, its greatest thickness (approx. 1.5 m) and Fe-content maxima lie in a central zone (WEBER 1964). The axis of this enrichment zone at Aalen is apparently located in the area of Heuchelbachtal, Zochental and Osterbucher

Steige southwest of Aalen and has a strike from there in a northeasterly direction across Aalen via the village of Röthardt to the Braunenberg hill near Aalen-Wasseralfingen. In the directions deviating from the longitudinal axis of the enrichment zone, thickness and ore content decrease considerably (WILD 1951; WEBER 1964; FRANZ & NITSCH 2009). In the area of Attenhofen and Oberalfingen, which directly adjoins the Braunenberg hill in northeastern direction, the thickness of the Aalener Flöz decreases to 0.6–0.85 m (WEBER 1964). The rocks of the Eisensandstein Formation are fully marine subtidal neritic arenaceous deposits with signs of directional sediment flow by current activity. The sandstones and iron oolites form several kilometers wide flat rock bodies, whose longitudinal axis is oriented approximately NE - SW, parallel to the ancient coastline which was located some 150–200 km away (WILD 1951; FRANZ & NITSCH 2009).

The best descriptions of the Eisensandstein Formation of Aalen-Wasseralfingen and the adjoining area are by SCHULER (1865) and SCHLEH (1927). Due to the inten-

sive mining in numerous pits and galleries in the Aalen - Wasseralfingen - Attenhofen - Oberaltingen area, SCHULER was able to record the strata sequence closely and thus gain a detailed picture of the horizontal and vertical distribution of the individual beds (Fig. 2; SCHULER 1865, fig. 1). Today it would be impossible to obtain even a comparably good picture of the stratigraphic sequence. We therefore re-illustrate here in simplified form and restricted to the aims of this publication SCHULER's (1865) description

of the "Braunjura β" of the area around Aalen-Wasseralfingen with ammonites found in the region of Aalen. In his time, 1' (= 1 Württembergischer Fuß) measured 28.6490 cm. We make some additions to his observations by SCHLEH (1927).

WEBER (1964, pl. 3, right column) presented a section from the Wasserfallbank up to the Sowerbyi-Oolith of Wasseralfingen, which we refigure here in modern biostratigraphical terms (Fig. 3).

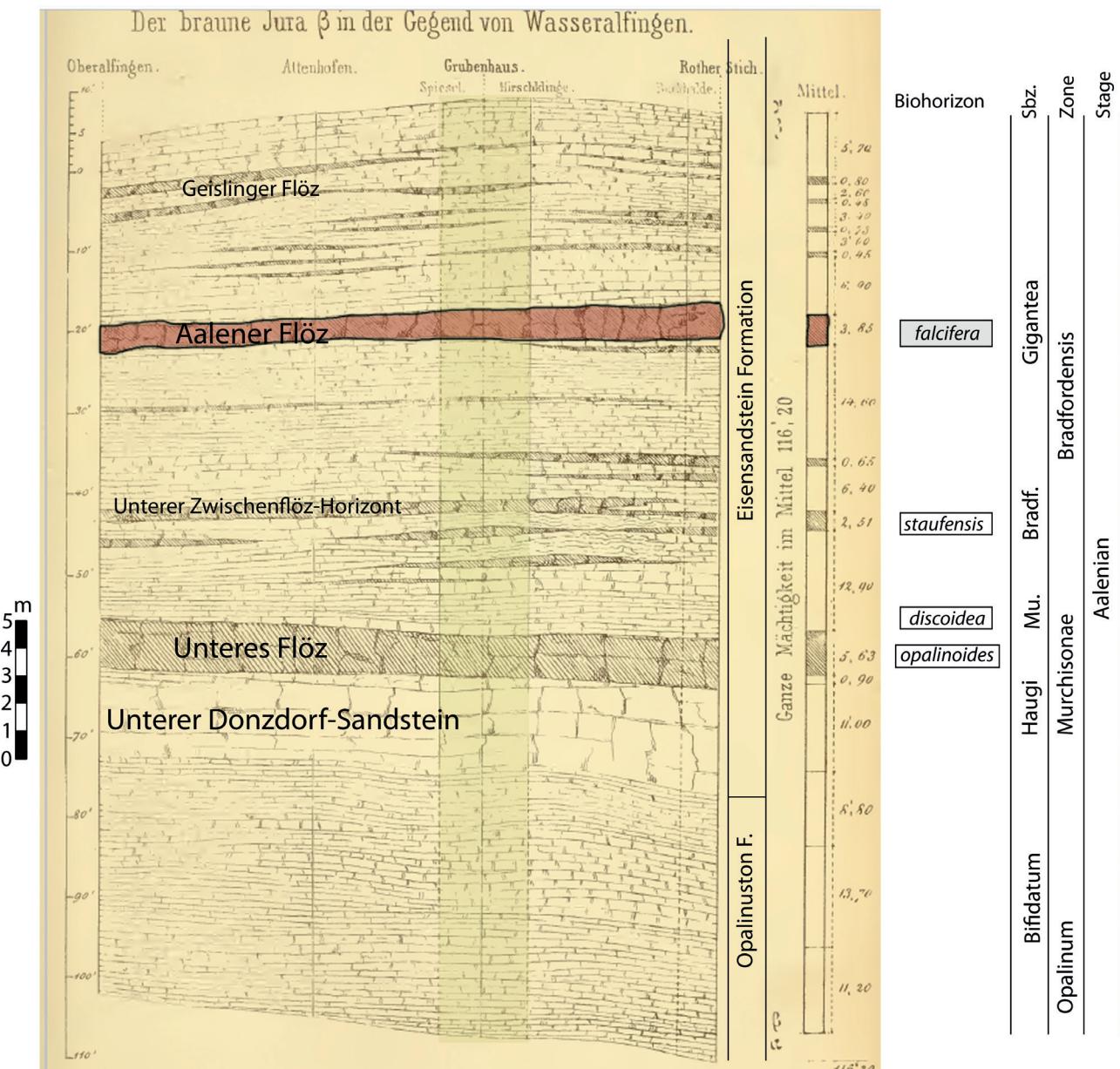


Fig. 2. Section of the Eisensandstein Formation (with the exception of the top of the Oberer-Donzdorf-Sandstein Member) at Aalen-Wasseralfingen (modified from SCHULER 1865), to show the wedging out of the smaller iron ore seams over short distances. The iron ore seams are shaded in grey, the Aalener Flöz (= Oberes Flöz) in brown and the area of Wasseralfingen in olive. Abbreviations: F. = Formation; Mu. = Murchisonae; Bradf. = Bradfordensis; Sbz. = Subzone.

The areas of the Aalener Flöz in the Braunenberg above Aalen-Wasseraufingen (see profile Fig. 2), which were mined in SCHULER's time and the "Süßes Löchle", which enabled the mining of the iron ore of the Aalener Flöz somewhat further north in the Braunenberg near Aalen-Wasseraufingen adjoin each other. Thus, despite the lenticular character of most of the individual seams (with the exception of the Unteres Flöz and the Aalener Flöz), the profile description by SCHULER (1865), with some additions by SCHLEH (1927) is likely to agree with the stratigraphic sequence in the area of the "Süßes Löchle", except for marginal deviations.

The Eisensandstein Formation is overlain by the Bajocian Wedelsandstein Formation, which starts with the Sowerby-Oolith Member.

Eisensandstein Formation: c. 30.5–31 m (according to FRANZ & NITSCH 2009, the Eisensandstein Formation extends from the base of the Unterer Donzdorf Sandstein Member to the base of the Sowerby-Oolith Member).

Oberer-Donzdorf-Sandstein Member: c. 8.5–9 m

- Claystone: c. 7.0–7.5 m (based on WEBER 1964, pl. 3, right column and SCHLEH (1927).

- Sandstone: c. 1.63 m [5.70'].

Oberer Flözhorizont Member: c. 6.36 m [22.21']

- Alternating sequence of sandstones and ore seams: c. 5.26 m [18.36'], at the top containing the Geislinger Flöz.

- **Aalener Flöz** (= Oberes Flöz): c. 1.10 m [3.85'], iron-oolitic seam. The ammonites occur mainly in the iron-oolitic "Dachbank" (0.3 m) at the top of the Aalener Flöz (SCHLEH 1927, ETZOLD 1980). Most of the fossils in institutional collections from the Eisensandstein Formation originate from the Aalener Flöz (ETZOLD 1980).

Ammonites: *Brasilia falcifera*, *B. floccosa*, *B. similis*, *B. aff. decipiens*, *B. intralaevis*, *B. aff. pinguis*, *B. platychora*, *B. aff. platychora*, *B. platys*, *B. sp.*, *Ludwigia gradata*, *Lytoceras amplum*, *Ceccaites sieboldi*.

Personatensandstein Member: 10.62 m [37.06']

- Sandy shales, claystone and soft sandstones (partly with thin iron-oolitic seams): c. 4.18 m [14.60'].

- Unterer Zwischenflözhorizont: c. 2.74 m [9.56']

- Iron-oolitic seam, wedging out towards the North: c. 0.72 m [2.51'].

- Whitish to grey sandy shales and: 1.83 m [6.40'].

- Iron-oolitic seam: c. 0.72 m [2.51'].

Ammonites (from the ore seams): *Staufenia staufensis* [after WEBER 1964 and DIETL & ETZOLD 1977].

- Sandy shales, sandstone, claystone, locally iron-oolitic seam: c. 3.70 m [12.90']: At the top sandy shales, sandstone and claystone; in the middle part locally an iron-oolitic seam with sandstone and sandy shales and claystone below. At the base dark brown sandstones.

Ammonites: *Staufenia discoidea*, *Ludwigia* sp. [c. 1.35–1.6 m above the top of the Unteres Flöz; cited from WEBER 1964 and DIETL & ETZOLD 1977].

Unteres Flöz Member: c. 1.9 m [6.62' = average thickness in Wasseraufingen]. At the top iron-oolitic (1.61 m [5.62']). At the base c. 0.26–max. 0.71 m [0.90'–max. 2.5'] "Sohl-

stein", brown to beige/reddish, very hard calcareous sandstone, unweathered blueish-grey, at some parts increasing to c. 0.7 m and wedging out both N and S.

Ammonites (from the iron-oolitic part): *Ancolioceras opalinoides*, "*Staufenia*" *sinon* [type horizon], *Ludwigia haugi* [type horizon], *L. obtusiformis* [cited from WEBER 1964 and DIETL & ETZOLD 1977], *L. crassa*.

Unterer-Donzdorf-Sandstein Member: c. 3.15 m [11.00'] yellow sandstone.

Ammonites: [after WEBER 1964 and DIETL & ETZOLD 1977]: *Ancolioceras opalinoides*.

The underlying beds of the Opalinuston Formation are not described here.

3. Description of the ammonite fauna of the Aalener Flöz (= Oberes Flöz)

ZIETEN (1830) figured a plate with ammonites from the iron ore seams of Aalen. In our view, most specimens originate from the Unteres Flöz. Subsequently, QUENSTEDT (1845–1849, 1886) figured many ammonites from the iron ore seams of Aalen and introduced some new species based on these ammonites. Some of these taxa, originally described by QUENSTEDT in trinominal nomenclature, are now available (ICZN 2005). SPIEGLER (1966) also figured specimens from the Upper Aalenian of Aalen.

Most ammonites under investigation belong to the family Graphoceratidae BUCKMAN, 1905. Ammonites of the morphogenus *Brasilia* are typical of the Bradfordensis Zone of the Upper Aalenian (CONTINI 1969; CHANDLER 1997). Some of the specimens with a broad whorl section are still assigned to the genus *Ludwigia*, which is characteristic for the Murchisonae Zone, but persists into the Bradfordensis Zone.

- *Brasilia falcifera* (ALTHOFF, 1940) [M] (Pl. 1, Fig. 1). *B. gigantea* (BUCKMAN, 1888) is very similar, but differs by its weaker ornament, whereas *B. falcifera* shows clear primary ribs on the inner whorls and bulging ribs until the end of the phragmocone. *B. latecostata* (ALTHOFF, 1940) is more involute with a stronger ribbing on the inner whorls. Previously, RIEBER (1963) and WEBER (1964) stated that *B. falcifera* occurs in the Aalener Flöz.

- *B. floccosa* (BUCKMAN, 1899) [M] (Pl. 1, Fig. 2). An almost identical specimen from the horizon à *gigantea* (Gigantea Subzone) of the Jura Franc-Comtois was figured by CONTINI (1969, pl. 20, fig. 5) as *Ludwigia* (*Brasilia*) *gigantea floccosa*.

- *B. similis* (BUCKMAN, 1889) [M] (Pl. 1, Fig. 3; Pl. 2, Fig. 5). CONTINI (1969) figured similar specimens as *Ludwigia* (*Brasilia*) *similis maubeugei*.

- *B. aff. decipiens* (BUCKMAN, 1888) [M] (Pl. 2, Fig. 1). *B. planata* (QUENSTEDT, 1887) differs from *B. aff. decipiens* by its ribbed inner whorls, is more evolute and shows a somewhat more quadratic whorl-section.

- *B. intralaevis* (QUENSTEDT, 1886) [?m] (Pl. 2, Fig. 2).
 - *B. platychora* (BUCKMAN, 1899) [M] (Pl. 2, Fig. 3).

In contrast to the otherwise similar *B. platys* (BUCKMAN, 1925) with smooth whorls, *B. platychora* exhibits a ventrolateral ribbing. This ribbing is best seen by lateral illumination, but not discernible on the plates. *B. latecostata* (ALTHOFF, 1940) and *B. geisingenensis* (DIETZE et al., 2014) show a similar morphology as well, but lack the ventrolateral ribbing of *B. platychora*.

- *B. aff. pinax* (BUCKMAN, 1899) [M] (Pl. 2, Fig. 4). The specimen differs from *B. pinax* by its more tabulate venter.

- *B. aff. platychora* (BUCKMAN, 1899) [M] (Pl. 3, Fig. 1; Pl. 4, Fig. 2). These specimens differ from typical *B. platychora* by a fading out of the ventrolateral ribbing at the end of the phragmocone.

• *B.* sp. [m] (Pl. 3, Fig. 2).

- *Ludwigia gradata* BUCKMAN, 1904 [M] (Pl. 3, Figs. 3, 4). The closely connected species *L. extralaevigata* (QUENSTEDT, 1886) is more evolute and originates from a slightly older level (*staufensis* biohorizon, Bradforden-sis Subzone).

- *B. platys* (BUCKMAN, 1925) [M] (Pl. 4, Fig. 1). *B. latecostata* (ALTHOFF, 1940) is very similar and may be synonymous with *B. platys*.

It should be noted that most of these graphoceratid morphospecies have a considerable stratigraphical range (see e.g. CHANDLER 1997) and are not restricted to the biohorizon described here, but occur in younger and older strata as well. It is just the variability of the graphoceratid ammonite fauna that can be used to access its correlation to a single biohorizon.

Besides graphoceratids, two further ammonite taxa can be assigned to the ammonite fauna of the Aalener Flöz, the lytoceratid *Lytoceras amplum* (OPPEL, 1862) (Pl. 5, Fig. 1) and the hammatoceratid *Ceccaites sieboldi* (OPPEL, 1862) (Pl. 5, Fig. 2). Both type specimens exhibit the same rock matrix and preservation as the other ammonites of this ore seam. There are several additional large-sized specimens of *L. amplum* including the paralectotype in the collection of the SMNS. All of them originate from the same bed but show some variation in respect of the remarkably inflated whorl section. *L. amplum* was placed in *Megalytoceras* BUCKMAN, 1905 (RULLEAU 1998); however, a critical review showed that this assignment cannot be accepted because this species lacks the typical ornament of *Megalytoceras* (HOFFMANN 2010). *Ammonites sieboldi* is the type species of *Ceccaites* CRESTA, 1997. KOVÁCS (2009) questioned the validity of this genus and considered it being a junior synonym of *Planammatoceras* BUCKMAN, 1922. We here retain this taxon in *Ceccaites* because of its juvenile stage with prominent parabolic nodes on the flanks unknown from *Planammatoceras*. Since its original description, *Ceccaites sieboldi* has never been recorded again from the Jurassic of Swabia. *Ceccaites sieboldi* has been cited from

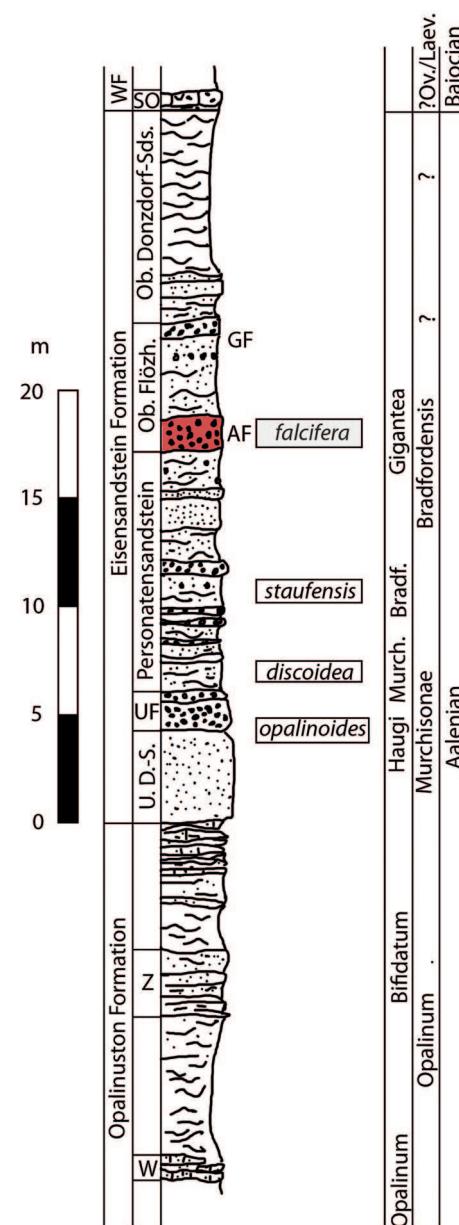


Fig. 3. Section from the Wasserfallbank Member (Opalinuston Formation) and the Eisensandstein Formation up to the Sowerbyi-Oolith Member (Wedelsandstein Formation) of Aalen-Wasseraalfingen (SW Germany) (based on WEBER 1964, fig. 3, right column). The iron ore beds are recognisable by thick dots; the Aalener Flöz (= Oberes Flöz) is shaded in red. Left of the section: lithostratigraphy; right of the section: biostratigraphy (biohorizons, subzones, zones, stages). Abbreviations: WF = Wedelsandstein Formation; W = Wasserfallbank Member; Z = Zopfplatten Member; U. D.-S. = Unterer-Donzdorf-Sandstein Member; UF = Unteres Flöz; Personatensandstein = Personatensandstein Member; Ob. Flözh. = Oberer Flözhorizont Member; Ob. Donzdorf-Sds. = Oberer-Donzdorf-Sandstein Member; AF = Aalener Flöz; GF = Geislinger Flöz; SO = Sowerbyi-Oolith Member; Murch. = Murchisonae; Bradf. = Bradfordensis; Ov. = Ovalae; Laev. = Laeviuscula

a couple of Mediterranean localities (Hungary, Southern Alps, Southern Spain, southeastern France, Morocco) under various generic assignments (CRESTA 1997; Kovács 2009). A specimen very close to the holotype has been illustrated from Iran (SEYED-EMAMI et al. 2006, 2020), however, without precise stratigraphical control. The same hammatoceratid morphotype occurs in the *gigantea* horizon at Horn Park in Dorset thus confirming a similar age of occurrence there. *Lytoceras amplum* and *Ceccaites sieboldi* indicate close connections between the Aalenian Jurassic epicontinental sea in present-day southern Germany and the Tethys Ocean.

4. Bio-/chronostratigraphy and correlation

4.1. Bio-/chronostratigraphy

We focus on the Aalener Flöz and thus restrict the biostratigraphical description to the beds of the Eisen-sandstein Formation from the Unterer-Donzdorf-Sandstein Member to the Aalener Flöz, supplemented by some short comments on the Geislinger Flöz above. The results of the biostratigraphy of the beds below the Aalener Flöz are still preliminary; an investigation of the ammonite fauna of the Unteres Flöz is in preparation.

Upper Aalenian

Murchisonae Zone

Haugi Subzone

The Unterer-Donzdorf-Sandstein Member of Aalen Wasseralfingen is assigned to the Haugi Subzone. WEBER (1964) noted *A. opalinoides* from the Unterer Donzdorf-Sandstein of nearby Aalen-Oberalfingen. From the area of Essingen, which lies just a few km West of Aalen, WEBER (1964) recorded “*Staufenia*” *sinon*, *A. opalinoides* and *Ludwigia haugi obtusiformis* from a calcareous sandstone bed 1.2 m below the Unteres Flöz of Essingen in the top of an at least 2.9 m thick sandstone bed (?Unterer Donzdorf Sandstein).

The Unteres Flöz Member lies also in the Haugi Subzone. The type specimens of *Ludwigia haugi* and “*Staufenia*” *sinon* originate from the Unteres Flöz of “Aalen”; probably also the type specimen of *L. crassa* HORN, 1909. In these levels occur various species of the genus *Ludwigia* and a range of morphologies between “*Staufenia*” *sinon* and *Ancolioceras opalinoides* from the Unteres Flöz of Aalen and Aalen-Wasseralfingen. This fauna, as well as ammonites described from the Haugi Subzone of Geisingen and the Wutach area (HORN 1909; RIEBER 1963; DIETZE

et al. 2014) represent the *opalinoides* biohorizon. At present, we regard these faunas as isochronous; however, investigations for a clarification are in progress.

Murchisonae Subzone

The Personatensandstein Member (at about 1.5 m above its base) has yielded a single specimen of *Staufenia discoidea* (WEBER 1964; DIETL & ETZOLD 1977), which indicates either the *discoidea* α or the *discoidea* β biohorizon (RIEBER 1963; DIETZE et al. 2022).

Bradfordensis Zone

Bradfordensis Subzone

WEBER (1964) and DIETL & ETZOLD (1977) stated that *Staufenia staufensis* occurs in the area of Aalen in the Unterer Zwischenflözhorizont. This bed thus belongs to the *staufensis* biohorizon (RIEBER 1963; DIETZE et al. 2017). A small specimen of *St. staufensis* from Aalen was already figured by QUENSTEDT (1887, pl. 57, fig. 5).

Three specimens of *Brasilia* spp. from an unknown iron seam in the collection of the SMNS show a typical preservation with a brownish to golden opalescent shell. These specimens probably originate from a younger level than the *staufensis* biohorizon; however, the exact stratigraphic position is unknown.

Gigantea Subzone

The Aalener Flöz (= Oberes Flöz) at Aalen-Wasseralfingen yields ammonites of the here newly introduced *falcifera* biohorizon of the Gigantea Subzone (Bradfordensis Zone). Until now there was a consensus in the literature that the Aalener Flöz (= Oberes Flöz) in the area of Aalen and Aalen-Wasseralfingen can be assigned to the Bradfordensis Subzone of the Bradfordensis Zone (RIEBER 1963; WEBER 1964; DIETL & ETZOLD 1977; FRANZ & NITSCH 2009). This must be corrected here.

The ammonite fauna of the *falcifera* biohorizon is morphologically intermediate between the ammonite faunas of the *geisingensis* and the *decipiformis* biohorizons of the Gigantea Subzone (Fig. 4; DIETZE et al. 2014). In the *geisingensis* and in the *falcifera* biohorizons ammonites with a *Graphoceras*-like morphology are still missing. On the other hand, ammonites morphologically close to *B. decipiformis* such as the morphospecies *B. falcifera* (Pl. 1, Fig. 1), *B. aff. platychora* (Pl. 3, Fig. 1) and *B. decipiens* (Pl. 2, Fig. 1) do not occur in the *geisingensis* bio-

Concavum	Formosum	yet to be worked out	?Geisingen, Ringsheim, Wutach
	Concavum	<i>cavatum</i>	Zollernalb, ?Kappishäusern, ?Metzingen
Bradfordensis	Gigantea	<i>decipiformis</i>	Geisingen
		<i>falcifera</i>	Aalen (herein)
		<i>geisingensis</i>	Geisingen
		<i>gigantea sensu Contini</i>	Geisingen, Wutach (condensed)
Murchisonae	Bradfordensis	<i>staufensis</i>	Swabian Alb, Wutach, Geisingen , Ringsheim, Aalen
	Murchisonae	<i>discoidea β</i>	Wochenberg, Plettenberg, ?Aalen ¹
		<i>discoidea α</i>	Wochenberg, Gosheim, ?Aalen ¹
		<i>latiumbilicus</i>	Wochenberg, ?Gosheim
		yet to be worked out	Gosheim
	Haugi	yet to be worked out	Gosheim, Geisingen
		<i>opalinoides</i>	Geisingen, Wutach, Aalen, ?Wochenberg
		<i>subfalcatum</i>	Aichelberg
Opalinum	Bifidatum [ex Comptum]	<i>vialii</i>	Wochenberg, Gosheim
		<i>evolutum</i>	Aichelberg area
		<i>crassicostatum</i>	Swabian Alb, Wutach, N Franconian Alb
		<i>uncinatum</i>	Aichelberg area
		<i>bifidatum/rieberi</i>	Aichelberg area
	Opalinum	<i>hansrieberi</i>	Swabian Alb]
		<i>opaliniforme</i>	Swabian Alb
		<i>dilucidum</i>	Swabian Alb, Franconian Alb
		<i>opalinum</i>	Swabian Alb, Wittnau

Fig. 4. Biohorizons of the Aalenian in SW Germany. The *falcifera* biohorizon described herein is marked in grey. ¹The *discoidea α* and *discoidea β* biohorizons cannot be discriminated at Aalen.

horizon. In the *geisingensis* biohorizon all graphoceratids exhibit a ribbing stage on the inner whorls. Some ammonites of the *falcifera* biohorizon show a reduced ribbing on the inner whorls as well as many *B. decipiformis* from the *decipiformis* biohorizon (DIETZE et al. 2014). Large-sized specimens of *B. falcifera* similar to the type specimen of this species occur only in the Gigantea Subzone. The specimens previously determined as *L. falcifera* from the Bradfordensis Subzone of the Bradfordensis Zone (DIETZE et al. 2014, 2017) are smaller and are now revised as *B. aff. falcifera*.

From an iron ore seam showing a shell-rich matrix in Wasseralfingen near the inn “Erzgrube” following above the Aalener Flöz, probably from the Geislenger Flöz, U. SAUERBORN collected a *Brasilia* sp. with a slim whorl section, nearly parallel flanks and smooth, high whorls. Ammonites sharing this morphology (diameter up to 25 cm), preservation and matrix are housed in the collection of the SMNS. QUENSTEDT (1887, pl. 59, fig. 16 [photographically refigured by SCHLEGELMILCH 1985, pl. 12, fig. 1], fig. 17) figured such ammonites from the Geislenger Flöz of Kuchen as *Ammonites murchisonae planatus*. A description of these ammonites and their biostratigraphical interpretation is beyond the scope of this work.

Concavum Zone

To date no ammonites characteristic for the Concavum Zone have been recorded from the Aalen area (WEBER 1964; DIETL & ETZOLD 1977). The biostratigraphical subdivision of the strata following above the Aalener Flöz up to the top of the Eisensandstein Formation at Aalen is unclear due to the lack of biostratigraphically diagnostic ammonites. There must exist at least one further ammonite biohorizon (see above), however, its position in the section is still unknown.

4.2. Correlation

SW Germany

An exact correlation with the ammonite fauna of the Gigantea Subzone of Ringsheim (REICHENBACH 1998; BOSCH 2006) is only possible if these faunas are thoroughly investigated. In the Geisingen clay pit, DIETZE et al. (2014) already assumed the existence of a biohorizon between the *geisingensis* and the *decipiformis* biohorizon; this can be confirmed here. A correlation with the ammonites from the Geislenger Flöz from the area of Aalen and the surroundings of Geisingen is presently not possible due to the lack of precisely collected ammonites.

S England

The ammonite fauna of the *falcifera* biohorizon shows a very close similarity to the graphoceratid assemblage of the *gigantea* biohorizon in Dorset (CHANDLER 1997). Particularly in the area of Beaminster, this biohorizon has yielded many thousands of specimens, so that there is a high degree of certainty when making comparison with other areas and biohorizons.

Despite the similarities we refrain to identify and name the herein introduced *falcifera* biohorizon as the *gigantea* biohorizon for four reasons: (1) the sample from Aalen is relatively small; until larger numbers of bed-by-bed collections from the area and beyond are analyzed we reserve judgement. (2) We want to avoid any confusion with the use of the assumed slightly older *gigantea* biohorizon sensu CONTINI (Fig. 4). (3) The nominal morphospecies *B. gigantea* is missing in the SCHÖNE collection and in the collections of the SMNS and the Tübingen University. Therefore, we cannot ascertain whether the *gigantea* biohorizon of S England has a slightly different age, since typical broad, large morphospecies of *B. gigantea* seem to be absent in Aalen. However, we cannot exclude that the observed morphological differences between the ammonites of both biohorizons are only due to ecological reasons. (4) In SW Germany, it is possible to divide the older parts of the Gigantea Subzone into three biohorizons (*gigantea* sensu CONTINI, *geisingensis* and *falcifera*; see DIETZE et al. 2014; Fig. 3). In SW England, the *gigantea* biohorizon of the Gigantea Subzone follows directly above the *bradfordensis, similis* biohorizon of the Bradfordensis Subzone (CHANDLER 1997).

The term *falcifera* biohorizon is therefore presently used in SW Germany in preference to the British *gigantea* biohorizon.

E France

The horizon à Gigantea (CONTINI 1969; CONTINI et al. 1997) is assumed to be older than the *falcifera* and *geisingensis* biohorizons (for justification see DIETZE et al. 2014: 76).

Luxembourg

SADKI et al. (2020) described some graphoceratids, including typical *B. gigantea*, from the Gigantea Subzone of Rumelange-Hutberg which are similar to the graphoceratids of the *falcifera* biohorizon.

Acknowledgements

We thank WOLFGANG AUER (Altlußheim, Germany), Dr. MATTHIAS FRANZ (Freiburg im Breisgau, Germany) and Prof. Dr. HANS RIEBER (Esslingen, Switzerland) for many constructive

discussions. Prof. Dr. ALEXANDER NÜTZEL (München, Germany) and Dr. INGMAR WERNEBURG (Tübingen, Germany) provided access to the collections under their care. ULRICH SAUERBORN (Essingen, Germany) donated an important specimen from Aalen-Wasseraufingen. Finally, we acknowledge the suggestions and improvements by Dr. MATTHIAS FRANZ (Freiburg im Breisgau, Germany) and an anonymous referee.

6. References

- ALTHOFF, W. (1940): Die Ammonitenzonen der oberen Ludwigschichten von Bielefeld. – *Palaeontographica*, (A), **92**: 1–44.
- BAUER, K. (1982): Der Bergbaupfad in Wasseraufingen. In: BAUER, K. (ed.): *Aalener Jahrbuch 1982*, pp. 123–144; Stuttgart & Aalen (Theiss Verlag).
- BOSCH, K. (2006): Geologie und Fossilien. – In: Zweckverband Abfallbehandlung Kahlenberg (ed.): *Blickpunkt Kahlenberg*, pp. 25–50; Ringsheim.
- BUCKMAN, S. S. (1887–1907): A monograph of the ammonites of the “Inferior Oolite series”. – *Monographs of the Palaeontographical Society*: cclxii + 456 pp.
- BUCKMAN, S. S. (1905): On certain genera and species of Lytoceratidae. – *Quarterly Journal of the Geological Society of London*, **61**(241): 142–154.
- BUCKMAN, S. S. (1909–1930): *Yorkshire Type Ammonites/Type Ammonites*, 1–7, 790 pls.; London (Wheldon & Wesley).
- CHANDLER, R. B. (1997): The Graphoceratid Ammonite Succession in the Aalenian and lowest Bajocian (Middle Jurassic) at Horn Park, Dorset, UK. – *Proceedings of the Dorset Natural History and Archaeological Society*, **118**: 85–106.
- CONTINI, D. (1969): Les Graphoceratidae du Jura Franc-Comtois. – *Annales scientifiques de l’Université de Besançon, série 3, Géologie*, **7**: 1–95.
- CONTINI, D., ELMI, S., MOUTERDE, R. & RIOULT, M. (1997): Aalénien. In: CARIOU, É. & HANTZPERGUE, P. (eds.): *Biostratigraphie du Jurassique ouest-européen et méditerranéen*. – *Bulletin du Centre des Recherches Elf Aquitaine Exploration et Production, Mémoires*, **17**: 37–40.
- CRESTA, S. (1997): Hammatoceratidi aaleniani di Monte Erice (Sicilia occidentale, Italia). – *Bollettino del Servizio Geologico d’Italia*, **114**: 27–56.
- DIETL, G. & ETZOLD, A. (1977): The Aalenian at the Type Locality. – *Stuttgarter Beiträge zur Naturkunde*, (B), **30**: 1–13.
- DIETZE, V., CHANDLER R. B. & SCHWEIGERT, G. (2021): Ein neuer Ammoniten-Biohorizont an der Basis des Ober-Aaleniums der Schwäbischen Alb: der *subfalcatum*-Biohorizont. – *Jahreshefte der Gesellschaft für Naturkunde in Württemberg*, **177**: 213–239.
- DIETZE, V., HOFBAUER, A., RIEBER, H., WANNENMACHER, N.† & SCHWEIGERT, G. (2022): Ammonites and stratigraphy of the Achdorf Formation (Braunjura Group; Aalenian) at the Wochenberg Hill near Schömberg-Schörzingen (W Swabian Alb, SW Germany). – *Zitteliana*, **96**: 69–101.
- DIETZE, V., RIEBER, H., AUER, W., FRANZ, M., SCHWEIGERT, G., CHANDLER, R. B., RIETER, M. & CHIARINI, R. (2014): Aalenian (Middle Jurassic) ammonites and stratigraphy of the Geisingen clay pit (SW Germany). – *Palaeodiversity*, **7**: 61–127.
- DIETZE, V., RIEBER H. & WANNENMACHER, N. (2017): Der *stauferensis*-Horizont (Bradfordensis-Zone, Ober-Aalenium, Mittlerer Jura) am Plettenberg (westliche Schwäbische Alb, SW Deutschland). – *Zitteliana*, **89**: 235–252.
- ETZOLD, A. (1980): Geologische Karte 1 : 25000 von Baden-Württemberg, Erläuterungen zu Blatt 7126 Aalen. 281 pp.; Freiburg & Stuttgart (Landesvermessungsamt).
- FRAAS, O. (1871): Begleitworte zur geognostischen Karte von Württemberg, Atlasblatt Aalen. 31 pp.; Stuttgart.
- FRANZ, M. & NITSCH, E. (2009): Zur lithostratigraphischen Gliederung des Aalenium in Baden-Württemberg. – *LGRB-Informationen*, **22**: 123–146.
- FREYBERG, B. v. (1951): Zur Stratigraphie und Fazieskunde des Doggersandsteins und seiner Flöze. – *Geologica Bavaria*, **9**: 1–108.
- GÜMBEL, C. W. (1864): Geognostische Verhältnisse der Fränkischen Alb (Franken-Jura). – *Bavaria, Landes- und Volkskunde des Königreichs Bayern*, **3**(9): 1–74.
- HOFFMANN, R. (2010): New insights on the phylogeny of the Lytoceratoidea (Ammonitina) from the septal lobe and its functional interpretation. – *Revue de Paléobiologie*, **29**(1): 1–156.
- HORN, E. (1909): Die Harpoceraten der Murchisonae-Schichten des Donau-Rhein-Zuges. – *Mitteilungen der Badischen Geologischen Landesanstalt*, **6**: 251–323.
- ICZN (2005): Opinion 2123. F.A. QUENSTEDT’s trinominal nomenclature (1845–1888): usage of the third names of ammonites stabilized and 34 important QUENSTEDT names of ammonites placed on the Official List of Specific Names in Zoology (Cephalopoda, Ammonoidea). – *Bulletin of Zoological Nomenclature*, **62**: 158–163.
- KOVÁCS, Z. (2009): Toarcian–Aalenian Hammatoceratinae (Ammonitina) from the Gerecse Mts (NE Transdanubian Range, Hungary). – *Fragmenta Palaeontologica Hungarica*, **29**: 1–72.
- MAYER, W. K. (2010): Der Unterjura in der Umgebung von Schwäbisch Gmünd. 255 pp.; München (Verlag Dr. Friedrich Pfeil).
- OPPEL, A. (1862–1863): Ueber jurassische Cephalopoden. – *Palaeontologische Mittheilungen aus dem Museum des königlich Bayerischen Staates*, **1**: 127–266.
- QUENSTEDT, F. A. (1843): Das Flözgebirge Württembergs. Mit besonderer Rücksicht auf den Jura. 558 pp.; Tübingen (Laupp).
- QUENSTEDT, F. A. (1845–1849): *Petrefactenkunde Deutschlands. 1. Cephalopoden*. 580 pp.; Tübingen (Fues).
- QUENSTEDT, F. A. (1856–1857): Der Jura. 842 pp.; Tübingen (Laupp).
- QUENSTEDT, F. A. (1886–1887): Die Ammoniten des Schwäbischen Jura. 2. Der Braune Jura, pp. 441–885; Stuttgart (Schweizerbart).
- REICHENBACH, B. (1998): Die Fossilien des Kahlenbergs – Teil A: Die Kopffüßer. In: REICHENBACH, B., BOSCH, K., GIBIS, G. & SCHULTE-FISCHEDICK, W. (eds.): *Der Kahlenberg und seine Schätze*, pp. 77–106; Ringsheim (Zweckverband Abfallbe seitigung Kahlenberg).
- RIEBER, H. (1963): Ammoniten und Stratigraphie des Braunjura β der Schwäbischen Alb. – *Palaeontographica*, (A), **122**: 1–89.
- RULLEAU, L. (1998): Evolution et systématique des Phylloceratidae et des Lytoceratidae du Toarcien et du Dogger inférieur de la région lyonnaise. – *Documents des Laboratoires de Géologie Lyon*, **149**: 1–167.
- SCHLEGELMILCH, R. (1985): Die Ammoniten des süddeutschen Doggers. 284 pp.; Stuttgart & New York (Gustav Fischer).
- SCHLEH, F. (1927): Eine Studie über den Braunjura β im nordöstlichen Schwaben und seine Eisenoolithflöze. – *Abhandlungen zur praktischen Geologie und Bergwirtschaftslehre*, **2**: 1–43.

- SADKI, D., WEIS, R. & BRAUN, P. (2020): Graphoceratidés (Ammonitina) de l'Aalénien moyen (Jurassique) de Rumelange-Hutberg (Grand-Duché de Luxembourg). – Ferrantia, **83**: 104–129.
- SCHULER, J. (1865): Die Bestimmung der Mächtigkeit des braunen Jura bei Wasseralfingen. – Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg, **21**: 67–81.
- SEYED-EMAMI, K., WILMSEN, M. & FÜRSICH, F. T. (2020): A summary of the Jurassic System in North and East-Central Iran. – Zitteliana, **94**: 99–156.
- SEYED-EMAMI, K., FÜRSICH, F. T., WILMSEN, M., MAJIDIFARD, M. R., CECCA, F. & SHEKARIFARD, A. (2006): Stratigraphy and ammonite fauna of the upper Shemshak Formation (Toarcian-Aalenian) at Tazareh, eastern Alborz. – Journal of Asian Earth Sciences, **28**: 259–275.
- SPIEGLER, W. (1966): Graphoceratidae des Ober-Aalenium (Jura, NW-Deutschland). – Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg, **35**: 5–113.
- WEBER, H. S. (1964): Zur Stratigraphie und Ammonitenfauna des Braunjura (Dogger) β in der östlichen Schwäbischen Alb. – Arbeiten aus dem Geologisch-Paläontologischen Institut der Technischen Hochschule Stuttgart, Neue Folge, **44**: 1–174.
- WEBER, H. S. (1967): Zur Westgrenze der ostschwäbisch-fränkischen Fazies des Braunjura (Doggers) β in der Schwäbischen Alb (Württemberg). – Jahresberichte und Mitteilungen des oberrheinischen geologischen Vereins, Neue Folge, **49**: 47–54.
- WILD, H. (1951): Zur Bildungsgeschichte der Braunjura-β-Flöze und ihrer Begleitgesteine in Nordost-Württemberg. – Geologisches Jahrbuch, **65**: 271–298.
- ZIETEN, C. H. v. (1830–1834): Die Versteinerungen Württembergs, oder naturgetreue Abbildungen der in den vollständigsten Sammlungen, namentlich der in dem Kabinett des Oberamts-Arzt Hartmann befindlichen Petrefacten, mit Angabe der Gebirgs-Formationen, in welchen dieselben vorkommen und der Fundorte. 102 pp.; Stuttgart (Schweizerbart).

Addresses of the authors:

VOLKER DIETZE, Meraner Straße 41, 86720 Nördlingen, Germany; dietze.v@t-online.de

ROBERT. B. CHANDLER, Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK; aalenian@blueyonder.co.uk

GÜNTER SCHWEIGERT, Staatliches Museum für Naturkunde Rosenstein 1, 70191 Stuttgart, Germany; guenter.schweigert@smns-bw.de

Manuscript received: 27 July 2022, revised version accepted: 17 August 2022.

Plate 1

Ammonites of the Eisensandstein Formation, Aalener Flöz (= Oberes Flöz) at Aalen-Wasseralfingen; Upper Aalenian, Bradfordensis Zone, Gigantea Subzone, *falcifera* biohorizon.

(1a, b) *Brasilia falcifera* (ALTHOFF, 1940) [M]; GPIT-PV-122881.

(2a, b) *B. floccosa* (BUCKMAN, 1899) [M]; GPIT-PV-122882.

(3a, b) *B. similis* (BUCKMAN, 1899) [M]; GPIT-PV-122883.

Scale bar equals 10 cm. Ammonites: x 2/3. Beginning of body chamber is indicated by an asterisk.



Plate 2

Ammonites of the Eisensandstein Formation, Aalener Flöz (= Oberes Flöz) at Aalen-Wasseraufingen; Upper Aalenian, Bradfordensis Zone, Gigantea Subzone, *falcifera* biohorizon.

- (1a, b) *Brasilia* aff. *decipiens* (BUCKMAN, 1888) [M]; GPIT-PV-122884.
(2a, b) *B. intralaevis* (QUENSTEDT, 1886) [?m]; GPIT-PV-122885.
(3a, b) *B. platychora* (BUCKMAN, 1899) [M]; GPIT-PV-122886.
(4a, b) *B.* aff. *pinax* (BUCKMAN, 1899) [M]; GPIT-PV-122887.
(5a, b) *B. similis* (BUCKMAN, 1899) [M]; GPIT-PV-122888.

Scale bar equals 10 cm. Ammonites: x 2/3. Beginning of body chamber is indicated by an asterisk.



Plate 3

Ammonites of the Eisensandstein Formation, Aalener Flöz (= Oberes Flöz) at Aalen-Wasseraufingen; Upper Aalenian, Bradfordensis Zone, Gigantea Subzone, *falcifera* biohorizon.

(1a, b) *Brasilia* aff. *platychora* (BUCKMAN, 1899) [M]; GPIT-PV-122889.

(2a, b) *B.* sp. [m]; GPIT-PV-122890.

(3a, b) *Ludwigia gradata* (BUCKMAN, 1904) [M]; GPIT-PV-122891.

(4a, b) *L. gradata* (BUCKMAN, 1904) [M]; GPIT-PV-122892.

Scale bar equals 10 cm. Ammonites: x 2/3. Beginning of body chamber is indicated by an asterisk.

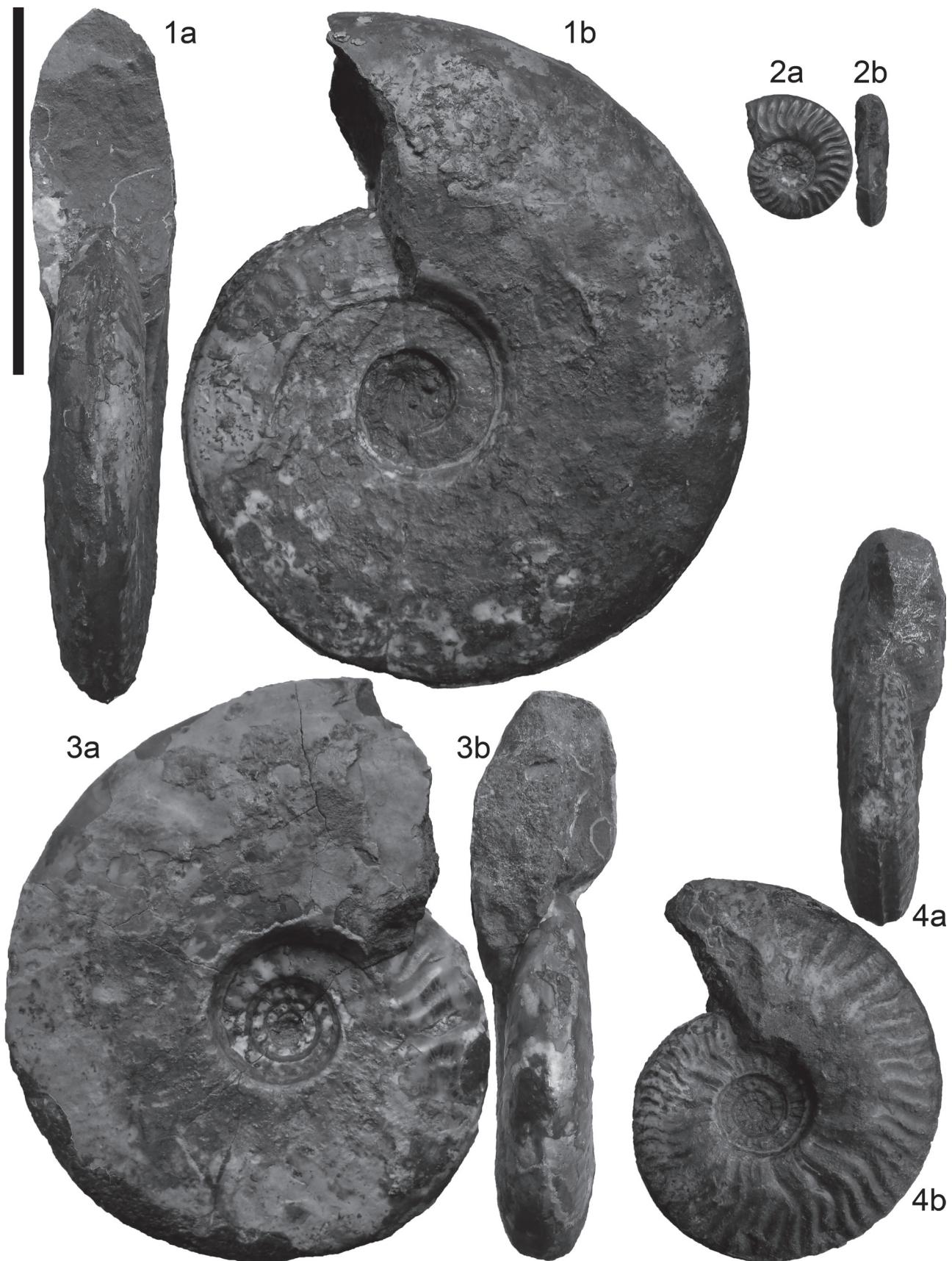


Plate 4

Ammonites of the Eisensandstein Formation, Aalener Flöz (= Oberes Flöz) at Aalen-Wasseralfingen; Upper Aalenian, Bradfordensis Zone, Gigantea Subzone, *falcifera* biohorizon (Assignment of these ammonites to the Oberes Flöz is on the basis of the identical preservation and identical matrix matched with those specimens collected bed-by-bed in Pls. 1–3).

(1a, b) *Brasilia platys* (BUCKMAN, 1925) [M]; SMNS 70647/1.

(2a, b) *B. aff. platychora* [M]; SMNS 70647/2.

Scale bar equals 10 cm. Ammonites: x 2/3. Beginning of body chamber is indicated by an asterisk.



Plate 5

Tethyan ammonites of the Eisensandstein Formation, Aalener Flöz (= Oberes Flöz) at Aalen-Wasseraufingen; Upper Aalenian, Bradfordensis Zone, Gigantea Subzone, *falcifera* biohorizon.

- (1a, b) *Lytoceras amplum* (OPPEL, 1862) [M], lectotype; SNSB-BSPG AS VIII 527.
(2a, b) *Ceccaites sieboldi* (OPPEL, 1862) [M]; holotype; SNSB-BSPG AS VIII 77.

Scale bar equals 10 cm. Ammonites: x 2/3.

