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New records of ostracods and ammonites from the Aalenian (mainly Concavum Zone) of the Zollernalb (Swabian Alb, SW Germany)

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Abstract

The lithostratigraphy and ammonite/ostracod biostratigraphy and the accompanying fauna of several sections and outcrops around the Hohenzollern (Zollernalb, SW Germany), ranging from the topmost Opalinuston Formation (uppermost Lower Aalenian) to the basal Wedelsandstein Formation (lowermost Lower Bajocian) are described and analyzed. The study of ostracods from 41 samples from the Aalenian and Lower Bajocian of the Heiligenbach, Hausterberg and Roschbach sections has yielded approximately 4,100 specimens. Significant changes in the ostracod assemblage occur at the base of the Lower Aalenian "Comptum" Subzone, at the Bradfordensis/Gigantea subzonal boundary, at the Bradfordensis/Concavum zonal boundary and at the Aalenian/Bajocian boundary (Concavum/Discites zones). A minor change occurs above the Calceola-Bank within the Concavum Zone. The following new ostracod species are described: *Cytheropterina crassicostata* **sp. nov.**, *Eucytherura eberti* **sp. nov.** and *Eucytherura foveolata* **sp. nov.** In addition, 15 presumably new species are briefly described; 10 'incertae sedis' taxa are figured, but left in open nomenclature. The ammonite faunas of the Inopernabank and Konglomeratbank beds (Upper Aalenian, Bradfordensis Zone, Gigantea Subzone) as well as the ammonite faunas from the Calceolabank and Rostrote Kalkbank beds (Upper Aalenian, Concavum Zone, Concavum Subzone, *cavatum* biohorizon) are described and correlated with those of other areas.

Zusammenfassung

Die Lithostratigraphie und die Ammoniten-/Ostracoden-Biostratigraphie sowie die Begleitfauna mehrerer Profile und Aufschlüsse in der Umgebung des Hohenzollern (Zollernalb, SW-Deutschland), von der obersten Opalinuston-Formation (oberstes Unter-Aalenium) bis zum basalen Wedelsandstein (unterstes Unter-Bajocium), werden beschrieben. Die Auswertung von 41 Proben (aus dem Aalenium bis zum Unter-Bajocium) vom Heiligenbach, Hausterberg und Roschbach hat ca. 4100 Ostracoden erbracht. Signifikante Änderungen in der Ostracoden-Gemeinschaft gibt es an der Basis der "Comptum"-Subzone (Unter-Aalenium), den Grenzen der Bradfordensis-/Gigantea-Subzone, der Bradfordensis-/Concavum-Zone sowie an der Aalenium/Bajocium Grenze (Concavum-/Discites-Zone). Eine weniger stark ausgeprägte Änderung der Ostracoden-Gemeinschaft erfolgt innerhalb der Concavum-Zone, oberhalb der Calceola-Bank. Folgende neue Arten werden beschrieben: *Cytheropterina crassicostata* **sp. nov.**, *Eucytherura eberti* **sp. nov.** und *Eucytherura foveolata* **sp. nov.** Darüber hinaus werden 15 wahrscheinlich neue Arten kurz beschrieben; 10 "incertae sedis"-Taxa werden in offener Nomenklatur abgebildet. Die Ammonitenfaunen der Inopernabank und der Konglomeratbank (Ober-Aalenium, Bradfordensis-Zone, Gigantea Subzone) werden ebenso wie diejenige der Calceolabank und der Rostroten Kalkbank (Ober-Aalenium, Concavum-Zone, Concavum-Subzone, *cavatum*-Horizont) beschrieben und mit Ammonitenfaunen anderer Gebiete korreliert.

† deceased

Keywords

Upper Aalenian, Achdorf Formation, ammonites, ostracods, Zollernalb, SW Germany

Schlüsselworte

Ober-Aalenium, Achdorf-Formation, Ammoniten, Ostracoden, Zollernalb, SW-Deutschland

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1. Introduction and previous studies

In the context of the field works on the occasion of the investigation of the lithostratigraphy as well as the ammonite and ostracod biostratigraphy of the "Unterer Wedelsandstein" and "Sowerbyi-Oolith" members (Wedelsandstein Formation; Lower Bajocian) of the Zollernalb (Dietze et al. 2019), the survey of the sections was expanded to the underlying beds of the Achdorf Formation (uppermost Lower and Upper Aalenian). Surprisingly, some of these beds yielded a rich ammonite fauna. This was quite unexpected, since Hahn (1975) mentioned that ammonites are very rare in the Upper Aalenian of this area. The microfauna samples are very rich in ostracods. Therefore, we decided to publish the lithostratigraphical and biostratigraphical results regarding the Achdorf Formation and parts of the Opalinuston Formation in a separate publication, which is presented here.

Our knowledge on the Aalenian ostracod fauna from Germany is mainly based on studies from the 1930's to 1960's as summarized by Dietze et al. (2019). Ernst (1989), Ohmert (1996, 2004), Brand and Mönnig (2009), Franz et al. (2009, 2014), and Dietze et al. (2017a, 2019), provided more recent data. Publications on Aalenian ostracods from other European areas include Bate (1963a, b, 1968, 1978, 2009), Sheppard (1981), Morris (1983), Ainsworth (1986, 1990, 1991), Ainsworth et al. (1989), Whittaker and Hart (2009) [Great Britain, Ireland], Dépêche (1985), Bodergat (1997) [France], Arias et al. (2009) [Spain], Tröster (1987), Reisdorf et al. (2016), and Tesakova (2017) [Switzerland]. Aalenian ostracods have also been described from Argentina (Ballent 1991; Boomer and Ballent 1996; Ballent and Whatley 2000, 2009) and Iran (Kochhann et al. 2015).

There is only little information available on the ammonites of the uppermost Aalenian (Concavum Zone) in SW Germany. Stratigraphic data and numerous local details were provided by Beisswenger (1920), Rieber (1922), Schmierer (1925, 1926), Stahlecker (1926, 1934), Schmidt (1933), Erb (1938), Lörcher (1939), Boomgaard (1948), Rieber (1961), Hahn (1975f), and Hiller and Kunze (1979). Rieber (1963) described and figured well-preserved ammonites from the Concavum Zone of the "Hofwald" section near Metzingen (Middle Swabian Alb). The so-called "Concava-Bank" of the Zollernalb in Rieber (1963: 16) corresponds to our "Konglomeratbank" (see also Rieber 1922: 46). Bayer (1969) described some hammatoceratid ammonites from the Concavum Zone of the Wutach area and the "Hofwald" section. Ohmert (1981) dealt as well with the outcrops in the "Hofwald". Sanns and Schweizer (1987), among others, investigated the lithology and formation of the "*concava*-Bank" bed. Finally, Franz and Nitsch (2009) revised the lithostratigraphy of the Aalenian in Baden-Württemberg.

2. Description of the sections

All sections are described bottom-up.

2.1 Balingen-Zillhausen (Roschbach)

Opalinuston Formation (Zillhausen Member)
Bed no.

1. [**Zopfplatten**] (ca. 1.0 m [Rieber 1963]).

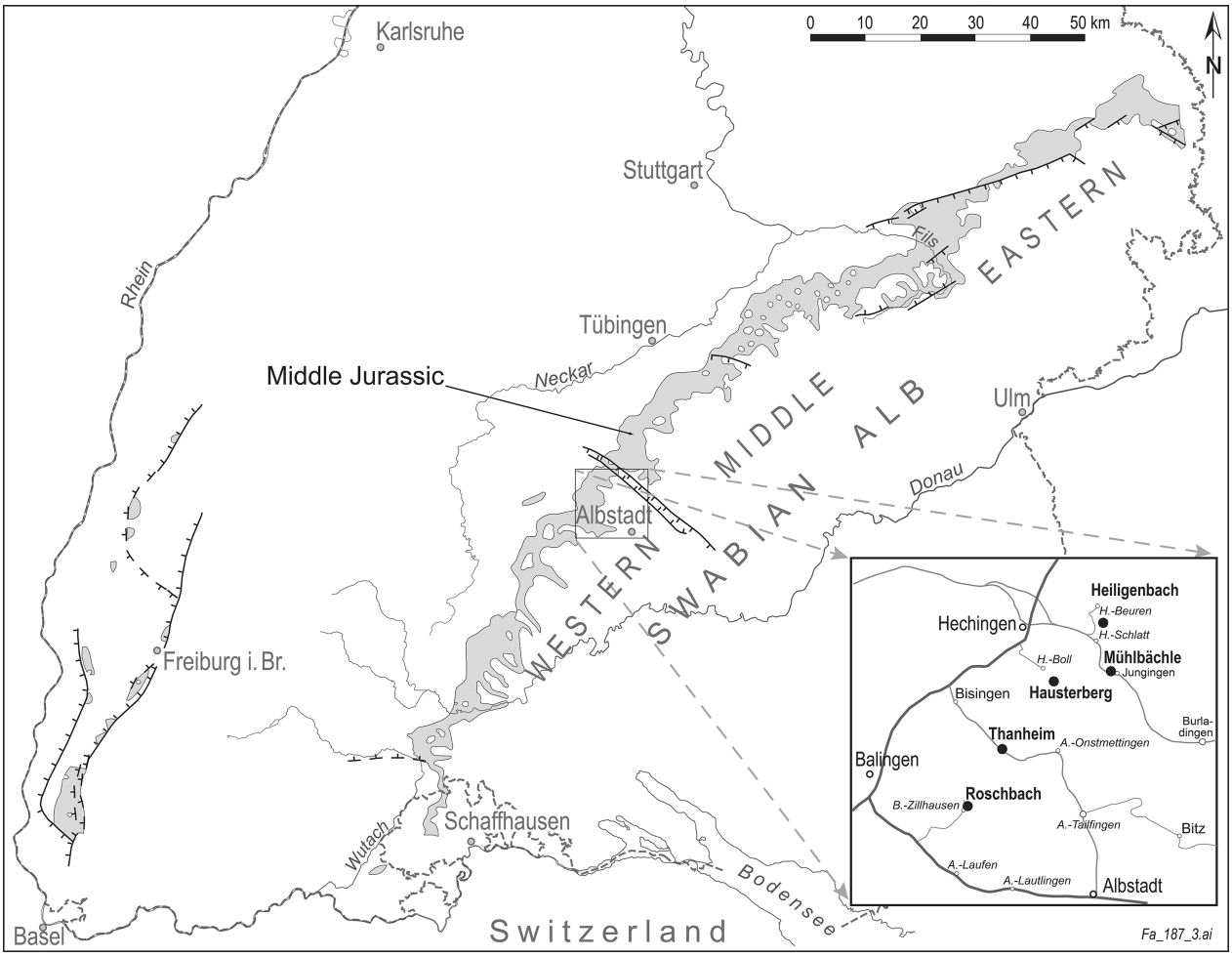

Figure 1. Location map of the sections studied in the Zollernalb (enlarged square).

2. (ca. 8.0 m [Rieber 1963]): claystone with layers of siderite concretions (only the uppermost 2 m are exposed) at 0.4 m, 0.9 m and 1.5 m below the top.

Achdorf Formation

3. (0.15–0.2 m): grey, hard marly limestone, with bivalves and *Leioceras crassicostatum*.
4. (0.15 m): grey carbonaceous marlstone; in the upper part gritty, with siderite concretions.
5. (0.03 m): grey, very hard marly limestone nodules.
6. (0.2 m): grey marlstone with compressed *Leioceras crassicostatum*.
7. (0.05 m): light grey, pyritic marly limestone nodules with dark grey *Chondrites* burrows. Mainly small specimens of *Leioceras* "*comptum*", irregularly embedded and partly accumulated.
8. (0.4 m): carbonaceous marlstone with higher clay content than in beds 4 and 6.
9. (0.03 m): grey marly limestone nodules.
10. (0.2 m): clay marlstone.
11. (0.18 m): marly limestone, partially splitting in the lower third. At the base with hazelnut-sized pebbles. Above very hard marly limestone concretions with shrinkage cracks (septaria) and fine shell debris.
12. (ca. 2.0 m): claystone, badly exposed.
13. (0.05 m): grey, hard marly limestone.
14. (ca. 5.5 m): claystone with layers of septaria und siderite concretions (section is divided by a wooden bridge at the "Geopfad" into a lower and an upper part) below: ca. 4.0 m claystone with a layer of septaria (0.05 m) ca. 1.8 m above the base above: ca. 1.5 m claystone (with layers of siderite concretions at 1.1 m, 0.8 m, 0.7 m and 0.4 m below the top; ca. 0.85 m below the top, a hard, sandy, micaceous marly limestone with ichnofossils; 0.25 m below the top another septaria layer).
15. (0.05 m): hard carbonaceous marlstone.
16. (0.2 m): greyish brown marly limestone with *Ludwigia murchisonae* (see Rieber 1963).
17. (0.4–0.45 m): grey carbonaceous marlstone.
18. (0.25 m): greyish brown, marly limestone.
19. (0.15 m): carbonaceous claystone.
20. (0.25 m): grey, hard marly limestone; with *Staufenia staufensis* and *Brasilia bradfordensis* (Rieber 1963). This is the top layer of the small waterfall.
21. (0–0.12 m): grey, very hard, loaf-shaped marly limestone nodules with *Staufenia staufensis* (SMNS 70519/1 [microconch]). From a corresponding nodule layer of the nearby Bezighofenbach section (Rieber 1963), a large *S.* cf. *staufensis* (SMNS 70519/55) with a relatively wide umbilicus was recorded.

22. (ca. 1.7 m): grey marlstone, mostly not exposed. (Rieber (1963) described 4 harder beds up to 1.65 m above bed 20, the uppermost one as an oolitic nodule layer with *Staufenia staufensis*).
23. (ca. 6 m): claystone, not exposed; only the uppermost 0.3 m are visible.
24. (0.05–0.15 m): **[Inopernabank]** spotty-grey, tough, marly limestone with greyish brown bark and isolated small, rounded pebbles. At the base larger *Thalassinoides* burrows, in the lower part of the bed small, flattened marlstone pebbles (0.03–0.05 m). Few fossils: *Gryphaea* sp., *Pinna* sp., belemnites.
25. (6.0 m): dark claystone with several layers of siderite concretions in the upper 0.5 m.
26. (0.05–0.1 m) **[Konglomeratbank** (= bed 3 in Dietze et al. 2019)**]**: grey marly limestone with abundant pebbles. *Ludwigella arcitenens* (Fig. 16: 3a, b).
27. (ca. 0.3 m): dark grey, laminated carbonaceous claystone, with fine shell debris and small nodules (up to 5 mm). Rare, compressed *Graphoceras* sp., a fragmentary *Graphoceras* sp. (SMNS 70519/2) at the top sample Ro19-1: 0–0.05 m above the Konglomeratbank sample Ro19-2. 0.25–0.3 m above the Konglomeratbank
28. (max. 0.1 m) **[Calceolabank** (= bed 5 in Dietze et al. 2019)**]**: grey, marly limestone with many *Gryphaea calceola* in its lower part, in clay-rich parts predominantly in "convex upward" position. Some of the shells are stacked into each other. The layer is nodular in some places and then wedges out. At one point many large *Trigonia alemanica* and compressed ammonites (?*Graphoceras*) occur. At another place nearby well-preserved *Graphoceras* cf. *concavum* (Fig. 16: 1, 4) and *Brasilia* cf. *decipiformis* (Fig. 21: 2a, b, 5a, b).
29. (0.15 m): carbonaceous claystone with few small gryphaeids.
30. (0.1–0.15 m): carbonaceous claystone with masses of small gryphaeids (*Gryphaea calceola*) up to 2 cm in diameter and small phosphorite concretions. Sample Ro19-3
31. (0.15 m): grey calcoolitic marlstone (reddish brown in weathered state), with single hard marly limestone nodules. Few bivalves and belemnites.
32. (0.15 m) **[Rostrote Kalkbank** (= bed 9 in Dietze et al. 2019)]: hard limestone, rusty red crust, inside greenish grey and brown-red marbled.
33. (0.95 m; see Ohmert 2004): carbonaceous claystone. Sample Ro19-4: 0–0.05 m above the Rostrote Kalkbank Sample Ro19-5: 0.05–0.15 m above the Rostrote Kalkbank

Wedelsandstein Formation

34–36. [**Sowerbyi-Oolith** (= beds 11–13 in Dietze et al. 2019)**]** (see Franz 1986, Dietze et al. 2019).
34. (0.05–0.07 m): limestone nodules, calcitic ooids only in *Chondrites* burrows.
35. (0.06–0.1 m): dark grey, muscovite-bearing, laminated oolitic claystone with belemnites and *Hyperlioceras*.
36. (0.04–0.13 m): grey elongated limestone nodules with irregular surfaces, hard, calcitic oolites (0.1–0.2 mm diameter), with small pebbles, in places densely packed. Bivalves (*Gryphaea*, *Entolium*), belemnites, serpulids; strongly bioturbated (*Chondrites*). Ammonites: *Hyperlioceras* sp. and *Euhoploceras* sp. (see Dietze et al. 2019).

Higher up **Unterer Wedelsandstein** (see Dietze et al. 2019).

2.2 Hechingen-Boll (Hausterberg)

Landslide above the former Friedrichstal castle near Hechingen-Boll

Achdorf Formation
Bed no. / sample no.

1. (min. 1.5 m): claystone, thickness unknown. Only uppermost part exposed.
2. (0–01.15 m): nodular bed of grey marly limestone, with small light grey, phosphoritic pebbles (0.2–1 cm) and marly limestone pebbles up to 3 cm, partly compressed. *Graphoceras* sp.
3. (1.5 m): dark grey claystone
4. (0.15 m): nodular bed, like bed 2, but continuously developed.
5. (ca. 4 m): grey claystone
   - not exposed
   - Slipped blocks from the **Rostrote Kalkbank** (0.15 m) and the **Calceolabank** (0.15 m) with *Gryphaea calceola*, *Graphoceras* sp. (SMNS 70519/3), *Euaptetoceras* sp. (SMNS 70519/4).
6. (ca 7–8 m): claystone, mostly badly exposed. The upper 3 m excavated for sampling. Layers of siderite concretions at 0.15 m, 0.2 m, 0.5 m and 1.5 m below top. 1.6 m below top 0.10–0.15 cm long and 0.03–0.04 m thick lenses of light grey, lenticularly bedded, fine-sandy limestones.
   - Ha19-1 (3.05–2.55 m below bed 7)
   - Ha19-2 (2.05–1.55 m below bed 7)
   - Ha19-3 (1.05–0.25 m below bed 7)
   - Ha19-4 (0.15–0.25 m below bed 7)
7. (0.15 m) [**Sowerbyi-Oolith**]: claystone, with occasional irregular-shaped, often flat nodules (up to 0.10 m long and 0.04 m thick) of greyish limestone with borings, the sediment infill of which is calcoolitic. The nodules are settled on all sides with bryozoans, oysters and serpulids and show in places a fine, dark brown coating. Small phosphoritic pebbles (up to 0.05 m) are not rare. Some of them show parallel scratch-like traces. In the pebbles occasionally casts of endobenthic bivalves occur. In the claystone fragments of *Actinostreon*, *Ctenostreon* and fragments of abraded belemnites

with borings occur. One fragmentary *Hyperlioceras* from the "Weinhalde" section, 700 m SE of the Hausterberg section.
- Ha19-5 / (above bed 7)

8. (0.15 m): sandy marly limestone with separation joints. Large *Thalassinoides* burrows at the base; *Zoophycos*.
9. (0.3 m): marly claystone; at the base sandy, at the top silty.
   - Ha19-6

2.3 Jungingen (Mühlbächle and Starzel)

2.3.1 Mühlbächle

Achdorf-Formation:
Bed no. / sample no.

1. (min. 0.5 m): claystone
2. (0.1–0.12 m): pyrite-bearing grey, weathered rusty, hard marly limestone. Many tiny gryphaeids, rare belemnites and bivalves. Few, mostly very small ammonites. *Brasilia bradfordensis* (Fig. 19: 1a, b)
3. (0.45 m): claystone. In the upper part a single carbonaceous burrow (diameter up to 0.04 m) was observed.
4. (0.05–0.1 m): hard, grey marly limestone with many pebbles of different size and burrows at the base.
5. (1.8–2.0 m): claystone; only partly exposed.
6. (0.05–0.08 m): grey marly limestone with pebbles; accumulations of very small gryphaeids.
7. (1.6 m): claystone with several layers of siderite concretions (0.4, 0.6, 0.8, 0.9, 1.0, 1.15 and 1.3 m above base).
8. (0.05–0.08 m) flat to nodular, hard, grey marly limestone with occasional pebbles.
9. (0.01–0.05 m): marlstone.
10. (0.15–0.18 m): **[Inopernabank]** greyish brown, hard marly limestone, easily splitting in weathered state. Numerous larger pebbles, especially in the lower part, where they can be flattened. Small, light grey pebbles give the rock a speckled appearance. Large burrows at the base. Bivalves are characteristic for the Inopernabank (big *Pholadomya*, *Inoperna sowerbyana*, *Gryphaea calceola* [smaller ones than those in the Calceolabank]). Some of the endobenthic bivalves are still in life position (see Quenstedt 1857: 357).
11. (ca. 3.5–4.0 m) claystone, not exposed.
12. (0.1–0.12 m) **[Konglomeratbank]**: hard, greyish brown marly limestone, with big pebbles. Large *Pholadomya* in life position.
13. (0.35 m): grey marl with abundant *Gryphaea calceola* (up to 0.03 m).
14. (0.15–0.18 m) **[Calceolabank]** (= bed 12 in Dietze et al. 2019): Hard, grey, pyrite-bearing marly limestone. Partly easily splitting. Weathered brown and decomposing. At the base abundant *Gryphaea calceola* (up to 0.06 m large), only very rarely with right valves. The gryphaeids are embedded individually or in accumulations. Well-preserved ammonites are relatively common, predominantly in the lower third of the bed: *Brasilia* cf. *decipiens* (Fig. 19: 5a, b), *B*. aff. *decipiens* (Fig. 20: 3a, b), *Graphoceras* aff. *magnum* (Fig. 20: 1a, b), *G. cavatum* (Fig. 21: 2a, b), *G*. cf. *cavatum* (Fig. 20: 2a, b; Fig. 21: 1a, b), *G. pulchrum* (Fig. 22: 3a, b), *G. decorum* (Fig. 22: 1a, b), *G. formosum* (Fig. 22: 2a, b, 5a, b), *G. fallax* (Fig. 22: 4), *Ludwigella cornu* (Fig. 19: 2), *L. attracta* (Fig. 19: 3), *L. micra* (Fig. 19: 4), *Euaptetoceras* cf. *euaptetum* (Fig. 23: 1a–c), *E.* cf. *kochi* (Prinz) (The ammonite figured in Fig. 24 comes from an excavation pit in Jungingen 500 m west of the Mühlbächle stream).
15. (0.20 m): grey carbonaceous claystone.
16. (0.05 m): single hard marly limestone nodules (up to 0.05 m).
17. (0.20 m): grey carbonaceous claystone with small phosphoritic nodules. Masses of small gryphaeids (*Gryphaea calceola*).
18. (0.10 m): rough, phacoidal, reddish marlstone with occasional hard marly limestone nodules; pholadomyids. *Graphoceras concavum* is recorded from the Bachenau section (Rieber 1922, 1963), which is situated about 50 m east of the Mühlbächle.
19. (0.08–0.1 m): light grey, very hard limestone with numerous dark grey burrows (*Chondrites* and cylindrical burrows up to 4 mm in diameter). Occasional compressed ammonites. Thin marly joint with bed 20.
20. (0.1–0.12 m) **[Rostrote Kalkbank]** (= bed 15 in Dietze et al. 2019): On the outer surface weathered with a typical rusty red margin. In fresh state a hard, light grey, reddish and greenish grey marbled limestone. *Graphoceras* sp.
21. (8.0 m) (= bed 16 in Dietze et al. 2019): claystone (thickness according to A. Rieber 1922). Poorly exposed.
    - Mue19-1

Wedelsandstein-Formation:

22. (0.15–0.2 m) **[Sowerbyi-Oolith]** (= bed 17 in Dietze et al. 2019): grey carbonaceous claystone with marly limestone nodules. Some nodules show concentric growth structures. Club-shaped borings are filled with calcitic oolites. The surface of rounded to flat nodules is densely covered on all sides with bryozoans, serpulids and sessile foraminifers. Some other nodules are grey inside, calcoolitic, with scattered very small light grey pebbles. Rare serpulids, belemnites, bivalves and pebbles occur in the matrix. The very irregular-shaped, calcoolitic limestone nodules are overgrown as well. In the claystone between the nodules occasional belemnites and endobenthic bivalves, *Entolium*.

Higher up follows the **Unterer Wedelsandstein** (see Dietze et. al. 2019).

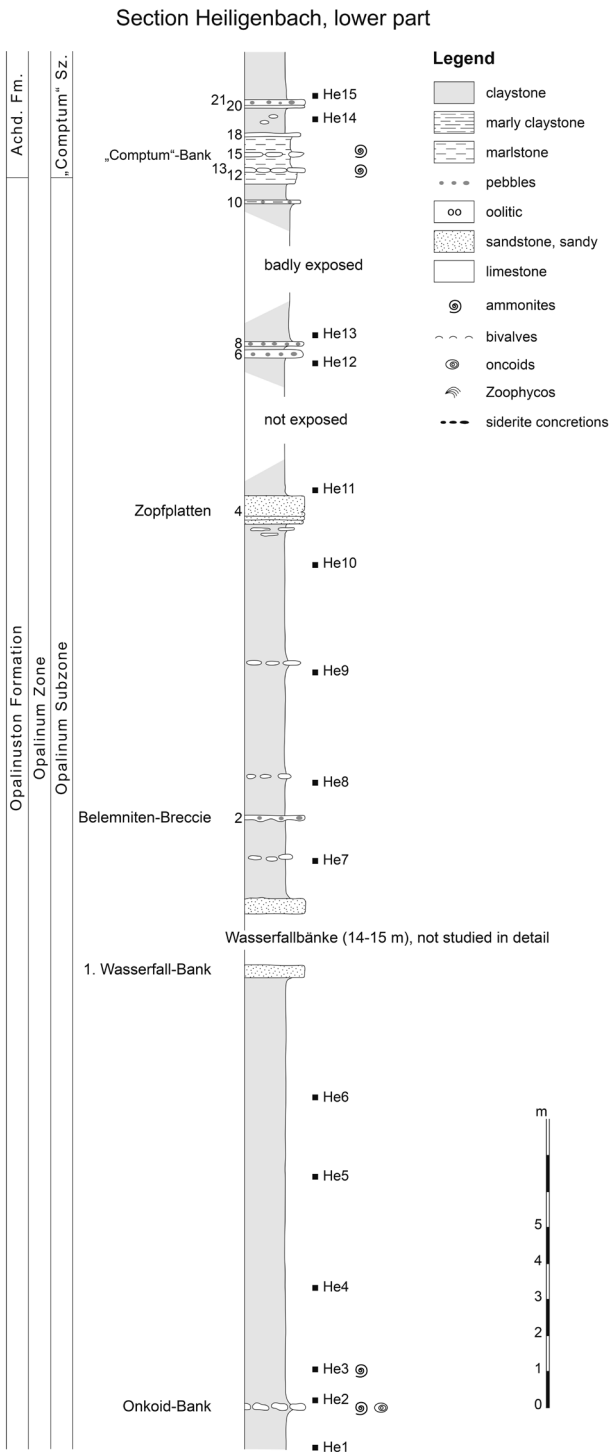

Figure 2. Section Heiligenbach, lower part. Achd. Fm = Achdorf Formation; Sz. = Subzone.

2.3.2 Starzel (river bed near the road Jungingen–Killer, see Lörcher (1939: 224):

Achdorf-Formation:
bed no.

1. (min. 0.4 m): claystone
2. (0.05 m): grey, flat nodular marly limestone.
3. (0.01–0.05 m): marly joint.
4. (0.15–0.2 m) **[Inopernabank]**: hard, grey limestone, in places speckled with small, light grey pebbles and large burrows at the base. Larger, mostly flattened pebbles occur predominantly in the lower part of the bed. The bed varies greatly in thickness and compactness. Large *Pholadomya lirata*, *Inoperna sowerbyana*, *Goniomya literata*, *Gryphaea calceola* (up to 0.03 m), *Entolium* sp., *Propeamussium pumilum*, and *Oxytoma inaequivalvis*. Small gastropods, belemnites and ammonites. *Graphoceras cavatum* (Fig. 13: 2a, b, 9a, b), *G.* aff. *fallax* (Fig. 13: 3), *Brasilia decipiens* (Fig. 13: 1a, b), *Ludwigella attracta* (Fig. 13: 7, 8), *L. tenuis* (Fig. 13: 4), *L.* aff. *tenuis* (Fig. 13: 5), *L. attenuata* (Fig. 13: 6), *Planammatoceras* sp. (Fig. 14: 1a–c). Lörcher (1939: 224) misidentified this bed as Calceolabank).
5. (min. 0.5 m): claystone.
6. Higher parts of the section are not exposed, except of the Rostrote Kalkbank bed above the railway bridge near the village Killer.

2.4 Hechingen-Beuren (Heiligenbach, Sießenwald, Hanneswiesle)

2.4.1 Heiligenbach

(the strata below bed 1 were not studied in detail)

Bed no. / sample no.

"Ob -1m" He19-1 1.0 m below Onkoidbank.
"Ob" (0.15–0.2 m) **[Onkoidbank]**: *L. opalinum* [m], about 11 m below "Wasserfallschichten". In its upper part a marly limestone, dark grey, upper and lower surface very irregular, with shrinkage cracks and oncoids (Fig. 3).
"x" (about 11 m): sandy, carbonaceous claystone, a single *Lytoceras dilucidum*.

- He19-2 0–0.1 m above Onkoidbank: numerous crinoids and bivalves.
- He19-3 1 m above Onkoidbank, numerous crinoids, *Leioceras opaliniforme* (body chamber).
- He19-4 2 m above Onkoidbank.
- He19-5 5 m below "Wasserfallschichten": Isolated lenticular, thin-layered, sandy-calcareous layers, micaceous, with crinoid debris (Pentacrinitenplatte with *Chariocrinus wuerttembergicus*), ichnofossils (*Gyrochorte*, *Palaeophycus* and others).
- He19-6 3 m below "Wasserfallschichten"

"WS" (about 14–15 m) **[Wasserfallschichten]**: with several cascades in the river bed (Rieber 1922; Lörcher 1939; Kobler 1972: 14, pl. 2 [left column]).

1. (2.0 m): claystone, dark grey (at approx. 1.0 ca. 0.04 m irregular carbonaceous marlstone pebbles.
   - He19-7 (middle)
2. (0.08–0.1 m) **[Belemnitenbreccie]**: hard, bluish-grey marly limestone, base very irregular; with a coquina of bivalves/echinoderms and grey pebbles, partially

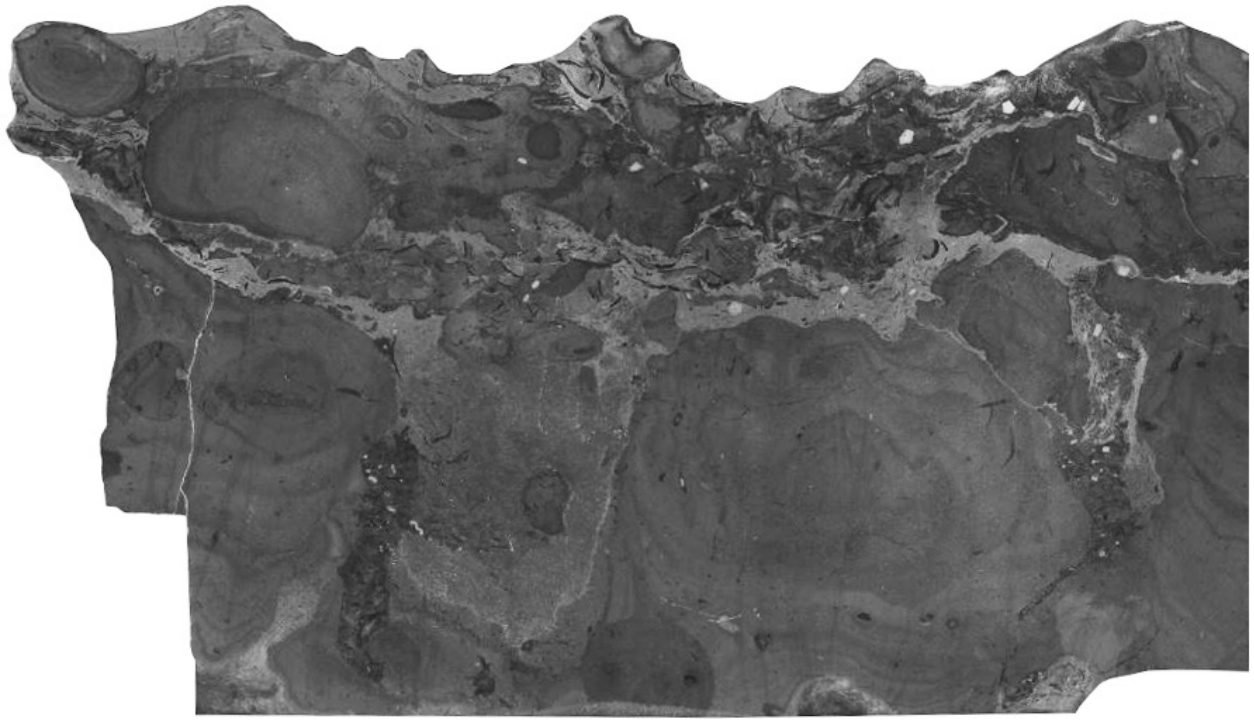

Figure 3. Obere Onkoidbank, polished section; the lower half of dark grey limestone bed consists of redeposited, marginally eroded, micritic oncoids up to 7 × 8 cm in size. This part is overlain by silty, fine sandy, fossil-bearing (crinoids, bivalve shells, rare belemnites) marly limestone, in which up to 4 cm large oncoids with borings and thin pyritized microbial crusts are embedded. This sediment also fills the interspaces between the oncoids. Opalinuston Formation, Heiligenbach. Width of the photo: 20 cm.

with bivalve borings, irregularly bedded. Abundant belemnites, *Gryphaea calceola*, *Chlamys textoria*.

3. (7–8 m): claystone with layers of siderite concretions; only partly exposed.
   - **3a**: 1.0 m above bed 2: layer of nodules (carbonaceous marlstone/siderite)
     - He19-8
     - He19-9 (3.0 m above bed 2): rare bivalves, *Bactrylium*, cylindrical burrows.
   - **3b**: ca. 4.0 m above bed 2: noticeable nodule layer (brown marly limestone)
     - He19-10 (1.0 m below top): burrows

   In the upper 0.25 m single mica-bearing fine sandy limestone plates (up to approx. 0.03 m thick) with a rich ichnofauna, *Gyrochorte comosa*.
4. (0.7 m) **[Zopfplatten]**: fine sandy limestone, mica-bearing, splitting into thin plates; *Gyrochorte comosa*.
5. (ca. 3.5 m): very poorly exposed
   - 1.5 m above bed 4: claystone with siderite nodules.
     - He19-11 small gastropods.
     - He19-12 (directly below bed 6): very numerous agglutinating foraminifera.
6. (0.15–0.2 m): grey, marly limestone, small pebbles (up to nut-size). Lörcher (1939) described ammonites probably coming from this bed (or from bed 10).
7. (ca. 0.1 m): dark grey claystone.
8. (0.05 m): grey marly limestone, few small pebbles.
9. (ca. 3–4 m): dark grey claystone, very badly exposed
   - He19-13 (middle)
10. (0.01 m): grey carbonaceous marl with a layer of pebbles.
11. (0.4 m): dark grey claystone.
12. (0.3 m): grey marlstone.
13. 0–10 cm grey, lenticular to nodular marly limestone; accumulations of remarkably small sized ammonites: *Leioceras "comptum"*, *L. evolutum*, *L. striatum*, *L. paucicostatum* (from the corresponding layer of the Steinlach creek north of Mössingen-Talheim: *L. crassicostatum*, *L. "comptum"*, *L. striatum*, *L. paucicostatum*, *L. evolutum*, *L.* sp. (with broad whorls)), occasional bivalves; shrinkage cracks.
14. (0.03 m) dark grey marly claystone.
15. (0–0.1 m): carbonaceous marl nodules, in places a continuous, very hard carbonaceous marlstone bed with calcite-filled shrinkage cracks (Septarienbank). Occasional small ammonites (*Leioceras "comptum"*).
16. (0.02 m) (directly on top of bed 15): sandy carbonaceous marl tiles, trace fossils (not continuously present).
17. (0.35 m): dark grey marly claystone.
18. (0.08 m): grey sandy carbonaceous marlstone.
19. (0.65 m): dark grey claystone with siderite nodules.
    - He19-14
20. (0.05–0.08 m): dark grey carbonaceous marl with small pebbles; thin marly claystone layer.
21. (0.1–0.12 m): grey carbonaceous marl with small pebbles **[**20 + 21: "Doppelbank"**]**
22. (ca. 2 m): dark grey claystone with grey limestone lenses.

- He19-15 agglutinating foraminifera

23. (0.05–0.07 m): grey carbonaceous marl, irregular surface; abundant pyrite, pebbles up to 0.03 m.
24. (ca. 1 m): dark grey claystone, approx. 0.7 m above bed 23 with a layer of siderite nodules.
25. (0.05 m): grey marly limestone with small pebbles.
26. (1.3 m): dark grey claystone, layers of siderite nodules at 0.15, 0.65, and 1.15 m above bed 25.
    - He19-16 (0.01 m above bed 25): crinoids
27. (0.08 –0.1 m): brown, coarsely conglomeratic marly limestone; bivalves and belemnites.
28. (3.5–4 m): dark grey claystone, only partly exposed.
    - He19-17(0.25 m below bed 29)
29. (0.15 m): grey lenticular splitting carbonaceous marl.
30. (0.15 m): light grey marly limestone with dark grey spots.
31. (0.03 m): brownish grey carbonaceous marlstone with masses of small pebbles.
32. (0.15 m): brown marly limestone with bivalves **[**29–32: **Staufensisbank]**
33. (ca. 6 m): claystone, not exposed; according to Lörcher (1939) with several carbonaceous beds.
    - He19-18 (0.5 m above bed 32)
    - He19-19 (0.2 m below bed 34)
34. (0.1–0.15 m): grey marly limestone, thin bivalve shells; single small pebbles.
35. (2 m): claystone.
    - He19-20 (0.4 m below bed 36)
36. (0.01 m): grey marly limestone, small pebbles up to 3 cm; shell debris. Belemnite, nautiloid (*Cenoceras*), *Graphoceras*.
37. (ca. 0.7 m): dark grey claystone.
38. (0.05 m): irregularly shaped bed of grey marly limestone.
39. (0.7 m): claystone; 0.4 m above bed 38 a layer of siderite nodules. Arthropod burrows at the top.
    - He19-21 (0.4 m above bed 38)
40. (0.1 m) **[Inopernabank]**: grey, coarse conglomeratic limestone, with phosphoritic spots; *Pholadomya lirata*, *Gryphaea calceola*, *Inoperna sowerbyana*, ammonites: *Graphoceras* cf. *caduciferum* (Fig. 17: 1a, b), ?*Brasilia* sp. (SMNS 70519/54).
41. (4 m) (= bed 1 in Dietze et al. 2019): dark grey claystone, occasional flat siderite nodules at 0.6 m below top.
    - He19-22 (41 middle)
    - He19-23 (41, 0.5 m below bed 42)
42. (0.08–0.1 m) **[Konglomeratbank]** (= bed 2 in Dietze et al. 2019; starting from here this section had already been sampled in 1988): blueish grey limestone with pebbles. A fragment of *Graphoceras* sp. (Fig. 17: 2).
43. (0.02 m): calcoolitic marl.
    - He19-24
44. (0.15–0.17 m): grey to brownish marly claystone.
    - He19-25
45. (0.17 m) **[Calceolabank]**: (= bed 5 in Dietze et al. 2019) grey marly limestone, lenticular splitting, on top 0.02 m oolitic marl. Thin-shelled bivalves, at the base (in places in marl lenses) abundant *Gryphaea calceola*. Ammonites: *Brasilia decipiens* (Fig. 18: 1), *B*. aff.

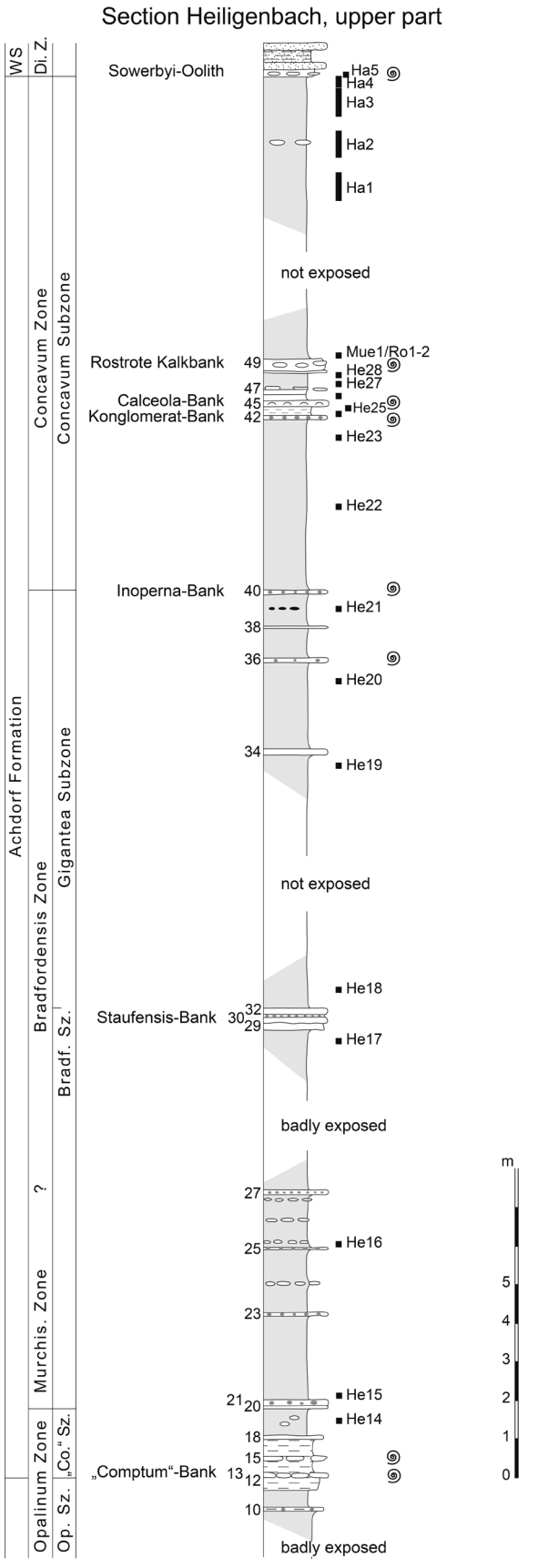

Figure 4. Section Heiligenbach, upper part, above the Rostrote Kalkbank, combined with the Mühlbächle, Roschbach and Hausterberg sections. WS = Wedelsandstein Formation; Murchis. = Murchisonae; Di. = Discites Zone; Op. Sz. = Opalinum Subzone; "Co. Sz. = "Comptum" Subzone; Bradf. Sz. = Bradfordensis Subzone.

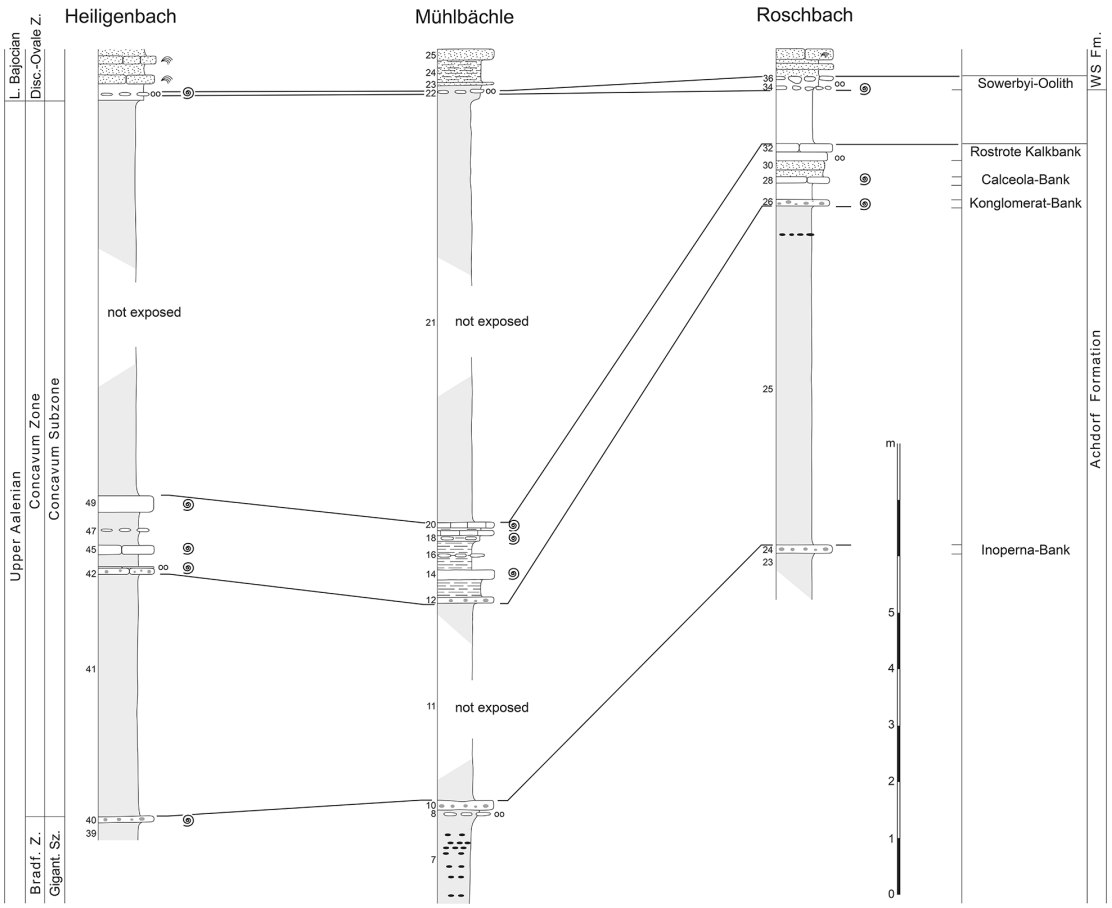

Figure 5. Sections Heiligenbach (above bed 49 combined with the Hausterberg section), Mühlbächle and Roschbach, detail of the Concavum Zone. L. Bajocian = Lower Bajocian, Bradf. Z. = Bradfordensis Zone; Disc.-Ovale Z. = Discites – Ovale zones; Gigant. Sz. = Gigantea Subzone.

decipiens (Fig. 18: 4a, b). *Graphoceras fallax* (Fig. 18: 5), *G. cavatum* (Fig. 18: 2), *G.* cf. *v-scriptum* (Fig. 18: 3), *Ludwigella arcitenens* (Fig. 17: 3), *L.* sp. (Fig. 17: 5), *Euaptetoceras infernense* sensu Buckman (Fig. 17: 4).

46. (0.02 m): greyish beige claystone.
    - He19-26
47. (0.05 m): single grey limestone nodules up to 5 cm, partly with numerous small *Gryphaea* and serpulids.
48. (0.33 m): grey laminated claystone, with abundant small gryphaeids, single belemnite.
    - He19-27 (at the base)
    - He19-28 (0.1 m above bed 47)
49. (0.25–0.35 m) **[Rostrote Kalkbank]** (= bed 9 in Dietze et al. 2019): reddish brown carbonaceous marl with marly limestone nodules; 2 or 3 layers of flat siderite nodules. At the base 0.05 m greenish brown marly limestone.
    This outcrop is covered by terrace gravel of the Heiligenbach.

2.4.2 Eastern tributary of the Heiligenbach coming from the Sießenwald, approx. 30 m east of the "Hunnengrab"

In the river bed there is a light grey, hard limestone bed (0.15 m) with a rust-coloured rim and many burrows. Its lithology resembles the lower bed of the Rostrote Kalkbank from the Mühlbächle section at Jungingen. An indeterminable ammonite fragment. A larger *Euaptetoceras* sp. (SMNS 70519/5) comes from a loose block of the Rostrote Kalkbank.

2.4.3 Hanneswiesle

This outcrop is located on a forest path in the Hanneswiesle district west of Beuren.

Bed no.

1. (0.08–0.1 m) **[Konglomeratbank]**.
2. (0.2 m): carbonaceous claystone.
3. (0.03 m): firm marlstone with many *Gryphaea calceola.*
4. (0.15–0.2 m) **[Calceolabank]**: brownish marly limestone, splitting into plates in places, but in places solid grey marly limestone with a reddish brown rim also in weathered state. Small gryphaeids are firmly fixed in clusters on the bed surface (see Erb 1938). Ammonites (*Graphoceras pulchrum* (Fig. 15: 5a, b), *G.* cf. *pulchrum* (Fig. 15: 4a, b), *G.* cf. *concavum* (Fig. 15: 1a, b), *G. decorum* (Fig. 15: 2), *G.* aff. *apertum* (Fig. 15: 3a, b), *Ludwigella arcitenens* (Fig. 15: 6a, b), *Euaptetoceras infernense* sensu Buckman (Fig. 14: 2a, b)) are mainly found in the lower part of the bed.

2.5 Bisingen-Thanheim (Heiligenkopf)

Since we did not find Aalenian ammonites in this outcrop, we here refer to Dietze et al. (2019) for the description of the section.

3. Description of the ostracod assemblages (M. Franz)

3.1 Methods

For the present study, a total of 41 samples were taken in September 2018 and September 2019. Individual samples, which were already taken in 1988 at the Heiligenbach, were included in the investigation.

Microfossils have been extracted by first drying the samples (0.5–1 kg), breaking them down with the aid of hydrogen peroxide (3% solution of H_2O_2) and then sieving them under water. The residues were then cleaned by boiling them for 15 minutes in a moderately concentrated sodium chloride solution (3 teaspoons NaCl / 0.25 l water). From the fractions > 0.5 mm and > 0.315 mm of the residues, 3–5 trays were examined. From the fractions > 0.2 mm and > 0.15 mm we examined 3 trays.

Photographs were taken using SEM in Stuttgart (SMNS).

3.2 Results

Introductionary remark:

The investigation of the Geisingen clay pit (Franz et al. 2018) has considerably increased the knowledge about the ostracod fauna of the Aalenian of SW Germany. The present investigation of approximately the same part of the section showed very good agreement in the Opalinum zone. However, several species are much rarer in the sections studied herein. In addition, strong changes in thicknesses and facies are noticeable. The vertical distribution of the species first described in Franz et al. (2018) – *Balowella catena*, *Cardobairdia tesakovae*, *Cytheropterina alacostata*, *Eucytherura eberti*, *Euc. foveolata*, *Euc*. sp. 3, *Euc*. sp. 5, *Pleurocythere ohmerti*, *Progonocythere scutula* – is consistent in both sections.

The 41 samples yielded a total of 4,149 specimens, ranging from 0 to > 700 specimens per sample. For a semi-quantitative analysis of the composition of the ostracod assemblages the greater numbers of single (right or left) valves were counted as 1, resulting in a total of 2.758 individuals.

A total of 108 species were identified, 329 specimens remained undetermined. From 34 species of the Upper Opalinuston Formation, 22 do not cross the boundary to the overlying Achdorf Formation. The Achdorf Formation yielded a total of 82 species including the 12 already known from the Opalinuston Formation. In the Lower Wedelsandstein Formation 4 new species appear, 11 persist from the Aalenian.

At zone or subzone level, two relative maxima in the total number of species are recorded in the Opalinum Subzone and Concavum Zone (Table 4). The highest number of species in the Concavum Zone correlates with the highest number of newly reported species as well as the total number of genera and families.

Short descriptions of new species of cytherurids (*Eucytherura* sp. 3–11, *Procytherura* sp. 2, P. sp. 5, *Procytheropteron* sp. 1) in our material are excluded. Ten presumably new species were found only in numbers of one to five specimens and could not be assigned to any known genus. For this reason, these taxa were left in open nomenclature. In the samples of the fine sandy layers, the ostracods are partly covered by remnants of sediment (mainly quartz grains) and/or fragmentarily preserved.

Abbreviations:

LGRB Landesamt für Geologie, Rohstoffe und Bergbau im Regierungspräsidium Freiburg, Germany;
SMNS Staatliches Museum für Naturkunde Stuttgart, Germany;
C carapace;
RV right valve;
LV left valve;
HT Holotype.

3.2.1 Systematic descriptions

In the following, the ostracod taxa that were found in the studied sections are listed in systematic order with information on their known occurrence. For detailed lists of synonyms, reference is made to Franz et al. (2018). Three new ostracod species are described. In addition, 15 presumably new species are briefly described in open nomenclature.

Order Myodocopida Sars, 1866
Family Polycopidae Sars, 1866
Genus *Polycope* Sars, 1866

***Polycope pelta* Fischer, 1961**

Material. 2 V in sample He19-9 and Mü I.
Distribution. Upper Toarcian to Upper Bathonian.

***Polycope* cf. *riegrafi* Brand, 1990**
Fig. 10: 1

Material. 2 C in sample He19-27
Distribution. Upper Aalenian, Concavum Zone; SW Germany.

***Polycope* sp.**

Material. 1 C, 4 V in samples He19-15–21.

Occurrence. Upper Aalenian, Murchisonae Zone – Concavum Zone; SW Germany.

Remarks: The material comprises predominantly very small, smooth carapaces and valves with no visible ornamentation and therefore it is not determinable to species level under the microscope. It cannot be excluded that they belong to different species.

Order Podocopida Müller, 1894
Family Cytherellidae Sars, 1866
Genus *Cytherella* Jones, 1849

***Cytherella apostolescui* Ainsworth, 1986**
Fig. 8: 1

Material. 30 C, 585 RV, 517 LV in samples He19-14–28, Mue19-1, Ha19-2–5 and Ro19-1–2.

Distribution. Upper Toarcian to Lower Oxfordian; SW Germany, Ireland.

***Cytherella apostolescui* ? ssp.**

Material. 12 RV in samples He19-24 and Ro19-1–2.

Distribution. Upper Aalenian, Concavum Zone; SW Germany.

Remarks. This ?subspecies was first described and figured from Thanheim (Dietze et al. 2019).

***Cytherella* cf. *fullonica* Jones & Sherborn, 1888**

Material. 1 C, 2 RV, 4 LV in samples He19-26 and Ro19-1–5.

Distribution. Upper Aalenian, Concavum Zone; SW Germany.

Genus *Cytherelloidea* Alexander, 1929

***Cytherelloidea* cf. *cadomensis* (Bizon, 1960)**

Material. 11 C, 18 RV, 28 LV in samples Ha19-4–6 and Ro19-1.

Distribution. Upper Aalenian to Lower Bajocian; England, France, SW Germany.

***Cytherelloidea* cf. *catenulata* (Jones & Sherborn, 1888)**
Fig. 8: 2

Material. 2 RV, 1 LV in samples He19-17–18.

Distribution. Upper Aalenian to Bathonian; England, France, SW Germany.

***Cytherelloidea lordi* Ainsworth, 1986**
Fig. 9: 1

Material. 1 C, 1 RV, in samples He19-18–19.

Distribution. Toarcian to Lower Bajocian; SW Germany, Great Britain.

Family Pontocyprididae Müller, 1894
Genus *Liasina* Gramann, 1963

? *Liasina cylindrica* Ainsworth, 1986
Fig. 10: 2

Material. 2 RV, 1 LV in samples Ha19-2–4 and Lin18-1.

Distribution. Toarcian to Aalenian; SW Germany, Ireland.

Family Healdiidae Harlton, 1933
Genus *Cardobairdia* van den Bold, 1960

***Cardobairdia tesakovae* Franz et al., 2018**
Fig. 6: 1

Material. 4 RV and 2 LV in samples He19-3–8.

Distribution. Lower Aalenian, Opalinum Zone; SW Germany, N Switzerland.

***Cardobairdia toarcensis* Ainsworth, 1986**
Fig. 10: 3

Material. 1 LV in sample He19-26.

Distribution. Toarcian to Aalenian; SW Germany, Ireland.

Family Bairdiidae Sars, 1888
Genus *Bairdiacypris* Bradfield, 1935

***Bairdiacypris triangularis* Ainsworth, 1986**
Fig. 9: 2

Material. 1 C, 1 RV in samples He19-19 and He19-22.

Distribution. Toarcian to Aalenian; SW Germany, Ireland.

Family Paracyprididae Sars, 1923
Genus *Paracypris* Sars, 1866

***Paracypris* cf. *goodlandensis* Howe & Laurencich, 1958**

Material. 1 RV, 2 LV in sample He19-12.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

***Paracypris* sp.**

Material. 1 C in sample He19-1.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Remark. The specimen is very small and preserved in pyrite and could therefore not be assigned with certainty to any species.

Family Macrocyprididae Müller, 1912
Genus *Macrocypris* Brady, 1868

***Macrocypris aequabilis* Oertli, 1959**
Fig. 9: 3

Material. 4 C samples in He19-19–21.

Distribution. Lower Aalenian to Lower Oxfordian; Germany, Scotland, N Switzerland, Russia.

***Macrocypris* ? *liassica* Bate & Coleman, 1975**
Fig. 10: 4

Material. 4 C, 3 RV, 1 LV in sample He19-27 and Ro19-3.

Distribution. Toarcian to Upper Aalenian; England, SW Germany; Upper Bathonian; N Germany.

***Macrocypris* sp.**

Material. 1 C, 1 R in samples He19-1 and He19-7.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Family Bythocytheridae Sars, 1926
Genus *Bythoceratina* Hornibrook, 1952

***Bythoceratina* (*Praebythoceratina*) sp. 1**
Fig. 8: 3

Material. 1 C, 8 RV, 9 LV in samples He19-16–27 and Ro19-4–5.

Occurrence. Upper Aalenian, Murchisonae to Concavum zones; SW Germany.

Description. A species of *Praebythoceratina* which is distinguished by the combination of the following features: an U-shaped lobe with an irregularly reticulate spine in the ventro-central area. Its anterior branch is strongly convex and irregularly reticulate, with dominant subvertical ridges. The posterior branch is broad and gently arched and covered with irregular pores. Along the anterior margin there is a pronounced bulge, which is also irregularly reticulate.

Genus *Patellacythere* Gründel & Kozur, 1971

***Patellacythere paravulsa* cf. *tenuis* Brand, 1990**
Fig. 10: 5

Material. 2 C, 6 RV, 7 LV in samples He19-21–27 and Ro19-1–3.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

***Patellacythere* cf. *vulsa* (Jones & Sherborn, 1888)**
Fig. 6: 2

Material. 1 LV in sample He19-9.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

***Patellacythere ungulina* (Triebel & Bartenstein, 1938)**
Fig. 10: 6

Material. 3 RV, 1 LV in sample Mue19-1.

Occurrence. Upper Aalenian, Concavum Zone; Germany.

Genus "*Monoceratina*" Roth, 1928

Remarks. This genus is in need of a revision and currently of unclear composition (Brand 1990.

***"Monoceratina"* aff. *posterocarinata* Brand, 1990**
Fig. 10: 7

Material. 2 C in sample He19-21 and Ro19-1.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

Genus *Tanycythere* Cabral et al., 2014

***Tanycythere posteroelongata* Cabral et al., 2014**
Fig. 10: 8

Material. 1 C in sample He19-27.

Distribution. Upper Toarcian to Upper Aalenian; SW Germany, Portugal.

Family Cytheruridae Müller, 1894
Genus *Cytheropterina* Mandelstam, 1956

***Cytheropterina alacostata* Franz et al., 2018**
Fig. 10: 9

Material. 4 RV, 14 LV in samples He19-27, Mue19-1, Ha19-2 and Ro19-4–5.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

***Cytheropterina bicuneata* (Braun) in Franz et al., 2018**

Material. 53 RV, 50 LV in samples He19-16–27, Mue19-1, Ro19-1–5, Ha19-2.

Distribution. Lower Aalenian to Lower Bajocian; SW Germany.

***Cytheropterina crassicostata* sp. nov.**

http://zoobank.org/6732D1E8-29AD-472F-B6F9-BCC64C020053

Fig. 10: 10–13

Etymology. *crassus* (lat.) = coarse, fat; costatus (lat.) = ribbed; referring to the broad rounded ribs.

Holotype. Right valve, figured on Fig. 10: 10, SMNS 70521/71.

Paratypes. two left valves, one right valve, figured on Fig. 10: 11–13, SMNS 70521/72–74.

Type locality. Heiligenbach valley near Hechingen-Beuren (SW Germany).

Type horizon. Achdorf Formation, claystone above the Calceolabank, bed no. 46 in Fig. 4; Concavum Zone.

Material. 11 RV, 11 LV in samples He19-26–27, Mue19-1 and Ro19-4–5.

Diagnosis. Medium size. Subtriangular outline, with broad, rounded irregular ribs; the underside of the alate extension being smooth except for its posterior part.

Description. Carapace medium-sized, subtriangular. Right and left valve (identical in outline and ornamentation): Anterior margin symmetrically rounded. The dorsal margin is straight, medianly slightly concave. The ventral margin converges, partly straight or in a slight curve, to the acuminate posterior end. The ventral margin is obscured by a broad triangular wing. The anterior and posterior marginal zones are covered with roundish pits. The anterior marginal zone is offset with a small, asymmetrically rounded step against the lateral surface. A broadly rounded, mediodorsally-anteroventrally running rib forms a second step running diagonally over the anterior half of the valve. From this rib another broad rib branches off slightly below the middle, running subvertically towards the edge of the wing. The adjoining surface, which ends in the symmetrically rounded tip of the broad wing, is characterised by three wide, flat, bulbous elevations separated by wide furrows and pits. The furrows and pits as well as the ribs and depressions are covered with roundish secondary pits. Posteriorly, this area is bounded by a slightly curved, subvertical, rounded rib that tapers from dorsal to ventral. The posterior marginal zone is offset with a further, almost straight, subvertical step. Marginal zone wide anteriorly (Fig. 10: 13). The underside of the wing, which in ventral view forms a rectangular triangle, is smooth, except for its posterior third. A triangular area is covered by small grooves which are most prominent along the posterior margin of the wing. Hinge and other internal details are not observed.

Comparisons. *Cytheropterina crassicostata* resembles in outline *Cytheropterina bicuneata* (Braun) as reported by Franz et al. (2018) from the Aalenian and Lower Bajocian of SW Germany, and *Cytheropterina cribra* Fischer, 1962 (p. 339, Fig. 25: 8–11) from the Toarcian to Bajocian. The main differences are the coarse, softly rounded ornamentation, the smooth underside of the wing and the bigger size.

Occurrence. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

Table 1. Dimensions of *Cytheropterina crassicostata* sp. nov.

	Length	Height	Width
Holotype	0.516 mm	0.338 mm	
Paratype	0.556 mm	0.364 mm	
Paratype	0.557 mm		0.222 mm
Paratype	0.555 mm	0.363 mm	

***Cytheropterina cribra* (Fischer, 1962)**

Material. 1 C, 4 LV in samples He19-7–12.

Distribution. Lower Toarcian to Upper Bajocian; France, Germany, Ireland, Spain, N Switzerland.

***Procytherura celtica* Ainsworth, 1986**

Fig. 6: 3

Material. 2 RV in samples He19-12 and from the Geisingen clay pit.

Distribution. Upper Toarcian to Lower Bajocian; Germany, Ireland.

***Procytherura euglyphea* Ainsworth, 1986**

Fig. 6: 4, 5

Material. 2 RV, 1 ? LV in samples He19-1 and He19-12.

Distribution. Upper Toarcian to Lower Bajocian; Germany, Ireland.

***Procytherura multicostata* Ainsworth, 1986**

Fig. 6: 6, 7

Material. 3 C, 4 RV, 6 LV in samples He19-5–26.

Distribution. Upper Toarcian to Lower Bajocian; SW Germany, Ireland.

***Procytherura* aff. *serangodes* Ballent & Whatley, 2000**

Fig. 8: 4

Material. 1 C in sample He19-15.

Distribution. Lower Aalenian to Lower Bajocian; SW Germany; mid-Callovian; Argentina.

***Procytherura* sp. 2 Franz et al., 2018**

Fig. 6: 8

Material. 1 RV in sample He19-8, 1 C in the Geisingen clay pit.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Description. Very small, subovoidal outline in lateral view. Lateral surface with five broadly rounded ribs, subhorizontal in the midventral to posteromedian area; in the anterior half of the valve bent anteroventrally. Roughly reticulated in the region of these ribs by subvertical transverse ribs.

***Procytherura* sp. 5**

Fig. 10: 14

Material. 1C, 1 RV in samples He19-24–25.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

Description. Very small, subtriangular outline in lateral view. Lateral surface weakly ornamented by two fine longitudinal ribs delimiting a spindle-shaped field, posteriorly rounded and anteriorly pointed. Parallel to the anterior margin there is a third, also very fine rib. Another middorsal-midanterior rib halves the acute-angled triangular field between the frontal rib and the upper longitudinal rib.

Genus *Tethysia* Donze, 1975

***? Tethysia* sp.**

Material. 1 LV in sample He19-8.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Genus *Eucytherura* Müller, 1894

***Eucytherura eberti* sp. nov.**

http://zoobank.org/12B4883C-8F55-481A-A41E-B2665DB8069F

Fig. 6: 9–11

2018 *Eucytherura* aff. *scottia* (Whatley, 1970). – Franz et al., p. 72, plate 3: 17.

2019 *Eucytherura* aff. *scottia* (Whatley). – Dietze et al., fig. 11.

Etymology. In honour of the German palaeontologist Martin Ebert, who initiated the investigation of the Geisingen clay pit with his extensive preliminary work.

Holotype. carapace, figured on Fig. 6: 9, SMNS 70521/9.

Paratypes. two carapaces, figured on Fig. 6: 10, 11, SMNS 70521/10–11.

Type locality. Heiligenbach valley near Hechingen-Beuren (SW Germany).

Type horizon. Achdorf Formation, claystone below the Inopernabank, bed no. 39 in Fig. 4; Bradfordensis Zone.

Material. 10 C, 28 RV, 34 LV from the Heiligenbach, Thanheim and Roschbach sections and the Geisingen clay pit.

Diagnosis. A new species of *Eucytherura* with broad, smooth posterodorsal, frontal and ventral ribs. Intercostate areas weakly reticulate.

Description. Very small, subrectangular. Left valve slightly larger than right with anterodorsal and posterodorsal overlap. Anterior margin weakly rounded with extremity below mid-height; posterior margin pointed in right and bluntly rounded in left valve, apex above mid-height. Posterior cardinal angle pronounced in both valves; anterior cardinal angle more rounded in right than in left valve. Dorsal margin slightly convex to straight; ventral margin medianly slightly convex. Greatest height at anterior cardinal angle; greatest width antero-ventrally; greatest length above mid-height. Ornament consists of a series of broad longitudinal ribs and swellings, and with weakly reticulate intervening areas. A broad, posteriorly weakly alate rib extends from a postero-ventral position across the ventro-lateral surface of the valve, terminating antero-ventrally. A similar broad rib extends mid-posteriorly to mid-dorsally. The eye tubercule is well developed and is connected to a narrower frontal rib, which parallels the anterodorsal margin. A less prominent second rib or elongate swelling parallels the latter mid-anteriorly. Intercostate areas are weakly reticulate, with a characteristic row of small elongate pits above the muscle-scar field. 3–4 small marginal denticles occur anteriorly. Normal pores few and wide-spaced. Internal details not observed.

Table 2. Dimensions of *Eucytherura eberti* sp. nov.

	Length	Height	Width
Holotype	0.306 mm	0.164 mm	
Paratype	0.292 mm	0.155 mm	
Paratype	0.318 mm		0.135 mm

Comparisons. *Euytherura eberti* closely resembles *Eucytherura scottia* Whatley, 1970 from the Callovian and Oxfordian of Scotland. It differs mainly in the length of the dorsal rib, the absence of the anterior tubercles, being replaced by two parallel ribs and the pits above the musclescar-field.

Distribution. Lower Aalenian to Upper Aalenian, Opalinum to Bradfordensis zones (Gigantea Subzone); SW Germany.

***Eucytherura foveolata* sp. nov.**

Fig. 6: 12–14

http://zoobank.org/7D6E8E7E-FA22-4597-837D-3E25EBF70FD7

2018 *Eucytherura* sp. 4. – Franz et al., p. 72, plate 3: 22

Etymology. From *fovea* (lat.) = pit; referring to the characteristic pits on the lateral surface.

Holotype. One carapace, figured in Fig. 6: 12, SMNS 70521/12.

Paratypes. Two carapaces, figured in Fig. 6: 13, 14, SMNS 70521/13–14.

Type locality. Drillcore KB 1/93 Geisingen (SW Germany).

Type horizon. Opalinuston Formation, Zillhausen Subformation, sample G08Fr, Lower Aalenian.

Material. 19 C, 2 RV, 2 LV from samples He 19-3–12 and from the Geisingen clay pit.

Diagnosis. A small-sized species of the genus *Eucytherura* with the following characteristics: pitted lateral surface with a fine median rib.

Description. Very small, subrectangular. Left valve slightly larger than right with dorsal overlap. Anterior margin rounded with extremity slightly below mid-height; posterior margin pointed in right and bluntly rounded in left valve, apex above mid-height. Posteri-

Table 3. Dimensions of *Eucytherura foveolata* sp. nov.

	Length	Height
Holotype	0.327 mm	0.158 mm
Paratype	0.318 mm	0.162 mm

or cardinal angle rounded; anterior cardinal angle pronounced in both valves. Dorsal margin straight in left, slightly convex in right valve; ventral margin straight or slightly concave. Greatest height at anterior cardinal angle; greatest length above mid-height. Ornament consists of a fine median, horizontal or subdiagonal rib, accompanied on both sides by shallow, about 15 µm wide, round or subangular pits with a rough surface. A third row of such pits running antero-medianly – postero-ventrally; further pits in variable numbers and positions scattered on the lateral surface. Particularly striking are 4 rhomboidally grouped pits (Fig. 6: 12) in the mid-dorsal area. Eye-tubercle only weakly developed. Internal details not observed.

Comparisons. All other previously known species of *Eucytherura* have a well-developed ornamentation with sharp or broad ribs and/or reticulate surfaces.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

***Eucytherura liassica* Bate & Coleman, 1975**
Fig. 6: 15

Material. 2C, 1 RV, 8 LV in samples He19-3–26 and Ro19-2.

Distribution. Toarcian to Upper Aalenian; England, SW Germany.

***Eucytherura michelseni* (Finger, 1983)**
Fig. 6: 16

Material. 2 C, 2 RV, 8 LV in samples He19-3–18 and Ro19-4–5.

Distribution. Upper Pliensbachian to Lower Bajocian; Denmark, England, Sweden, Germany, Argentina, ? Australia.

***Eucytherura* cf. *parairregularis* Brand, 1990**
Fig. 9: 4

Material. 5 C, 2 LV in samples He19-19–25, Ha19-4–5.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

***Eucytherura plumhoffi* Tesakova, 2017**
Fig. 7: 1

Material. 1 C, 3 RV, in samples He19-1–7.

Distribution. Lower Aalenian, Opalinum Zone; SW Germany, N Switzerland.

***Eucytherura transversiplicata* (Bate & Coleman, 1975)**
Fig. 7: 2

Material. 13 C, 9 RV, 7 LV in samples He19-3–28, Ha19-4–5 and Ro19-3–5.

Distribution. Pliensbachian to Bajocian; Argentina, Egypt, England, Germany, Ireland, North Africa, Wales.

***Eucytherura* cf. *yunga* Ballent & Whatley, 2009**
Fig. 9: 5

2018 *Tethysia* sp. 1 Tesakova. – Franz et al., p. 71, plate 3: 12.
2019 ? *Eucytherura* sp. 10. – Dietze et al., plate 7: 21.

Material. 1C, 10 RV, 6 LV in samples He19-19–27, Ro19-1, and from the Thanheim section and the Geisingen clay pit.

Distribution. Upper Aalenian to Lower Bajocian; Argentina, SW Germany.

***Eucytherura* aff. *yunga* Ballent & Whatley, 2009**
Fig. 10: 15

Material. 1 LV in sample He19-27.

Distribution. Upper Aalenian to Lower Bajocian; Argentina, SW Germany.

Remark. This specimen closely resembles plate 1: 7 in Ballent and Whatley (2009).

***Eucytherura* aff. sp. B Boomer & Ballent, 1996**
Fig. 10: 16

Material. 1 LV in sample He19-25.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany, N Switzerland.

Eucytherura sp. 1, *Euc*. sp. 3 and *Euc*. sp. 5 were first named and figured by Franz et al. (2018) but without descriptions; in the following we add their descriptions:

***Eucytherura* sp. 1 Franz et al., 2018**
Fig. 7: 3

Material. 5 RV, 1 LV in samples He19-2–12; 17 C, 1 RV from the Geisingen clay pit; 1 C from the Benken borehole (Switzerland).

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany, N Switzerland.

Description. Very small, subrectangular. Left valve slightly larger than right with dorsal overlap. Anterior margin rounded with extremity slightly below mid-height; posterior margin pointed in right and bluntly rounded in left valve, apex above mid-height. Posterior cardinal angle rounded; anterior cardinal angle pronounced in both valves, slightly more rounded in right valve. Dorsal and ventral margins slightly convex in both valves. Greatest height at

anterior cardinal angle; greatest length above mid-height. Shell ornamentation reduced to a regular reticulation with rounded meshes of uniform size. Hemispherical eye-tubercle well developed. Internal details not observed.

***Eucytherura* sp. 3 Franz et al., 2018**
Fig. 7: 4

Material. 25 C, 4 RV, 4 LV in samples He19-6–18 and from the Geisingen clay pit.

Occurrence. Lower to Upper Aalenian, Opalinum to Bradfordensis zones; SW Germany.

Description. Very small, subrectangular. Left valve slightly larger than right with dorsal overlap. Anterior margin rounded with extremity slightly below mid-height; posterior margin pointed in right and bluntly rounded in left valve, apex above mid-height. Posterior cardinal angle rounded; anterior cardinal angle pronounced in both valves, slightly more rounded in right valve. Dorsal margin straight in right valve and slightly convex in left valve. Greatest height at anterior cardinal angle; greatest length above mid-height. Shell surface regularly reticulate with rounded meshes of uniform size. Hemispherical eye-tubercle well developed. Starting from the eye-tubercle, a fine frontal rib, straight in the left valve, convex in the right valve, runs parallel to the anterodorsal margin. A second rib runs subvertically from the eye-tubercle and then bends mid-anteriorly to the anterior margin. A ventral rib starts posteroventrally and ends midventrally with its anterior end slightly ascending towards the ventromedian side. A short subvertical ridge is located at the posterior cardinal angle. Internal details not observed.

***Eucytherura* sp. 5 Franz et al., 2018**
Fig. 9: 6

Material. 1 C in sample He19-19; 5 RV, 1 LV from the Geisingen clay pit.

Occurrence. Lower to Upper Aalenian, Opalinum to Bradfordensis zones; SW Germany.

Description. Very small, subovoidal. Anterior margin asymmetrically rounded with extremity below mid-height; posterior margin pointed, apex above mid-height. Posterior cardinal angle rounded; anterior cardinal angle pronounced in both valves. Dorsal margin slightly convex, ventral margin convex. Greatest height at anterior cardinal angle; greatest length above mid-height. Shell surface irregularly and coarsely reticulated. The most striking feature is the gently undulating surface with slight anterodorsal, middorsal and anteroventral depressions. The eye-tubercle is fused with a short, indistinct frontal rib. A short bulge-like rib is located at the posterior cardinal angle. Internal details not observed.

***Eucytherura* sp. 10**
Fig. 10: 17, 18

Material. 1 RV, 1 LV in samples He19-24–25.

Occurrence. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

Description. Very small, subovoidal. Anterior margin asymmetrically rounded with extremity below mid-height; posterior margin rounded, apex above mid-height. Anterior and posterior cardinal angles rounded; both slightly more pronounced in right valve. Dorsal margin slightly concave in ther right valve, slightly convex in the left one. Greatest height at anterior cardinal angle; greatest length above mid-height. Shell surface reticulate, with wide rectangular to polygonal meshes. Eye-tubercle absent.

***Right valve*:** A long, well-defined frontal rib runs from the anterior cardinal angle to the anteroventral margin. The lateral surface is characterized by three fine ribs, the first of which starts in the median region, runs a short distance towards the anterior cardinal angle, then bends perpendicularly towards the anterior margin and after a second 45° bend towards the anteroventral margin. The median rib starts mid-posteriorly above mid-height and ends anteromedianly below mid-height. A long, upwardly curved ventral rib runs from the posteroventral margin to the anteroventral region. One (or two) ribs parallel the ventral rib on the ventral side of the valve.

***Left valve*:** The frontal rib is slightly curved (preservation?) and only weakly developed. The (dorso) median – mid-anterior rib meets the ventral rib at an 60° angle. The median rib starts mid-posteriorly above mid-height and ends anteromedianly at mid-height. Two ribs parallel the ventral rib on the ventral side of the valve. Further, especially internal details were not observed, partly for preservation reasons.

***Eucytherura* sp. 11**
Fig. 9: 7

Material. 1 RV, 2 LV in samples He19-18 and He19-24–25.

Occurrence. Upper Aalenian, Bradfordensis Zone; SW Germany.

Description. Very small, subrectangular to subtriangular. Anterior margin rounded with extremity slightly below mid-height; posterior margin pointed, apex above mid-height. Posterior cardinal angle rounded; anterior cardinal angle pronounced in both valves, slightly more rounded in left valve. Dorsal straight to slightly concave, ventral margin straight to slightly convex. Greatest height at anterior cardinal angle; greatest length above mid-height. Shell surface strongly reticulate, including the anterior and posterior margins. The coarse-meshed, very prominent reticulation is divided by three ribs, which in the median area delimit an approximately circular area. A middorsal – anteromedian rib, a second middorsal – posteromedian rib, and a ventral rib that is strongly curved up in the anterior midventral section towards the anteromedian region. Another rib starting at the anterior cardinal angle parallels the anterior edge of that circular area approximately halfway to the anterior margin. Eye-tubercle absent; internal details not observed.

Genus *Balowella* Wienholz, 1967

***Balowella catena* (Franz et al., 2018)**
Fig. 9: 8, Fig. 11: 1

2018 *Procytheropteron catena* sp. nov. – Franz et al., p. 73, plate 4: 4–6.

Material. 3 C, 22 RV, 26 LV in sample He19-18–28.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

? *Balowella* sp.

Material. 1 RV in sample He19-18.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone); SW Germany.

Remark. The single (juvenile ?) specimen is only tentatively placed in this genus due to its small size and poor preservation.

Genus *Cytheropteron* Sars, 1866

? *Cytheropteron* sp. 1
Fig. 11: 2, 3

Material. 3 RV, 4 LV in samples He19-25 – Ha19-3.

Occurrence. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

Description. Very small, triangular. Anterior margin rounded with extremity slightly below mid-height; posterior margin pointed, apex below mid-height. Cardinal angles rounded in left valve, cardinal angles pronounced in right valve.

***Right valve*:** Dorsal margin straight, medianly slightly convex, ventral margin slightly convex, medianly partly obscured by a median overhang of the lateral curvature. The punctate shell surface is longitudinally and vertically strongly curved with a ventral overhang. The curvature is concavely recessed in the uppermost area along a sharp oval bend, ending in a weak anteromedian lobe. A narrow anterodorsal depression parallel to the anterior margin is limited by a short, slightly curved frontal rib, ending above mid-height.

***Left valve*:** Dorsal margin strongly convex, otherwise identical to the right valve.

Hinge due to poor preservation not clearly visible, possibly merodont; other internal details not observed.

Genus *Procytheropteron* Ljubimova, 1955

***Procytheropteron* aff. *gramanni* Brand, 1990**
Fig. 11: 4, 5

Material. 3 RV, 2 LV in samples He19-22–24 and Ro19-1.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

Remarks. Our specimens resemble *Procytheropteron gramanni* Brand, 1990 (plate 9: 10) from the Upper Bathonian of NW Germany; they differ in age and in the coarser ornamentation and reticulation.

***Procytheropteron* sp. 1 Franz et al., 2018**
Fig. 11: 6

Material. 2 LV in sample He19–24 and from the Geisingen clay pit.

Distribution. Upper Aalenian, Bradfordensis Zone; SW Germany.

Description. Very small, ovoidal. Anterior margin almost symmetrically rounded; posterior margin pointed, apex at mid-height. Cardinal angles rounded in the left valve.

Dorsal margin straight to slightly convex, ventral margin convex, medianly partly obscured by a median overhang of the lateral curvature. The complete lateral surface is decorated with vertical, broadly rounded ribs. The ribs in the median part of the valve are irregular, interrupted at about mid-height, and offset laterally against each other. The vertical ribs are framed by a curved ventral rib, which is also rounded, and a similar dorsal rib, which almost touch each-other mid-posteriorly.

Internal details not observed.

Genus *Metacytheropteron* Oertli, 1957

***Metacytheropteron opalinum* Plumhoff, 1963**

Material. 3 C, 5 RV, 3 LV in samples He19-5–12.

Distribution. Upper Toarcian to Upper Aalenian; Germany.

Genus *Aphelocythere* Triebel & Klingler, 1959

***Aphelocythere dilgeri* Franz et al., 2018**
Fig. 7: 5

Material. 2 RV, 3 LV in samples He19-1–22.

Distribution. Lower Aalenian to Lower Bajocian; SW Germany.

***Aphelocythere pygmaea* Plumhoff, 1963**
Fig. 7: 6

Material. 7 C, 10 RV, 9 LV in samples He19-1–13.

Distribution. Lower to Upper Aalenian, Opalinum to Murchisonae zones; Germany, Switzerland.

***Aphelocythere* ? *pygmaea* Plumhoff, 1963**

Material. 1 C in sample He19-15.

Occurrence. Upper Aalenian, Murchisonae Zone; SW Germany.

***Aphelocythere recta* Ohmert, 2004**
Fig. 11: 7

Material. 1 C in sample Ro19-4.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

***Aphelocythere* aff. *recta* Ohmert, 2004**
Fig. 11: 8

Material. 1 RV in sample Ro19-4.

Occurrence. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

Remark. Ohmert (2004) mentioned this species as a probable ancestor of *Aphelocythere recta* from the top of the Concavabank.

? *Aphelocythere* sp. 1
Fig. 7: 7, Fig. 11: 9

Material. 2 C, 5 RV, 1 LV in samples G08Fr, G12 Fr, G13Fr, He19-6, He19-26–28.

Occurrence. Lower to Upper Aalenian, Opalinum to Concavum zones; SW Germany.

Description. Very small, subrectangular. Anterior margin rounded with extremity slightly below mid-height; posterior margin rounded, apex above mid-height. Cardinal angles rounded in both valves, slightly more pronounced in left valve. Dorsal margin straight, ventral margin slightly convex. The shell surface is smooth, with a number of pits, which are difficult to recognize due to bad preservation. Internal details not observed.

Family Cytherideidae Sars, 1925
Genus *Vernoniella* Oertli, 1957

***Vernoniella* ? *caytonensis* Bate, 1965**
Fig. 12: 10

Material. 1 C in sample Ro19-5.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

Remark. *Vernoniella* ? *caytonensis* was described from the Blagdeni Subzone in England; our specimen comes from the Concavum Zone and therefore has been tentatively placed in this species.

Family Schulerideidae Mandelstam, 1959
Genus *Asciocythere* Swain, 1952

"*Asciocythere*" sp.
Fig. 11: 10

Material. 4 C, 3 LV in samples He19-25–26 and Ha19-4.

Occurrence. Upper Aalenian to Lower Bajocian; SW Germany.

Remark. We have set *Asciocythere* in quotation marks, because the generic assignment of this species is doubtful.

Genus *Eocytheridea* Bate, 1963

***Eocytheridea elongata* Bate, 1963**
Fig. 11: 11

Material. 2 C, 7 RV, 5 LV in samples He19-21, Mue19-1 and Ro19-1–5.

Distribution. Upper Aalenian; England, SW Germany.

***Eocytheridea lacunosa* Bate, 1963**
Fig. 11: 12

Material. 52 C, 183 RV, 209 LV in samples He19-23–29 and Ro19-1–5.

Distribution. Upper Aalenian to Lower Bajocian; England, SW Germany.

Genus *Praeschuleridea* Bate, 1963

***Praeschuleridea ornata* (Bate, 1963)**
Fig. 9: 9

Material. 57 C, 106 RV, 136 LV in samples He19-18–29, Ha19-1–5 and Ro19-1–5.

Distribution. Lower Aalenian to Lower Bajocian; England, Germany.

***Praeschuleridea punctulata* (Plumhoff, 1963)**
Fig. 8: 5

Material. 36 C, 49 RV, 47 LV in samples He19-13–29, Ha19-1–5 and Ro19-1–5.

Distribution. Upper Toarcian to Lower Bajocian; Germany, Spain, Switzerland.

***Praeschuleridea* cf. *subtrigona* (Jones & Sherborn, 1888)**
Fig. 11: 13, 14

Material. 4 C, 5 RV, 13 LV in samples Ro19-1–5.

Occurrence. Upper Aalenian, Concavum Zone; SW Germany.

Remark. The specimens from the Roschbach section closely resemble *Praeschuleridea subtrigona* from the Upper Bajocian to Upper Callovian. It is only tentatively placed in this species because of the remarkable difference in age.

***Praeschuleridea ventriosa* (Fischer in Plumhoff, 1963)**
Fig. 7: 10

Material. 118 C, 52 RV, 76 LV in samples He19-2–21, Mue19-1, Ha19-1–3 and Ro19-1–5.

Distribution. Upper Toarcian to Lower Bajocian; Germany, Spain, Switzerland.

***Praeschuleridea* sp. A (Ainsworth, 1986)**
Fig. 8: 6

Material. 1 C, 2 LV in samples He19-17–25.

Distribution. Toarcian to Aalenian; Germany, Ireland.

***Praeschuleridea* sp. 1**
Fig. 11: 15–17

Material. 4 C, 2 RV, 4 LV in samples He19-27 and Ha19-5.

Occurrence. Upper Aalenian, Concavum Zone to Early Bajocian; SW Germany.

Description. Medium-sized, subovate. Left valve larger than right valve, overlapping along complete outline. Anterior margin slightly asymmetrically rounded, extremity just below mid-height. Posterior margin triangular, upper margin straight, lower margin convex, the two joining at an angle below mid-height. Dorsal margin convex, ventral margin convex with slight concavity in front of mid-length in the right valve. Anterior cardinal angle rounded, posterior cardinal angle sloping straight to the posterior margin. Valve ventrolaterally swollen. Small-sized pits irregularly distributed over the anterior valve surface, significantly denser in the posterior third. A narrow channel with densely arranged pits parallels the anterior margin. Anteroventrally and posteroventrally there is a row of finest denticles.

The partly broken (? paleohemimerodont) hinge shows terminal serrated teeth and remains of teeth in the median hinge area of the right valve.

Family Protocytheridae Ljubimova, 1955
Genus *Southcavea* Bate, 1964

? *Southcavea* sp.
Fig. 9: 10, 11

Material. 3 C, 7 RV, 4 LV in samples He19-18–25 and Ro19-1–2.

Occurrence. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone); SW Germany.

Genus *Pleurocythere* Triebel, 1951

***Pleurocythere kirtonensis* Bate, 1963**
Fig. 9: 12

Material. 1 RV, 1 LV in sample He19-18.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Lower Bajocian; England, southwest Germany.

***Pleurocythere ohmerti* Franz et al., 2018**
Fig. 11: 18

Material. 20 C, 29 RV, 27 LV in samples He19-24–29, Ha19-4–5 and Ro19-1–3.

Distribution. Upper Aalenian, Concavum Zone to Early Bajocian; SW Germany.

***Pleurocythere* sp. 1**
Fig. 8: 7

Material. 1 LV in sample He19-16.

Occurrence. Upper Aalenian, Murchisonae Zone; SW Germany.

Remark. This specimen resembles *Pleurocythere kirtonensis* in the arrangement of the ribs. In contrast to *P. kirtonensis* the ribs are broad and rounded. Possibly the median rib touches the ventral rib anteroventrally. More material is required for clarification.

? *Pleurocythere* sp.
Fig. 7: 8

Material. 1 RV, 1 LV in sample He19-1.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Remark. The two specimens may represent an ancestor of the genus *Pleurocythere*.

Family Progonocytheridae Sylvester-Bradley, 1948
Genus *Acrocythere* Neale, 1960

***Acrocythere pumila* Plumhoff, 1963**
Fig. 7: 9

Material. 4 C, 2 RV, 4 LV in samples He19-1–12.

Distribution. Lower Aalenian, Opalinum Zone; Germany, Switzerland.

***Acrocythere* aff. *pumila* Plumhoff, 1963**
Fig. 9: 13

Material. 3 LV in samples He19-18 and He19-27.

Occurrence. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; Germany.

Remark. In addition to the differentiation from *Acrocythere pumila* in Plumhoff, 1963, it should be noted that the reticulation between the median rib and the ventral rib in the posterior section is alternating here, whereas it is clearly linear in *A. pumila*.

Genus *Homocytheridea* Bate, 19 63

***Homocytheridea* sp. 1**
Fig. 8: 8

Material. 1 LV in sample He19-15.
Occurrence. Upper Aalenian, Murchisonae Zone; SW Germany.

***Homocytheridea* sp. 2**
Fig. 8: 9

Material. 22 C, 15 RV, 18 LV in samples He19-15–28, Mue19-1 and Ro19-4.
Occurrence. Upper Aalenian, Murchisonae to Concavum zones; SW Germany.

Genus *Camptocythere* Triebel, 1950

***Camptocythere pusilla* Plumhoff, 1963**
Fig. 12: 1

Material. 30 C, 43 RV, 36 LV in samples He19-24–28 and Ro 1–3.
Distribution. Upper Aalenian; Germany.

Genus *Aaleniella* Plumhoff, 1963

***Aaleniella* sp.**

Material. 1 C in sample He19-18.
Occurrence. Aalenian, Bradfordensis Zone; SW Germany.

Genus *Progonocythere* Sylvester-Bradley, 1948

***Progonocythere scutula* Franz et al., 2018**
Fig. 8: 10

Material. 1 C, 6 RV, 6 LV in sample He19-17.
Distribution. Upper Aalenian, Bradfordensis Zone; SW Germany.

***Progonocythere triangulata* Braun in Ohmert, 2004**
Fig. 12: 11

Material. 11 C, 34 RV, 34 LV in samples Ha19-4–5.
Distribution. Lower Bajocian; SW Germany. *Progonocythere triangulata* is the index species of the Triangulata ostracod Subzone (Ohmert 2004).

Genus *Kinkelinella* Martin, 1960

***Kinkelinella* (*Kinkelinella*) *adunca* Malz, 1966**
Fig. 12: 2

Material. 1 C, 4 RV, 16 LV in samples He19-23–29.
Distribution. Upper Aalenian to Lower Bajocian, Concavum to Discites zones; SW Germany.

***Kinkelinella* (*Kinkelinella*) *fischeri* Malz, 1966**
Fig. 8: 11

Material. 6 C, 18 RV, 22 LV in samples He19-14–18, Ha19-6, Lin 18-4, Mue19-1 and Ro19-1–5.
Distribution. Upper Toarcian to Upper Aalenian; France, Germany, Russia, Spain, Switzerland.

***Kinkelinella* (*Kinkelinella*) *levata* Ohmert, 2004**
Fig. 12: 3

Material. 4 C, 76 RV, 109 LV in samples He19-21–28 and Ro19-1–5.
Occurrence. Upper Aalenian to Lower Bajocian, Concavum to Discites zones; SW Germany.

***Kinkelinella* (*Kinkelinella*) *sermoisensis* (Apostolescu, 1959)**
Fig. 7: 11

Material. 2 C, 1 RV in sample He19-9.
Distribution. Lower Toarcian to Lower Bajocian; England, France, Germany, Ireland, Portugal, Russia, Spain, N Switzerland.

***Kinkelinella* (*Kinkelinella*) cf. *sermoisensis* (Apostolescu, 1959)**
Fig. 12: 4

Material. 9 C, 14 RV, 10 LV in samples Mue19-1 and Ro19-1–5.
Distribution. Upper Aalenian to Lower Bajocian; SW Germany.

***Kinkelinella* (*Ektyphocythere*) *triangula* (Brand, 1961)**
Fig. 12: 12

Material. 5 RV in samples Ha19-4–5.
Distribution. Early Bajocian; England, France, Germany, N Switzerland.

***Kinkelinella* sp. B Ohmert, 2004**
Fig. 12: 5

Material. 9 RV, 8 LV in samples He19-25–26, Mue19-1, Ha19-5 and Ro19-3–5.
Occurrence. Upper Aalenian to Early Bajocian, Concavum to Discites zones; SW Germany.

***Kinkelinella* sp. 2**
Fig. 8: 12

Material. 5 RV, 5 LV in samples He19-14–17 and Ro19-2.

Occurrence. Lower to Upper Aalenian, Opalinum Zone ("Comptum" Subzone) to Bradfordensis Zone; SW Germany.

Description. Anterior margin broadly rounded, accompanied by a flat marginal bulge. The dorsal margin slightly convex, with the greatest height in front of midlength of the valve. Posterior end flat, with narrowly rounded posterior margin. Ventral margin obscured by the the overhanging ventro-lateral curvature. The central part of the valve is ventrally strongly inflated, and clearly set off against the anterior and posterior ends. Remnants of two ventral ribs are visible parallel to the ventral margin. The remaining part of the valve shows only weak hints of a very fine, irregular reticulation.

***Ektyphocythere* aff. *anterocosta* Boomer, 1988**
Fig. 8: 13

Material. 1 RV in sample He19-14.

Occurrence. Toarcian to Lower Aalenian; England, SW Germany.

Family Neurocytheridae Gründel, 1975
Genus *Fuhrbergiella* Brand & Malz, 1962

***Fuhrbergiella* (*Praefuhrbergiella*) *horrida bicostata* Brand & Malz, 1962**
Fig. 12: 13

Material. 2 LV in samples Ha19-4–5.

Distribution. Lower Bajocian, Discites Zone; Germany.

Family Cytheridae Baird, 1850
Genus *Minyocythere* Lord et al., 2020

***Minyocythere tuberculata* (Luppold, 2012)**
Fig. 12: 6

Material. 5 C, 3 RV, 5 LV in samples Mue19-1 and Ro 3–5.

Distribution. Upper Aalenian to Lower Bajocian, Concavum to Humphriesianum zones; Germany.

Genus *Plumhofficythere* Luppold, 2003

***Plumhofficythere clavatoides* Luppold, 2003**
Fig. 12: 7

Material. 6 C, 30 RV, 24 LV in samples He19-23–28, Mue19-1 and Ro19-1–3.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to ? Lower Bajocian; England, France, Germany, Luxembourg.

Ostracoda incertae sedis

aff. *Ostracode* A Ballent, 1991
Fig. 7: 12

Material. 2 RV in samples He19-2 and He19-12.

Distribution. Aalenian to Bajocian; Argentina, SW Germany.

Gen. et sp. 9 Tesakova, 2017
Fig. 8: 14

Material. 1 RV in sample He19-17.

Distribution. Lower to Upper Aalenian, Opalinum to Bradfordensis zones; SW Germany, N Switzerland.

Gen. et sp. indet. 3 Franz et al., 2018
Fig. 7: 13

Material. 2 RV in samples He19-2 and He19-5.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Gen. et sp. indet. 5 Franz et al., 2018
Fig. 7: 14

Material. 4 RV, 1 LV in samples He19-3–27.

Distribution. Lower to Upper Aalenian, Opalinum to Concavum zones; SW Germany, N Switzerland.

Gen. et sp. indet. 7
Fig. 12: 8, 9

2019 Gen. et sp. indet. I. – Dietze et al., pl. 11, fig. 13.

Material. 4 RV, 1 LV in sample He19-22; one further RV from Thanheim.

Distribution. Upper Aalenian, Bradfordensis Zone (Gigantea Subzone) to Concavum Zone; SW Germany.

Gen. et sp. indet. 8
Fig. 7: 15

Material. 2 RV in samples He19-5–12.

Distribution. Lower Aalenian, Opalinum Zone; SW Germany.

Gen. et sp. indet. 9
Fig. 8: 15

Material. 1 RV, 1 LV in samples He19-17–18.

Occurrence. Upper Aalenian, Bradfordensis Zone; SW Germany.

Gen. et sp. indet. 10
Fig. 7: 16

Material. 1 RV, 2 LV in samples He19-12–15.

Occurrence. Lower to Upper Aalenian, Opalinum to Murchisonae zones; SW Germany.

Gen. et sp. indet. 11
Fig. 7: 17

Material. 1 LV in sample He19-8.

Occurrence. Lower Aalenian, Opalinum Zone; SW Germany.

Gen. et sp. indet. 12
Fig. 8: 16

Material. 1 LV in sample He19-16.

Occurrence. Upper Aalenian, Murchisonae Zone; SW Germany.

4. Description of the ammonite fauna

4.1 General remarks

The ammonite fauna of the Upper Aalenian of SW Germany is dominated by members of the subfamily Graphoceratinae Buckman, 1905, besides rare Hammatoceratinae Buckman, 1887. The Graphoceratinae originate in the subfamily Leioceratinae Spath, 1936. The family Graphoceratidae itself descends from the Upper Toarcian genus *Pleydellia* Buckman, 1899 (Grammoceratinae Buckman, 1905 within the family Hildoceratidae Hyatt, 1867) (Chandler 1997; Chandler et al. 2012, Howarth 2013).

The evolution within the Graphoceratidae occurred in a chronocline ranging from the lowermost Aalenian (Opalinum Zone, Opalinum Subzone) to the lowermost Bajocian (Discites Zone), with an immense morphological variability within each of the temporally succeeding faunas. In this plexus, individual morphologies sometimes have a long temporal range, whereas the variability of the succeeding faunas as a whole shifts – that is the reason why we can distinguish and define faunal biohorizons. Faunal biohorizons reflect the change of variation in the course of evolution of ammonites, here of Graphoceratidae (e.g., Chandler 1997, 2019; Chandler and Callomon 2009; Dietze et al. 2014, 2017). There is a gradual change from one genus to the next, so that we can – e.g., in the case of the ammonites under study here – find *Graphoceras* morphologies together with *Brasilia* morphologies coeval in a single bed, accompanied by specimens showing a mixture of characters of both morphogenera. For a slightly older (Bradfordensis Zone, Gigantea Subzone) overlap of the morphogenera *Brasilia* and *Graphoceras* (with a variability of the whole fauna closer to *Brasilia*) see Dietze et al. 2014 (ammonites therein were there described as chronospecies). An intersection of *Ludwiga* and *Brasilia* can be seen in the top of the Staufensisbank of the nearby Plettenberg/Hausen am Tann (Western Swabian Alb) sections (Dietze et al. 2017b; fauna described morphospecifically). Chandler (1997) demonstrated convincingly the evolution of the Graphoceratidae and the intersection of the nominal morphogenera in the Aalenian of Horn Park Quarry near Beaminster (Dorset, SW England).

In the literature, there are many attempts to classify the plexus of the Graphoceratidae into categories (families, subfamilies, morphogenera, morphospecies). The results of these attempts and the erection of new genera and species depended often by chance, depending on where the author had material from, often without any accurate stratigraphy. The great number of genera and species described in the literature (e.g. Buckman 1887–1907; Horn 1909; Hoffmann 1913; Althoff 1940; Rieber 1963; Géczy 1967; Contini 1969; Ureta Gil 1983; Henriques 1992; Chandler 1997; Howarth 2013) does by no means reflect the number of monophyletic genera and biological species, which was in fact much smaller (Chandler and Callomon 2009). These authors demonstrated the variation of a palaeobiospecies of the Leioceratinae, *Leioceras comptocostosum*, within one timeslice of the Scissum Zone (Lower Aalenian).

We here determined the ammonites conventionally as morphogenera and morphospecies, since we do not have enough material to describe these ammonites chrono- or (palaeo)biospecifically. However, it is most likely that all graphoceratid ammonites from the *cavatum* horizon described here represent a single palaeobiospecies.

4.2 Short comments on the ammonite fauna

4.2.1 Family Graphoceratidae Buckman, 1905, Subfamilies Leioceratinae Spath, 1936 and Graphoceratinae Buckman, 1905

Leioceras opalinum [m] and *L. opaliniforme* [M] occur about 10 m below the "Wasserfallschichten" in the Heiligenbach creek.

The ammonites from the "Comptum" Subzone are represented by *L.* "*comptum*", *L. crassicostatum*, *L. evolutum*, *L. paucicostatum* and *L. striatum*. They are significantly smaller than the *L.* "*comptum*" faunas from the Wochenberg and Gosheim (western Swabian Alb) which comprise more evolute morphs. These ammonites will be described later in detail.

A single *Brasilia bradfordensis* (Fig. 19: 1a, b) of the Bradfordensis Zone (Bradfordensis Subzone) was recovered from bed 2 of the Heiligenbach section.

The graphoceratid fauna of the Inopernabank (Bradfordensis Zone, Gigantea Subzone) and from the Kon-

glomeratbank to the Rostrote Kalkbank (Concavum Zone, Concavum Subzone) is characterized by the predominance of the morphogenus *Graphoceras*; less common are representatives of the morphogenus *Brasilia* and a substantial number of ammonites with various combinations of both morphogenera (cf. Rieber 1922: 47, 51). In the slightly older *decipiformis* horizon of the Gigantea Subzone (Bradfordensis Zone, see Fig. 26) ammonites of the genus *Brasilia* exhibit larger-sized and smooth shells, with generally broader whorl sections and a wider umbilicus compared to *Graphoceras* (Chandler 1997; Dietze et al. 2014). The ammonites determined as *B. decipiens* (Fig. 13: 1a, b, Fig. 18: 1), *B.* aff. *decipiens* (Fig. 20: 3a, b) and *B*. cf. *decipiformis* (Fig. 16: 2a, b, 5a, b) are very similar to examples of the genus *Brasilia* from the Bradfordensis Zone (Gigantea Subzone, *decipiformis* horizon) of Geisingen (SW Germany) and Dorset (SW England) (Dietze et al. 2014; Buckman 1887–1907; Chandler 1997). Some of the studied ammonites show mixed characters and are obviously intermediates between *Brasilia* and *Graphoceras*: *B.* aff. and *G.* cf. *decipiens* (Fig. 18: 4a, b; Fig. 19: 5a, b) show already the more compressed and involute morphology of *Graphoceras* (Howarth 2013), whereas in all other features it is still very close to *Brasilia*. *Graphoceras* aff. *magnum* (Fig. 20: 1a, b) and *G*. cf. *cavatum* (Fig. 20: 2a, b) show the broad whorls of *Brasilia*, but the ribbing style of primitive *Graphoceras*. The bulk of the ammonites belong to the genus *Graphoceras*. Besides *G*. cf. *concavum* (Fig. 16: 1, 4; Fig. 15: 1a, b) the poorly sculptured *G. cavatum* (Fig. 13: 2a, b, 9a, b; Fig. 18: 2; Fig. 21: 2a, b) and *G*. cf. *cavatum* (Fig. 21: 1a, b) are typical. *Graphoceras* with more sculptured flanks are assigned to *G. decorum* (Fig. 15: 2; Fig. 22: 1a, b), *G*. aff. *apertum* (Fig. 15: 3a, b), *G. pulchum* (Fig. 15: 5a, b; Fig. 22: 3a, b), *G*. cf. *pulchrum* (Fig. 15: 4a, b), *G*. cf. *v-scriptum* (Fig. 18: 3) and *G. formosum* (Fig. 22: 2a, b, 5a, b), respectively. The strongest sculptured *Graphoceras* belong to *G. fallax* (Fig. 18: 5; Fig. 22: 4), *G*. aff. *fallax* (Fig. 13: 3) and *G*. cf. *caduciferum* (Fig. 17: 1a, b).

We here follow Chandler (1997) in the determination of the microconchs and assign these to *Ludwigella*. They show often specifically distinguished morphologies (Buckman 1887–1907; Contini 1969; Chandler 1997) ranging from nearly smooth to strongly ribbed morphotypes: *Ludwigella tenuis* (Fig. 13: 4), *L. attenuata* (Fig. 13: 6), *L. arcitenens* (Fig. 16: 3a, b; Fig. 15: 6a, b; Fig. 17: 3), *L. cornu* (Fig. 19: 2) *L*. aff. *tenuis* (Fig. 13: 5), *L.* sp. (Fig. 17: 5), *L. micra* (Fig. 19: 4), and *L. attracta* (Fig. 13: 7, 8; Fig. 19: 3).

4.2.2 Family Hammatoceratidae Buckman, 1887, Subfamily Hammatoceratinae Buckman, 1887

A single record from the Inopernabank (Fig. 14: 1a–c) resembles in its nucleus *Bredyia diadematoides* (Mayer) as figured by Rieber (1963) from Kappishäusern near Metzingen (Rieber 1963); however, its body chamber recalls the slightly more evolute *Planammatoceras planiforme* Buckman (typical of the Lower and lower Upper Aalenian; Kovács 2009; Sandoval et al. 2020) or *Pl. lepsiusi* (Gemmellaro). Due to the combination of these characters we here determined this ammonite as *Planammatoceras* sp. Most of the few hammatoceratids from the *cavatum* biohorizon of the Concavum Subzone in the studied sections are rather large, with smooth, high-oval outer whorls, very complex suture lines and a narrow umbilicus on the inner whorls (Fig. 14: 2a, b; Fig. 17: 4). The best match in literature we could find is with *Euaptetoceras infernense* sensu Buckman. The original type series of *E. infernense* (Roman) consists of small nuclei, which are very similar to the innermost whorls of the ammonite figured on Fig. 14: 2a, b. A more evolute variant is *E*. cf. *kochi* (Prinz) (Fig. 24: 1a, b). There is a striking homoeomorphy of this specimen with *Brasilia decipiformis* or *Sonninia carinodiscus* (Quenstedt [LT: *Sonninia sowerbyi carinodiscus* Quenstedt, 1886, p. 502, pl. 63, Fig. 3]). A fragmentary *E*. cf. *euaptetum* (Fig. 23: 1a–c) recalls in its habitus already the slightly younger *E. amplectens*; however, the umbilicus of the latter is more involute. These smooth, large-sized hammatoceratids already resemble their presumed descendants, the Early Bajocian *Fissilobiceras ovale* (Quenstedt). A nearly complete compressed specimen from bed 49 of the Heiligenbach section (SMNS 70602) belongs to the genus *Euaptetoceras* as well; however, due to its bad preservation a specific determination is impossible.

5. Bio-/Chronostratigraphy

5.1 Ostracods (M. Franz)

5.1.1 Opalinum Zone

Pygmaea-pumila faunal assemblage (Franz et al. 2018; samples He19-1–12)

The ostracod assemblage consists of 360 individuals (average of 30 individuals per sample) representing 34 species. The assemblage is characterized by *Praeschuleridea ventriosa*, *Aphelocythere pygmaea*, *Metacytheropteron opalinum*, *Acrocythere pumila*, *Eucytherura transversiplicata*, *Euc. michelseni*, *Cardobairdia tesakovae*, *Eucytherura* sp. 1 Franz et al., *Euc*. sp. 3 Franz et al., and *Cytheropterina cribra*.

The zonal index species *Aphelocythere kuhni* (Ohmert 2004) is missing in our samples. Stratigraphically important are *Metacytheropteron opalinum*, *Cardobardia tesakovae*, *Eucytherura plumhoffi*, *Euc. foveolata* sp. nov. and *Procytherura euglyphea* in addition to the nominal species of this community. The very rare *Procytherura celtica* as well as Gen. et sp. indet. 3 and Gen. et sp. indet. 4 (Franz et al. 2018) have also only been found in the Opalinum Zone. A range chart is given in Appendix 1.

In samples He19-7–12, eight species have their last occurrences in this faunal assemblage: *Acrocythere pumila*, *Procytherura euglyphea*, *Eucytherura plumhoffi*, Ostracode A Ballent, *Eucytherura foveolata*, *Cardobairdia tesakovae*, *Metacytheropteron opalinum*, and *Eucytherura* sp. 1 Franz et al.

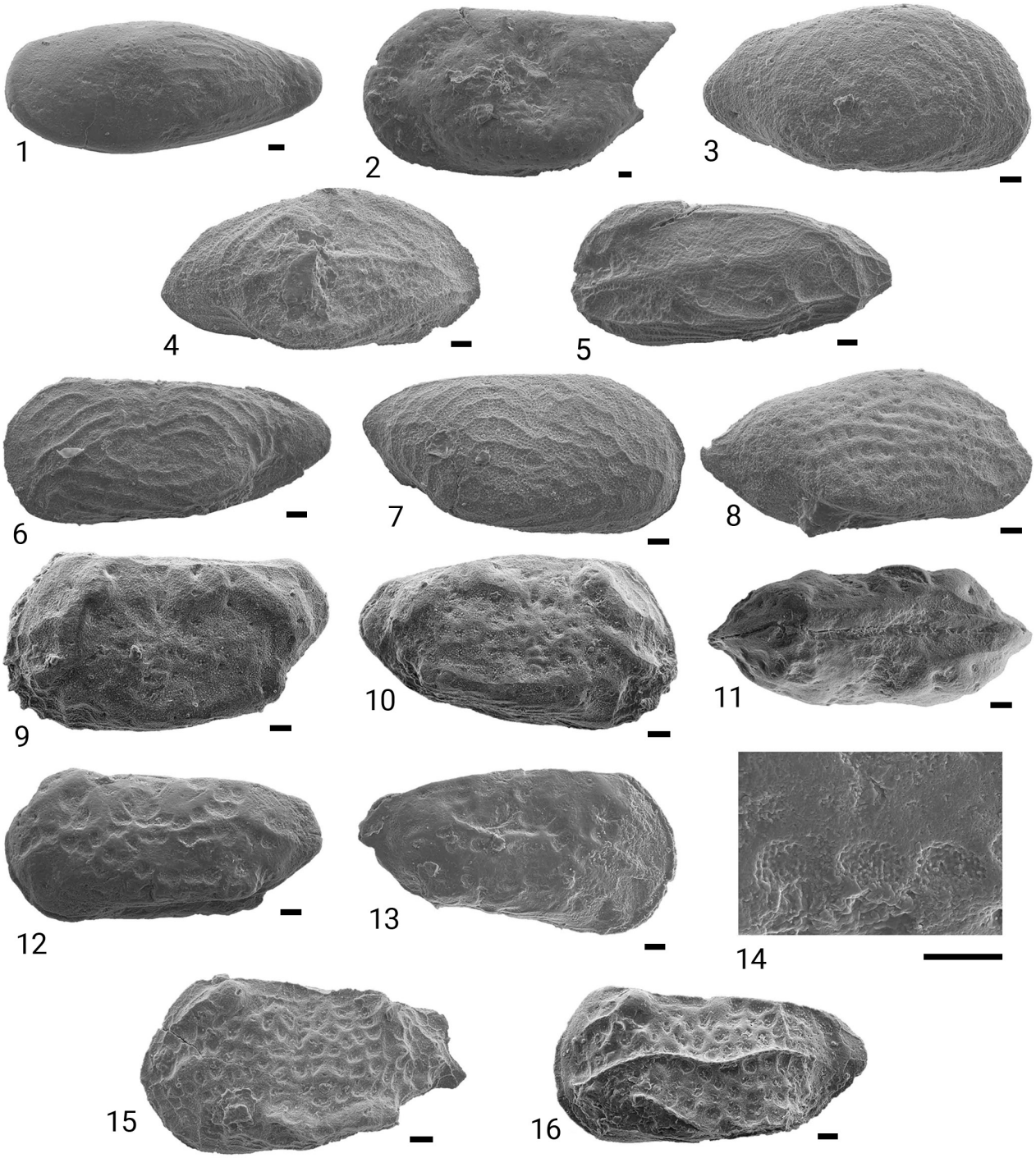

Figure 6. (1) *Cardobairdia tesakovae* Franz et al., SMNS 70521/1, LV, L: 0.426 mm; sample He19-6; **(2)** *Patellacythere* cf. *vulsa*, SMNS 70521/2, LV, L: 0.51 mm; sample He19-9; **(3)** *Procytherura celtica* Ainsworth, SMNS 70521/3, RV, L: 0.301 mm; sample He19-12. **(4, 5)** *Procytherura euglyphea* Ainsworth, **(4)** SMNS 70521/4, RV, L: 0.320 mm; sample He19-1; **(5)** SMNS 70521/5, LV, L: 0.327 mm; sample He19-12. **(6, 7)** *Procytherura multicostata* Ainsworth, **(6)** SMNS 70521/6, LV, L: 0.336 mm; sample He19-9; **(7)** SMNS 70521/7, RV, L: 0.319 mm; sample He19-16. **(8)** *Procytherura* sp. 2 Franz et al., SMNS 70521/8, RV, L: 0.325 mm; He19-8. **(9–11)** *Eucytherura eberti* sp. nov., **(9)** holotype, SMNS 70521/9, C, left view, L: 0.306 mm; sample He19-18; **(10)** Paratype, SMNS 70521/10, C, right view, L: 0.292 mm; sample He19-21; **(11)** paratype, SMNS 70521/11, C, dorsal view, L: 0.318 mm; sample He19-26. **(12–14)** *Eucytherura foveolata* sp. nov., **(12)** holotype, SMNS 70521/12, C, left view, L: 0.327 mm; sample G08Fr; **(13)** paratype, SMNS 70521/13, C, right view, L: 0.318 mm; sample G12Fr; **(14)** paratype, SMNS 70521/14, C, right view (detail), image width: 0.07 mm; sample G12Fr; **(15)** *Eucytherura liassica* Bate and Coleman, SMNS 70521/15, LV, L: 0.304 mm; sample He19-17. **(16)** *Eucytherura michelseni* (Finger), SMNS 70521/16, LV, L: 0.324 mm; sample He19-18. **(1–6, 8, 12–14)** Opalinuston Formation, Lower Aalenian, Opalinum Zone; **(7, 9–11, 15–16)** Achdorf Formation, Upper Aalenian, **(7)** Murchisonae Zone, **(15)** Bradfordensis Zone (Bradfordensis Subzone), **(9, 10, 16)** Bradfordensis Zone (Gigantea Subzone), **(11)** Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

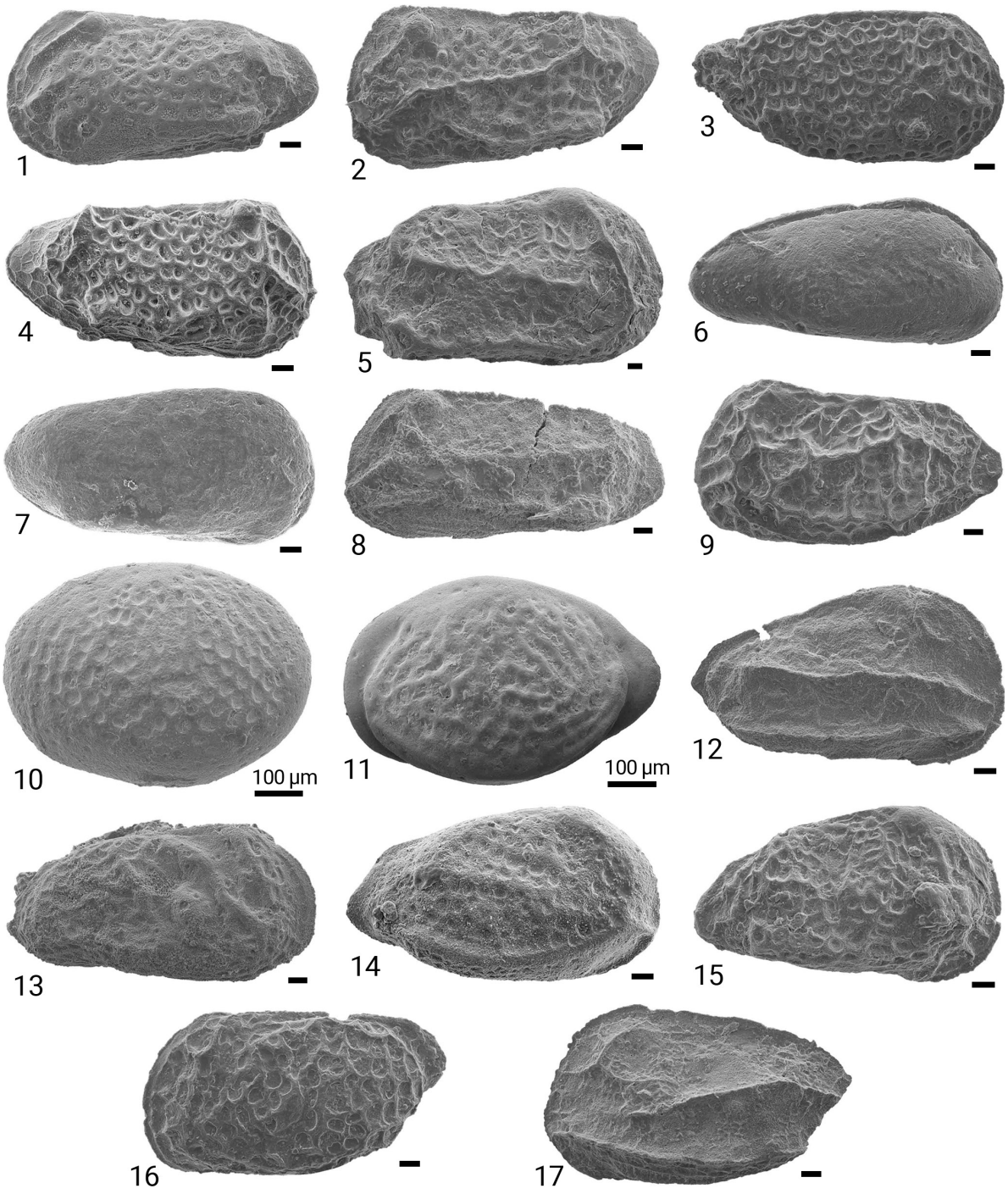

Figure 7. (1) *Eucytherura plumhoffi* Tesakova, SMNS 70521/17, C, left view, L: 0.309 mm; sample He19-7. **(2)** *Eucytherura transversiplicata* (Bate and Coleman), SMNS 70521/18, LV, L: 0.316 mm; sample He19-3. **(3)** *Eucytherura* sp. 1 Franz et al., SMNS 70521/19, RV, L: 0.320 mm; sample He19-12. **(4)** *Eucytherura* sp. 3 Franz, SMNS 70521/20, C, right view, L: 0.300 mm; sample He19-18; **(5)** *Aphelocythere dilgeri* Franz et al., SMNS 70521/21, RV, L: 0.460 mm; sample He19-18. **(6)** *Aphelocythere pygmaea* Plumhoff, SMNS 70521/22, C, right view, L: 0.343 mm; sample He19-12; **(7)** ? *Aphelocythere* sp. 1, SMNS 70423/119, C, right view, L: 0.308 mm; sample G08Fr; **(8)** ? *Pleurocythere* sp., SMNS 70521/23, LV, L: 0.354 mm; sample He19-1. **(9)** *Acrocythere pumila* Plumhoff, SMNS 70521/24, LV, L: 0.343 mm; He19-12. **(10)** *Praeschuleridea ventriosa* (Fischer in Plumhoff), SMNS 70521/25, LV, L: 0.650 mm; sample Mue19-1; **(11)** *Kinkelinella* (*Kink.*) *sermoisensis* (Apostolescu), SMNS 70521/26, LV, L: 0.656 mm; sample He19-9; **(12)** aff. Ostracode A Ballent, SMNS 70521/27, RV, L: 0.290 mm; sample He19-2. **(13)** Gen. et sp. indet. 3, Franz et al., SMNS 70521/28, RV, L: 0.342 mm; sample He19-5; **(14)** Gen. et sp. indet. 5 Franz et al., SMNS 70521/29, RV, L: 0.310 mm; He19-18; **(15)** Gen. et sp. indet. 8 Franz, SMNS 70521/30, RV, L: 0.280 mm; sample He19-12. **(16)** Gen. et sp. indet. 10, SMNS 70521/31, LV, L: 0.300 mm; sample He19-12. **(17)** Gen. et sp. indet. 11, SMNS 70521/32, LV, L: 0.324 mm; sample He19-8. **(1–3, 6–8, 10–12, 15–17)** Opalinuston Formation, Lower Aalenian, Opalinum Zone; **(4–5, 9, 14)** Achdorf Formation, Upper Aalenian, **(4–5, 14)** Bradfordensis Zone (Gigantea Subzone), **(9)** Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

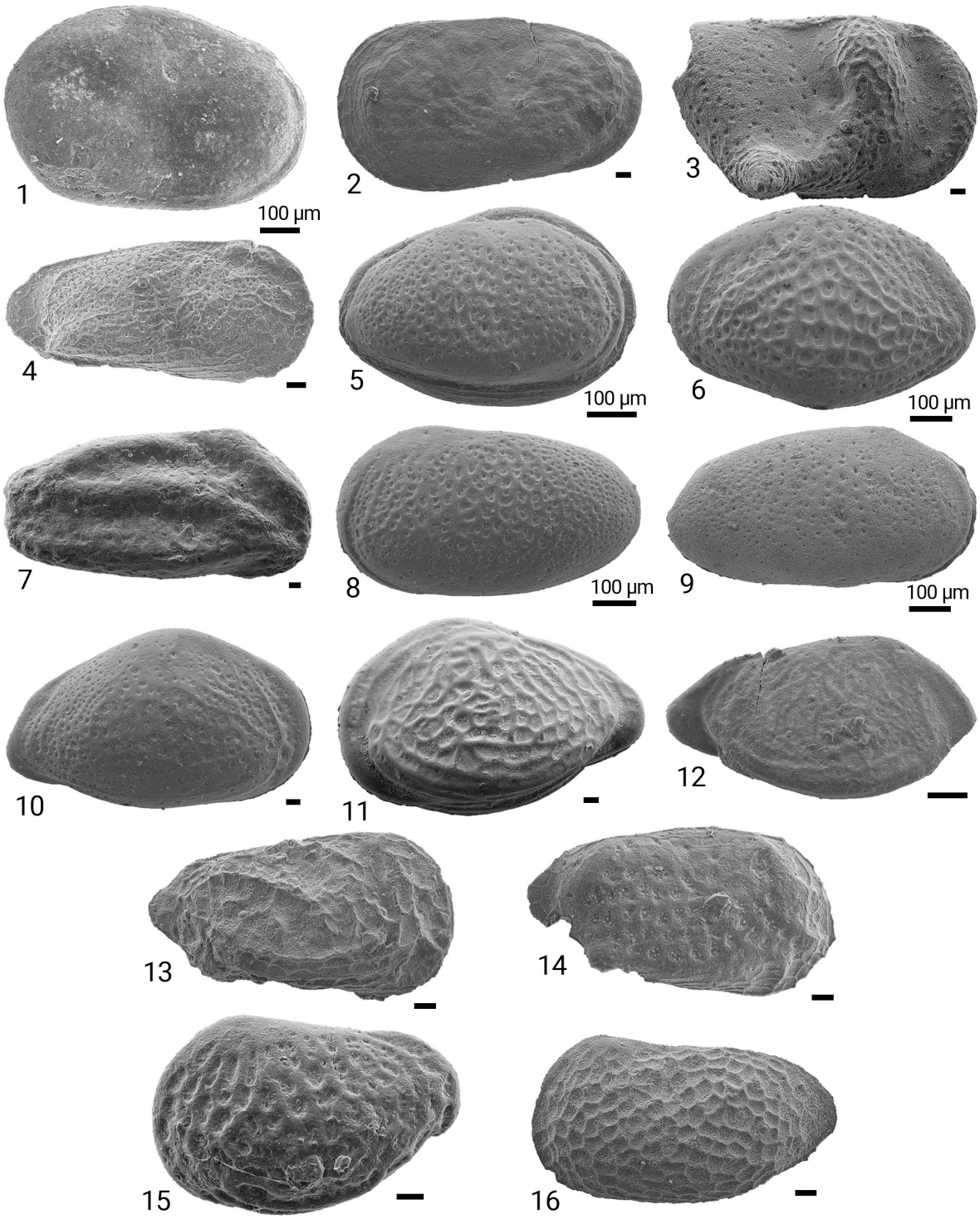

Figure 8. (1) *Cytherella apostolescui* Ainsworth, SMNS 70521/33, RV, L: 0.793 mm; sample He19-27. **(2)** *Cytherelloidea* cf. *catenulata* (Jones and Sherborn), SMNS 70521/34, LV, L: 0.438 mm; sample He19-17. **(3)** *Bythoceratina* (*Praebyth*.) sp. 1, SMNS 70521/35, RV, L: 0.416 mm; sample He19-18. **(4)** *Procytherura* cf. *serangodes* Ballent and Whatley, SMNS 70521/36, C, right view, L: 0.331 mm; sample He19-15; **(5)** *Praeschuleridea punctulata* (Plumhoff), SMNS 70521/37, C, right view, L: 0.606 mm; sample He19-15. **(6)** *Praeschuleridea* sp. A Ainsworth, SMNS 70521/38, LV, L: 0.733 mm; sample He19-17; **(7)** *Pleurocythere* sp. 1, SMNS 70521/39, RV, L: 0.585 mm; sample He19-16. **(8)** *Homocytheridea* sp. 1, SMNS 70521/40, LV, L: 0.707 mm; He19-15. **(9)** *Homocytheridea* sp. 2, SMNS 70521/41, RV, L: 750 mm; sample Mue19-1; **(10)** *Progonocythere scutula* Franz et al., SMNS 70521/42, RV, L: 0.464 mm; sample He19-17; **(11)** *Kinkelinella* (*Kink*.) *fischeri* Malz, SMNS 70521/43, C, left view, L: 0.412 mm; sample Lin18-4. **(12)** *Kinkelinella* sp. 2, SMNS 70521/44, RV, L: 0.444 mm; sample He19-17; **(13)** *Ektyphocythere* aff. *anterocosta* Boomer, SMNS 70521/45, RV, L: 0.281 mm; sample He19-14; **(14)** Gen. et sp. 9 Tesakova, SMNS 70521/46, RV, L: 0.296 mm; He19-17; **(15)** Gen. et sp. indet. 9, SMNS 70521/47, LV, L: 0.235 mm; sample He19-18. **(16)** Gen. et sp. indet. 12, SMNS 70521/48, LV, L: 0.306 mm; sample He19-16. Achdorf Formation **(13)** Opalinum Zone, ("Comptum" Subzone), **(4–5, 7–8, 16)** Murchisonae Zone, **(2, 6, 10, 12, 14)** Bradfordensis Zone (Bradfordensis Subzone), **(3, 15)** Bradfordensis Zone (Gigantea Subzone), **(1, 7)** Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

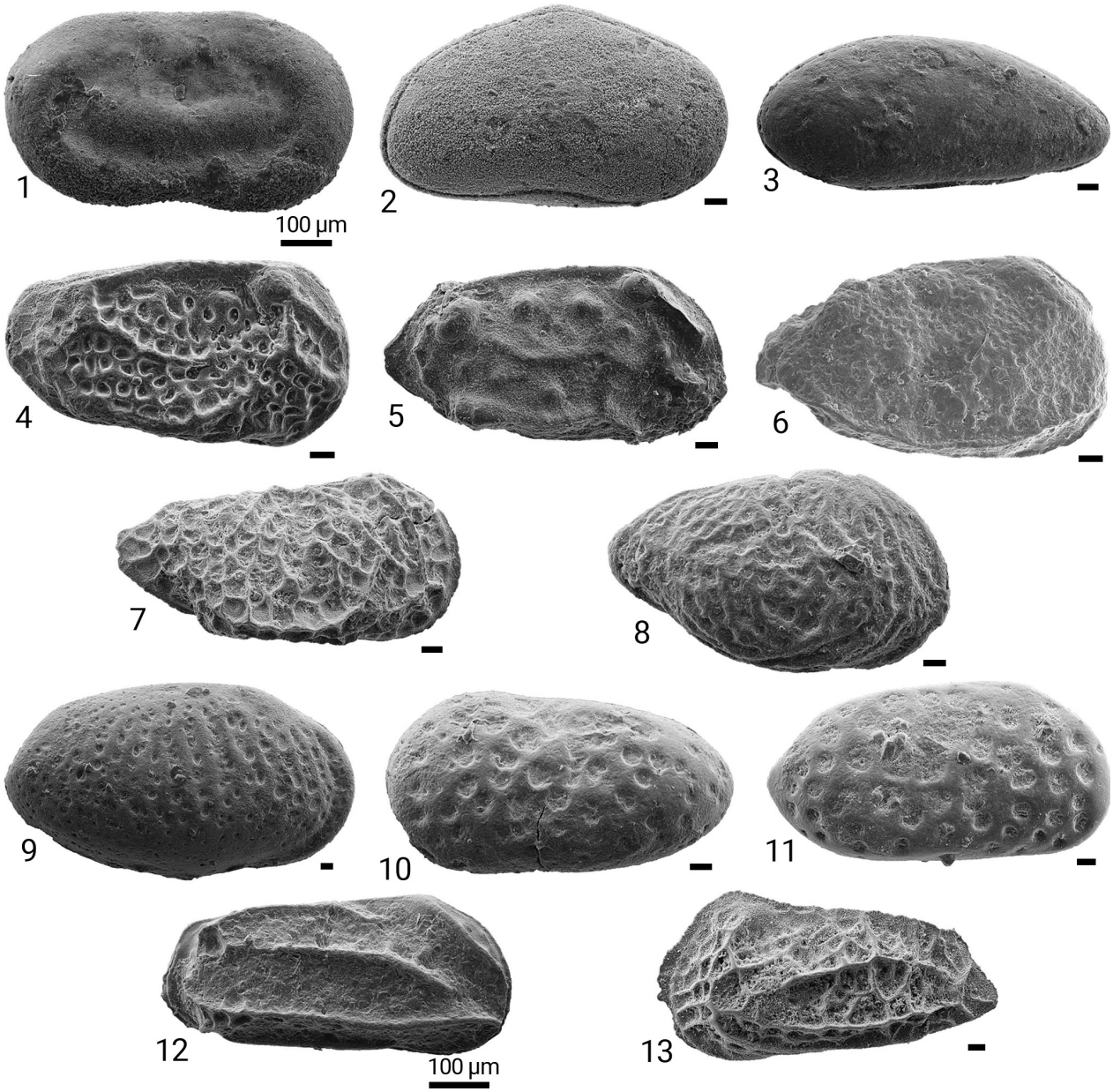

Figure 9. (1) *Cytherelloidea lordi* Ainsworth, SMNS 70521/49, C, right view, L: 0.688 mm; sample He19-19. **(2)** *Bairdiacypris triangularis* Ainsworth, SMNS 70521/50, C, right view, L: 0.309 mm; sample He19-19. **(3)** *Macrocypris aequabilis* Oertli, SMNS 70521/51, C, left view, L: 0.349 mm; sample He19-21. **(4)** *Eucytherura* cf. *parairregularis* Brand, SMNS 70521/52, C, right view, L: 0.281 mm; sample He19-19; **(5)** *Eucytherura* cf. *yunga* Ballent and Whatley, SMNS 70521/53, RV, L: 0.304 mm; sample He19-27. **(6)** *Eucytherura* sp. 5 Franz, SMNS 70521/54, RV, L: 0.295 mm; sample G11Fr; **(7)** *Eucytherura* sp. 11 Franz, SMNS 70521/55, RV, L: 0.327 mm; sample He19-25. **(8)** *Balowella catena* (Franz et al.), SMNS 70521/56, RV, L: 0.308 mm; sample He19-24. **(9)** *Praeschuleridea ornata* (Bate), SMNS 70521/57, RV, L: 0.578 mm; sample He19-21; **(10, 11)** ? *Southcavea* sp., **(10)** SMNS 70521/58, LV, L: 0.315 mm; **(11)** SMNS 70521/59, RV, L: 0.368 mm; sample He19-24; **(12)** *Pleurocythere kirtonensis* Bate, SMNS 70521/60, RV, L: 0.597 mm; sample He19-18. **(13)** *Acrocythere* aff. *pumila* Plumhoff, SMNS 70521/61, LV, L: 0.406 mm; sample He19-27; **(6)** Opalinuston Formation, Lower Aalenian, Opalinum Zone, **(1–5, 7–13)** Achdorf Formation, Upper Aalenian **(1–4, 9, 12)** Bradfordensis Zone (Gigantea Subzone), **(5, 7–8, 10–11, 13)** Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

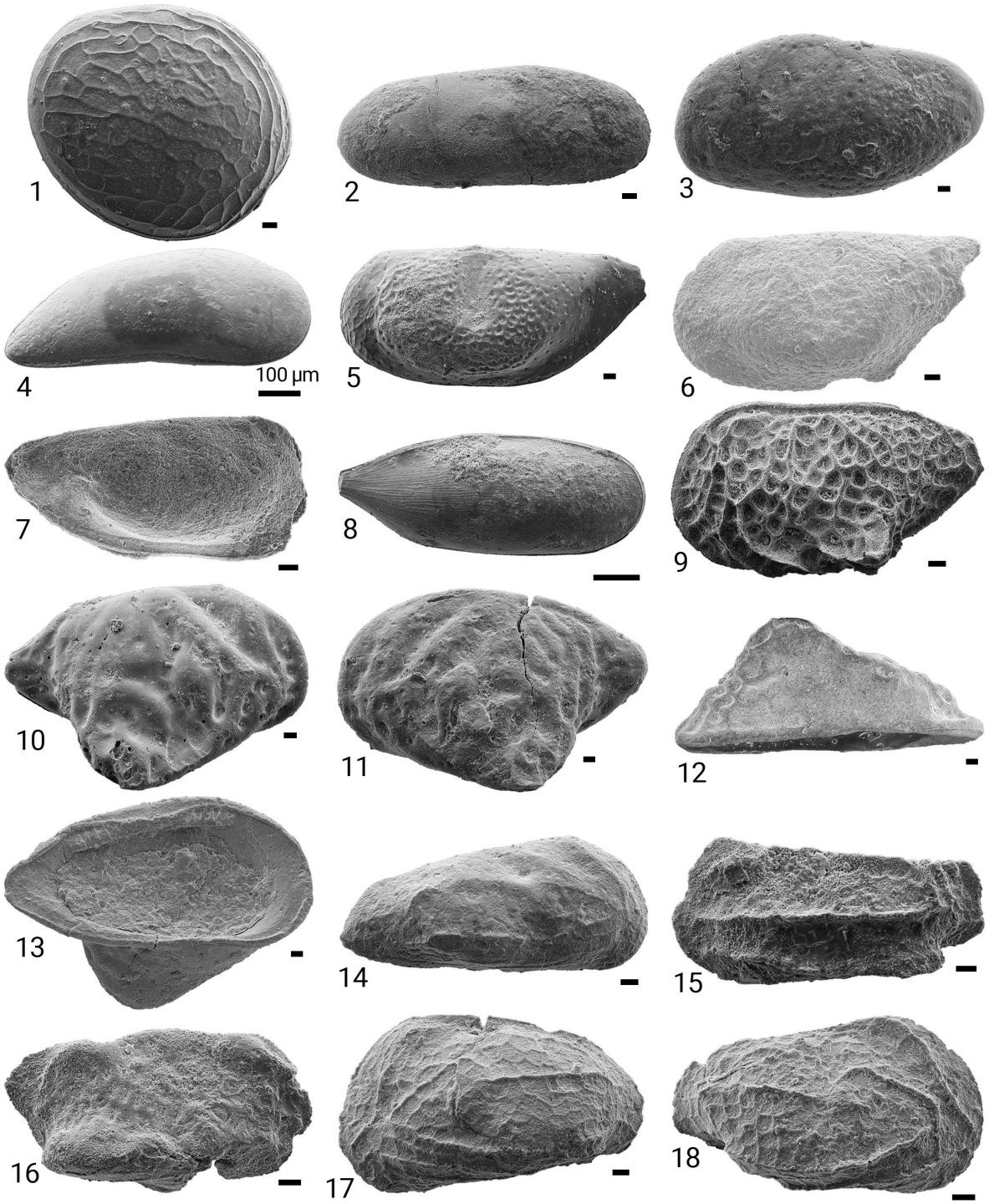

Figure 10. **(1)** *Polycope* cf. *riegrafi* Brand, SMNS 70521/62, C, right view, L: 0.345 mm; sample He19-27. **(2)** ? *Liasina cylindrica* Ainsworth, SMNS 70521/63, RV, L: 0.412 mm; sample Lin18-1. **(3)** *Cardobairdia toarcensis* Ainsworth, SMNS 70521/64, LV, L: 545 mm; sample He19-26. **(4)** *Macrocypris* ? *liassica* Bate and Coleman, SMNS 70521/65, C, right view, L: 0.750 mm; sample He19-27; **(5)** *Patellacythere paravulsa* cf. *tenuis* Brand, SMNS 70521/66, LV, L: 0.522 mm; sample He19-27. **(6)** *Patellacythere ungulina* (Triebel and Bartenstein), SMNS 70521/67, LV, L: 0.405; sample Mue19-1; **(7)** "*Monoceratina*" aff. *posterocarinata* Brand, SMNS 70521/68, C, right view, L: 0.324 mm; sample He19-21. **(8)** *Tanycythere posteroelongata* Cabral et al., SMNS 70521/69, C, right view, L: 0.676 mm; He19-27. **(9)** *Cytheropterina alacostata* Franz et al., SMNS 70521/70, LV, L: 0.368 mm; sample He19-27; **(10–13)** *Cytheropterina crassicostata* sp. nov., **(10)** holotype, SMNS 70521/71, RV, L: 0.516 mm; sample He19-27; **(11)** paratype, SMNS 70521/72, LV, L: 0.556 mm; sample He19-26, **(12)** paratype, SMNS 70521/73, RV, ventral view, L: 0.557 mm; sample He19-27; **(13)** paratype, SMNS 70521/74, LV, inner view, L: 0.555 mm; sample Ro19-4; **(14)** *Procytherura* sp. 5, SMNS 70521/75, RV, L: 0.363 mm; He19-24; **(15)** *Eucytherura* aff. *yunga* Ballent and Whatley, SMNS 70521/76, LV, L: 0.312 mm; sample He19-27. **(16)** *Eucytherura* sp. B Boomer and Ballent, SMNS 70521/77, RV, L: 0.277 mm; sample He19-25. **(17, 18)** *Eucytherura* sp. 10, **(17)** SMNS 70521/78, LV, L: 0.392; sample He19-25, **(18)** SMNS 70521/79, RV, L: 0.278 mm; sample He19-24. Achdorf Formation, Upper Aalenian, Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

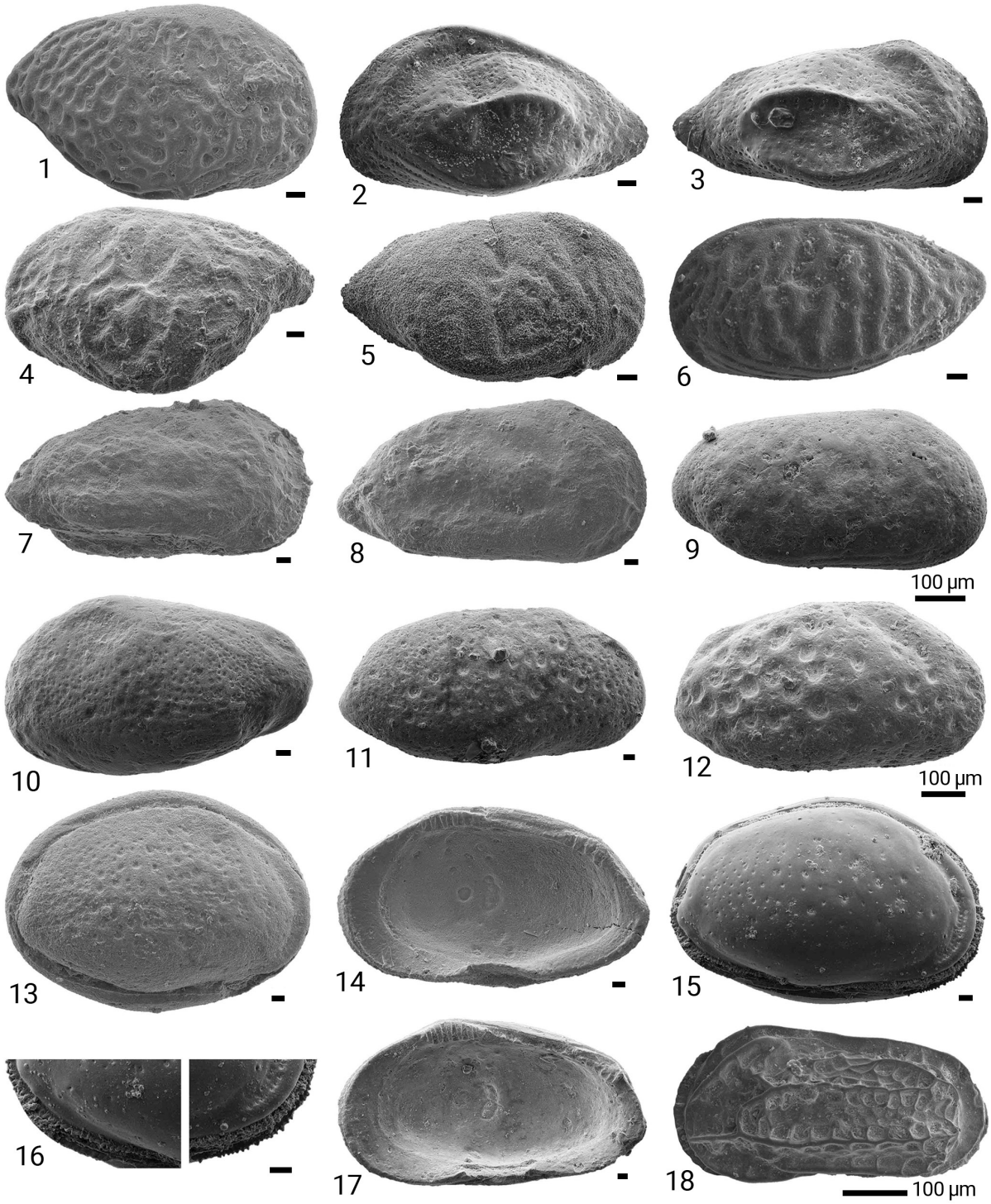

Figure 11. (1) *Balowella catena* (Franz et al.), SMNS 70521/80, C, right view, L: 0.329 mm; sample He19-18. **(2, 3);** ? *Cytheropteron* sp. 1, **(2)** SMNS 70521/81, LV, L: 0.322 mm; sample He19-27; **(3)** SMNS 70521/82, RV, L: 0.355 mm; sample He19-27. **(4, 5)** *Procytheropteron* aff. *gramanni* Brand, **(4)** SMNS 70521/83, LV, L: 0.373 mm; sample He19-26; **(5)** SMNS 70521/84, RV, L: 0.305 mm; sample He19-22. **(6)** *Procytheropteron* sp. 1 Franz et al., SMNS 70423/66, LV, L: 0.322 mm; sample G20b; **(7)** *Aphelocythere recta* Ohmert, SMNS 70521/85, C, right view, L: 0.460 mm; sample Ro19-4. **(8)** *Aphelocythere* aff. *recta*, SMNS 70521/86, C, right view, L: 0.466 mm; sample Ro19-4. **(9)** *Aphelocythere* sp. 1, SMNS 70521/87, RV, L: 0.630 mm; sample He19-27; **(10)** *"Asciocythere"* sp., SMNS 70521/88, RV, L: 436 mm; sample He19-26. **(11)** *Eocytheridea elongata* Bate, SMNS 70521/89, RV, L: 0.573 mm; sample He19-21. **(12)** *Eocytheridea lacunosa* Bate, SMNS 70521/90, RV, L: 0.705 mm; sample He19-25; **(13, 14)** *Praeschuleridea* cf. *subtrigona*, **(13)** SMNS 70521/91, C, right view, L: 0.512 mm; sample Ro19-5; **(14)** SMNS 70521/92, RV, inner view, L: 0.512 mm; sample Ro19-5; **(15–17)** *Praeschuleridea* sp. 1, **(15)** SMNS 70521/93, C, right view, L: 0.490 mm; sample He19-27, **(16)** SMNS 70521/93, C, right view, (detail); **(17)** SMNS 70521/94, RV, L: 0.620 mm; L: 0.620 mm; sample He19-27. **(18)** *Pleurocythere ohmerti* Franz et al., SMNS 70521/94, LV, L: 0.479 mm; sample Tst. 38-1988 (= He19-27). Achdorf Formation, Upper Aalenian, **(1, 6)** Bradfordensis Zone (Gigantea Subzone), **(2–5, 7–18)** Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

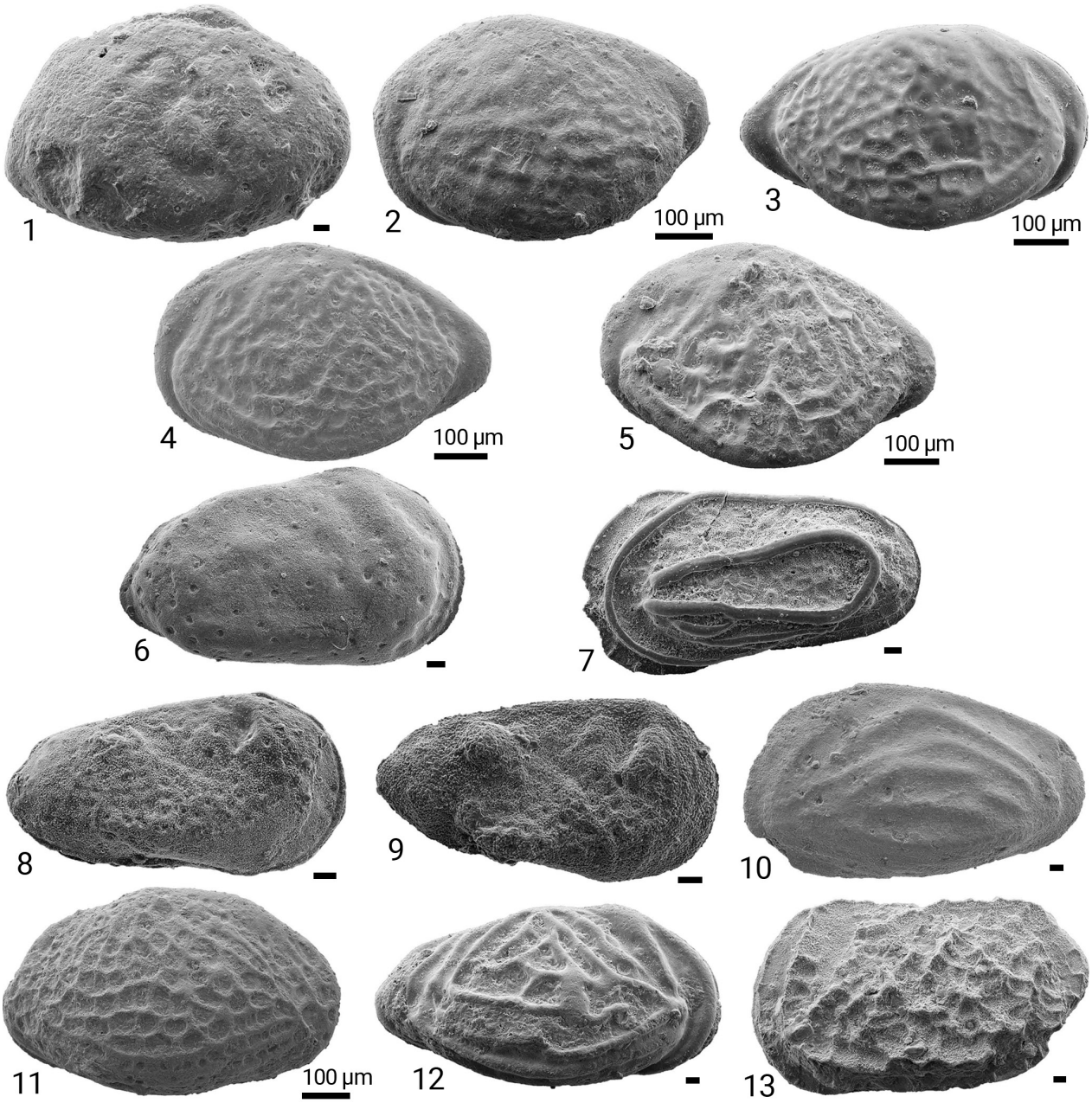

Figure 12. (1) *Camptocythere pusilla* Plumhoff, SMNS 70521/95, RV, L: 0.446 mm; sample He19-24; **(2)** *Kinkelinella* (*K.*) *adunca* Malz, SMNS 70521/96, LV, L: 0.598 mm; sample He19-24. **(3)** *Kinkelinella* (*Kink.*) *levata* Ohmert, SMNS 70521/97, RV, L: 0.636 mm; sample He19-27; **(4)** *Kinkelinella* (*Kink.*) cf. *sermoisensis*, SMNS 70521/98, LV, L: 0.640 mm; sample Mue19-1. **(5)** *Kinkelinella* sp. B Ohmert, SMNS 70521/99, LV, L: 0.623 mm; sample Ha19-5; **(6)** *Minyocythere tuberculata* (Luppold), SMNS 70521/100, RV, L: 0.400 mm; sample Mue19-1. **(7)** *Plumhofficythere clavatoides* Luppold, SMNS 70521/101, LV, L: 0.408 mm; sample He19-27; **(8, 9)** Gen. et sp. 7, **(8)** SMNS 70521/102, RV, L: 0.306 mm; sample He19-22; **(9)** SMNS 70521/103, RV, L: 0.291 mm, sample He19-22. **(10)** *Vernoniella* ? *caytonensis* Bate, SMNS 70521/104, C, left view, L: 0.535 mm; sample Ro19-5. **(11)** *Progonocythere triangulata* Braun in Ohmert, SMNS 70521/105, RV, L: 0.712 mm; sample Ha19-4; **(12)** *Kinkelinella* (*Ekt.*) *triangula* Brand, SMNS 70521/106, RV, L: 0.523 mm; sample Ha19-4. **(13)** *Fuhrbergiella horrida bicostata* Brand and Malz, SMNS 70521/107, LV, L: 0.560 mm; sample Ha19-5. Achdorf Formation, Upper Aalenian, **(5)** Bradfordensis Zone (Gigantea Subzone), **(1–4, 6–11)** Concavum Zone. Scale bars (if not indicated otherwise): 20 µm.

Figure 13. (1a, b) *Brasilia decipiens* (Buckman) [M], SMNS 70519/7. **(2a, b, 9a, b)** *Graphoceras cavatum* (Buckman) [M], (2) SMNS 70519/8, **(9)** SMNS 70519/9. **(3)** *G*. aff. *fallax* (Buckman) [M], SMNS 70519/10. **(4)** *Ludwigella tenuis* (Buckman) [m], SMNS 70519/11. **(5)** *L*. aff. *tenuis* (Buckman) [m], SMNS 70519/12. **(6)** *Ludwigella attenuata* (Buckman) [m], SMNS 70519/13. **(7, 8)** *L. attracta* (Buckman) [m], **(7)** SMNS 70519/14, **(8)** SMNS 70519/15**. (1a–8)** Jungingen (Starzel); Achdorf Formation, Bed 4, Upper Aalenian, Bradfordensis Zone (Gigantea Subzone). Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

Figure 14. (1a–c) *Planammatoceras* sp. [M], SMNS 70519/16. Jungingen (Starzel); Achdorf Formation, Bed 4, Upper Aalenian, Bradfordensis Zone (Gigantea Subzone). **(2a, b)** *Euaptetoceras infernense* sensu Buckman [M] (**2b**: innermost whorls from reverse flank), SMNS 70519/17. Hechingen-Beuren (Hanneswiesle); Achdorf Formation, Bed 4 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

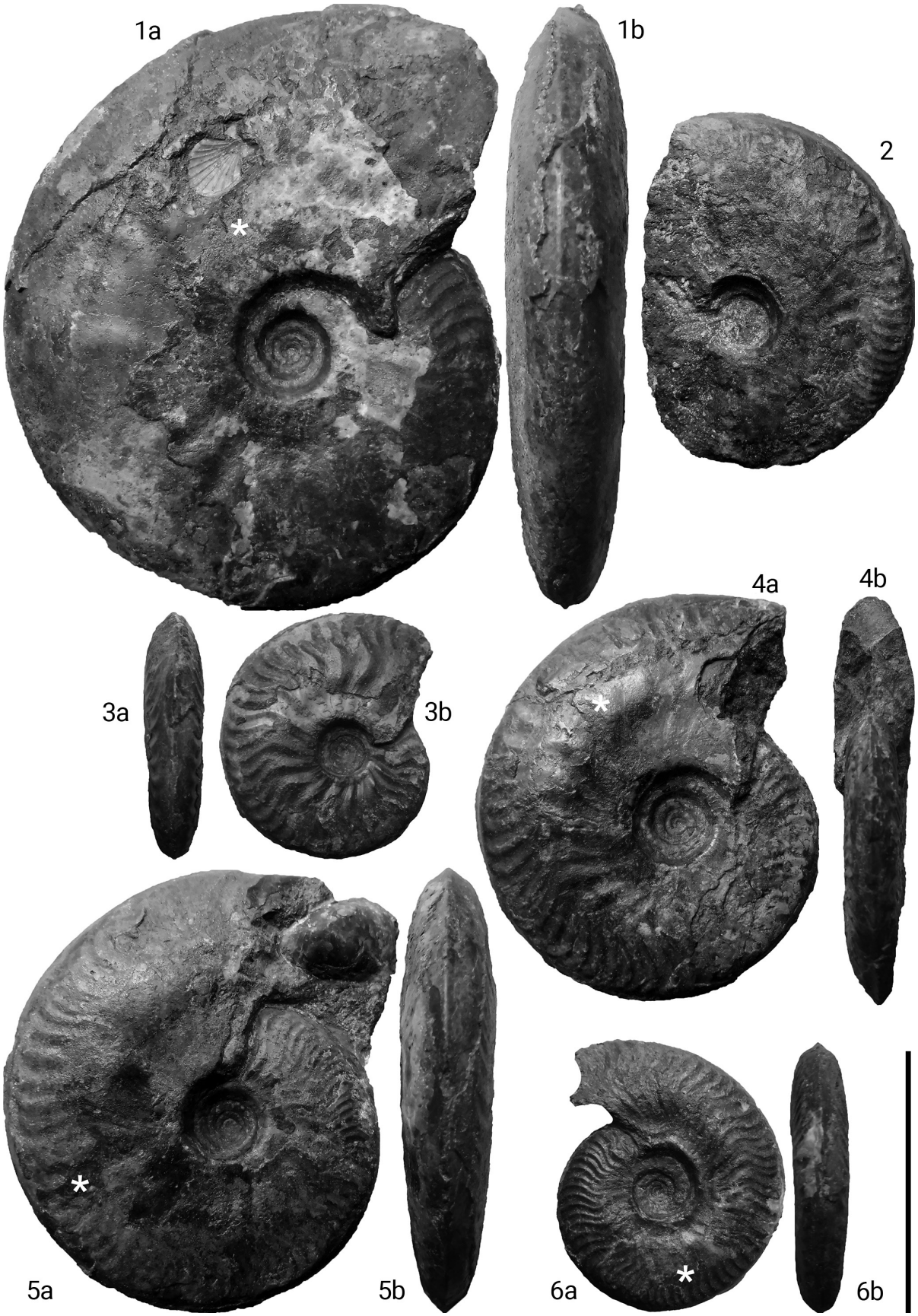

Figure 15. (1a, b) *G*. cf. *concavum* (Sowerby) [M], with *Propeamussium pumilum* (Lamarck), SMNS 70519/18. **(2)** *G. decorum* Buckman [M], SMNS 70519/19. **(3a, b)** *G*. aff. *apertum* (Buckman) [M], SMNS 70519/20. **(4a, b)** *G*. cf. *pulchrum* (Buckman) [M], SMNS 70519/21. **(5a, b)** *G. pulchrum* (Buckman) [M], SMNS 70519/22. **(6a, b)** *Ludwigella arcitenens* (Buckman) [m], SMNS 70519/23. **(1a–6b)** Hechingen-Beuren (Hanneswiesle); Achdorf Formation, Bed 4 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

Figure 16. (1, 4) *Graphoceras* cf. *concavum* (Sowerby) [M], (1) SMNS 70519/24, (4) SMNS 70519/25. **(2a, b, 5a, b)** *Brasilia* cf. *decipiformis* Dietze et al. [M], (2) SMNS 70519/26, (5) SMNS 70519/27. **(3a, b)** *Ludwigella arcitenens* (Buckman) [m], SMNS 70519/28. **(1–5b)** Balingen-Zillhausen (Roschbach), Upper Aalenian, Achdorf Formation; Concavum Zone (Concavum Subzone); **(3a, b)** Bed 26; **(1–2b, 4–5b)** Bed 28 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

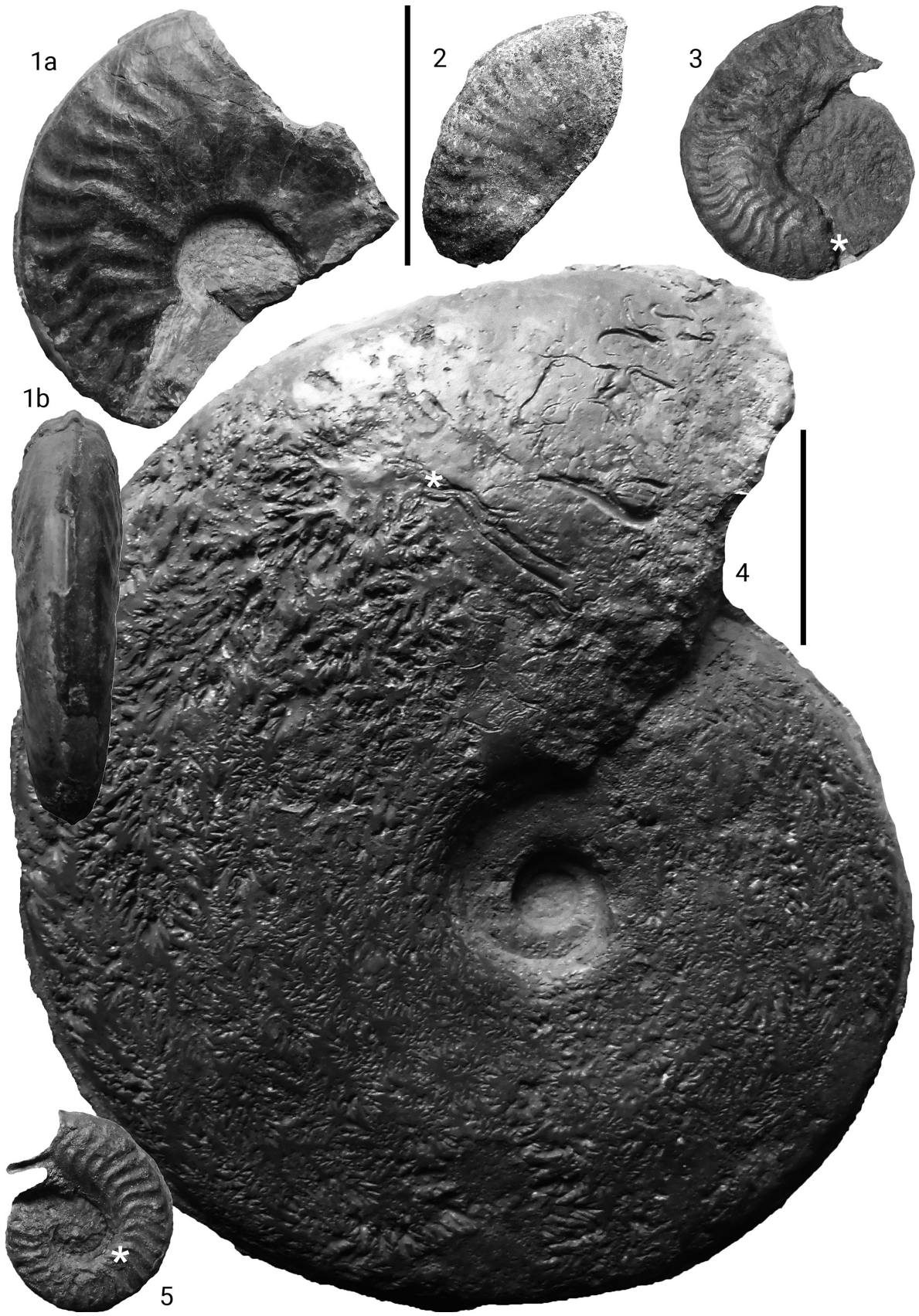

Figure 17. (1a, b) *Graphoceras* cf. *caduciferum* (Buckman) [M], Bed 40 [Inopernabank], Bradfordensis Zone, (Gigantea Subzone), SMNS 70519/29. **(2)** *Graphoceras* sp., Bed 45 [Konglomeratbank], Bradfordensis Zone, (Gigantea Subzone), SMNS 70519/30. **(3)** *Ludwigella arcitenens* (Buckman) [m], Bed 45 [Calceolabank], SMNS 70519/31. **(4)** *Euaptetoceras infernense* sensu Buckman [M], Bed 45 [Calceolabank], SMNS 70519/32. **(5)** *L*. sp. [m], Bed 45 [Calceolabank], SMNS 70519/33. **(3–5)** Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. **(1a–5)** Hechingen-Beuren (Heiligenbach), Achdorf Formation. Asterisk marks beginning of the body-chamber. Scale bar: 5 cm (shorter bar for Fig. 17.4).

Figure 18. (1) *Brasilia decipiens* (Buckman) [M], SMNS 70519/34. **(2)** *Graphoceras cavatum* (Buckman) [M], SMNS 70519/35. **(3)** *G.* cf. *v-scriptum* Buckman [M], SMNS 70519/36. **(4a, b)** *B.* aff. *decipiens* (Buckman) [M], SMNS 70519/37. **(5)** *G. fallax* (Buckman) [M], SMNS (70519/38. **(1–5)** Hechingen-Beuren (Heiligenbach), Achdorf Formation, Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

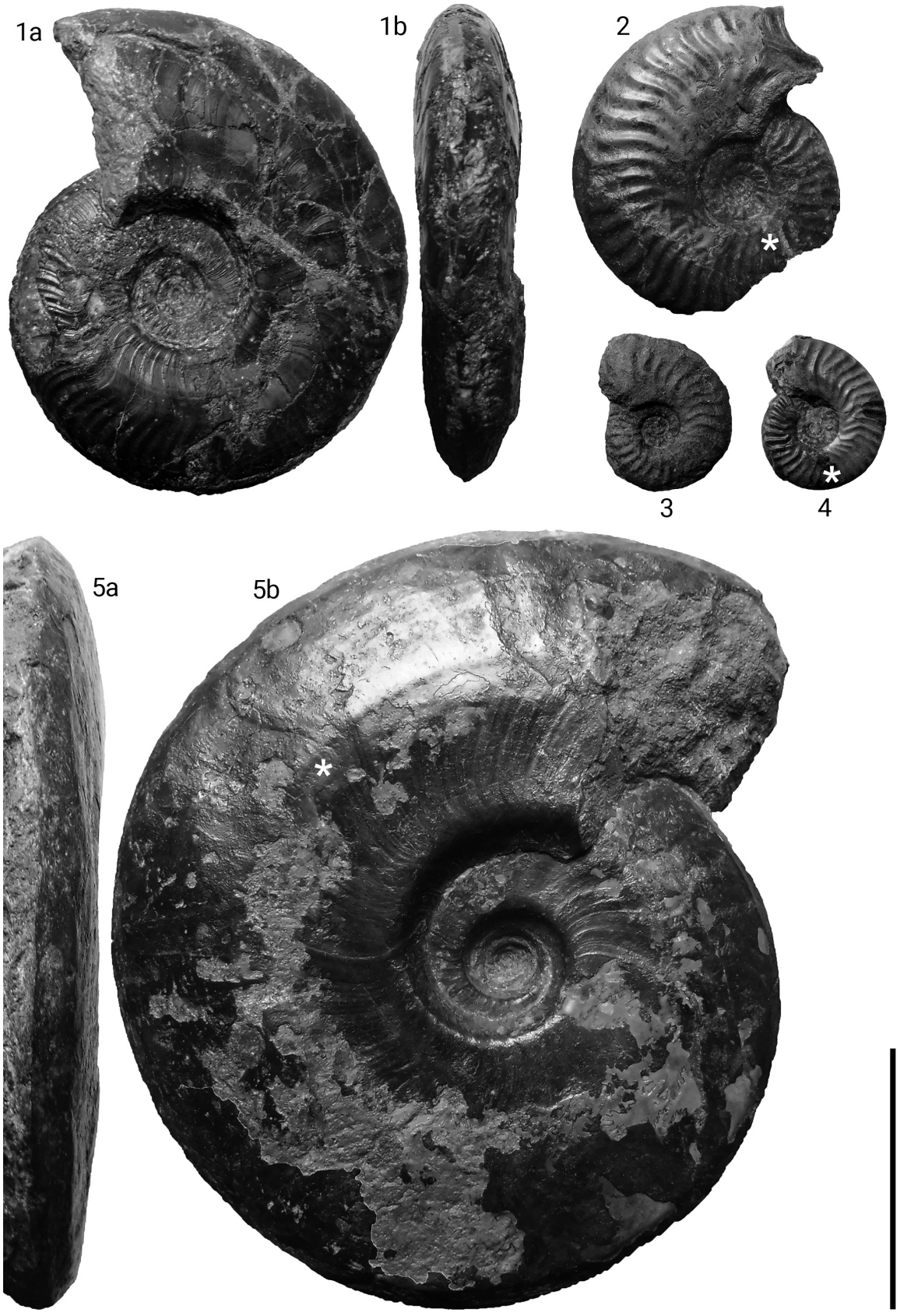

Figure 19. (1a, b) *Brasilia bradfordensis* (Buckman) [M], Bed 2, Bradfordensis Zone, (Bradfordensis Subzone), SMNS 70519/39. **(2)** *Ludwigella cornu* (Buckman) [m], SMNS 70519/40. **(3)** *L. attracta* (Buckman) [m], SMNS 70519/41. **(4)** *L. micra* (Buckman) [m], SMNS 70519/42. **(5a, b)** *B.* cf. *decipiens* (Buckman) [M], SMNS 70519/43. **(1a–5b)** Jungingen (Mühlbächle), Achdorf Formation, Bed 14 [Calceolabank], Upper Aalenian. **(2–5b)** Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

Figure 20. (1a, b) *Graphoceras* aff. *magnum* (Buckman) [M], SMNS 70519/44. **(2a, b)** *G.* cf. *cavatum* (Buckman) [M], SMNS 70519/45. **(3a, b)** *B.* aff. *decipiens* (Buckman) [M], SMNS 70519/46. **(1a–3b)** Jungingen (Mühlbächle), Achdorf Formation, Bed 14 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

Figure 21. (1a, b) *Graphoceras* cf. *cavatum* (Buckman) [M], SMNS 70519/47. **(2a, b)** *G. cavatum* (Buckman) [M], SMNS 70519/48. **(1a–2b)** Jungingen (Mühlbächle), Achdorf Formation, Bed 14 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

Figure 22. (1a, b) *Graphoceras decorum* Buckman [M], SMNS 70519/49. **(2a, b, 5a, b)** *G. formosum* (Buckman) [M], (2) SMNS 70519/56, (5) SMNS 70519/50. **(3a, b)** *Graphoceras pulcrum* (Buckman) [M], SMNS 70519/51. **(4)** *G. fallax* (Buckman) [M], SMNS 70519/52. **(1a–5b)** Jungingen (Mühlbächle), Achdorf Formation, Bed 14 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 5 cm.

Figure 23. (1a–c) *Euaptetoceras* cf. *euaptetum* Buckman [M], SMNS 70519/53. Jungingen (Mühlbächle), Achdorf Formation, Bed 14 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the body-chamber. Scale bar: 5 cm.

Figure 24. (1a, b) *Euaptetoceras* cf. *kochi* (Prinz) [M], collection S. Pfister. Jungingen (excavation pit in the street "Im Binder", about 0.5 km NW of the Mühlbächle stream), Achdorf Formation, Bed 14 [Calceolabank], Upper Aalenian, Concavum Zone (Concavum Subzone), *cavatum* biohorizon. Asterisk marks beginning of the bodychamber. Scale bar: 10 cm.

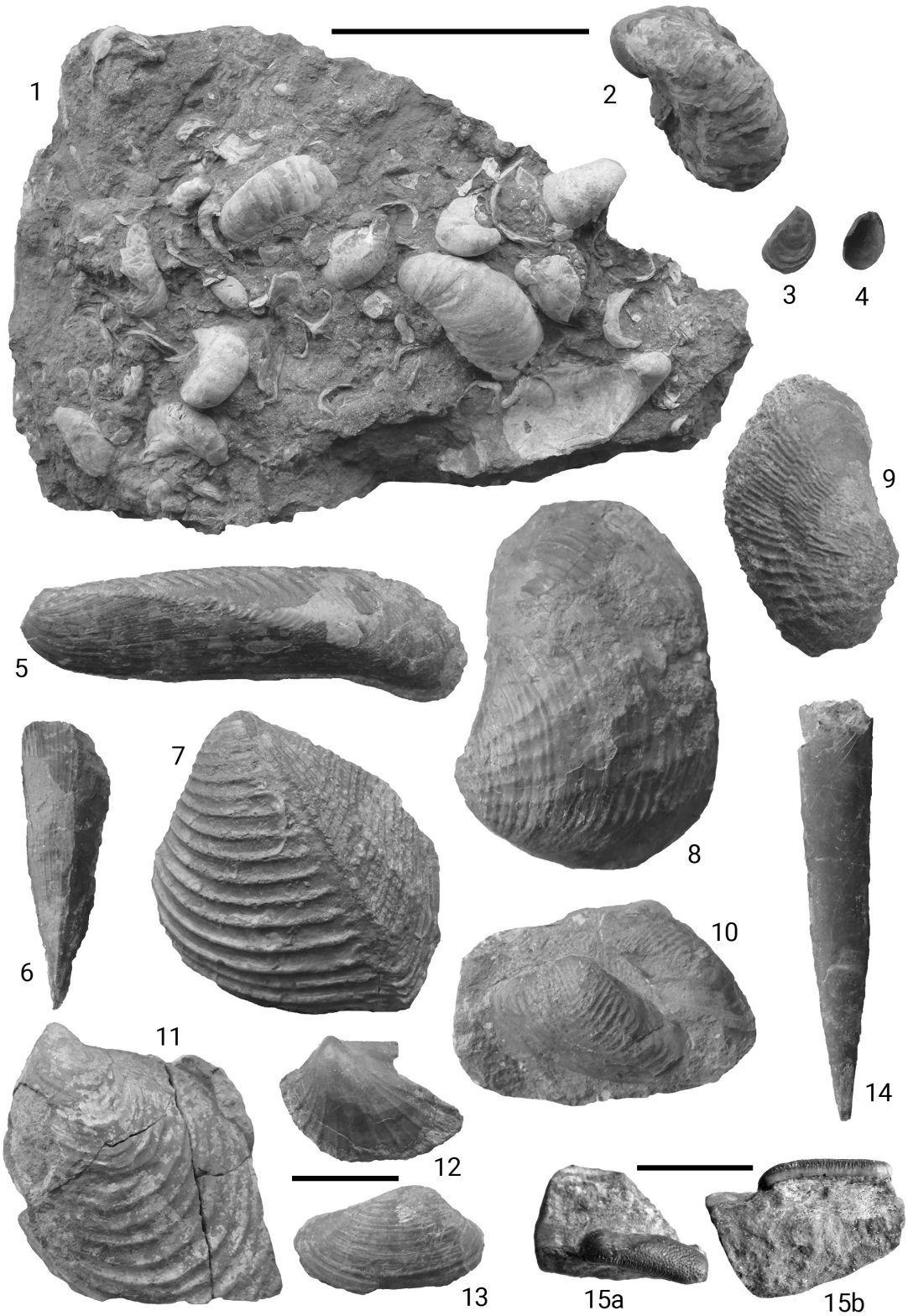

Figure 25. (1, 2) *Gryphaea calceola* Quenstedt, Jungingen, Mühlbächle, Calceolabank, SMNS 70528/1–2. **(3, 4)** juveniles of *Gryphaea calceola* Quenstedt, Jungingen, Mühlbächle, marlstone above Calceolabank, SMNS 70528/3–4. **(5)** *Inoperna sowerbyana* (d'Orbigny), Jungingen, Starzel river, Inopernabank, SMNS 70528/5. **(6)** *Pinna* sp., Jungingen, Starzel river, Inopernabank, SMNS 70528/6. **(7)** *Trigonia alemanica* Rollier, Balingen-Zillhausen, Roschbach, Calceolabank, SMNS 70528/7. **(8)** *Pholadomya lirata* (Sowerby), Jungingen, Starzel river, Inopernabank, SMNS 70528/8. **(9)** *Pholadomya fidicula* (Sowerby), Hechingen-Beuren, Heiligenbach, Inopernabank, SMNS 70528/9. **(10)** *Goniomya literata* (Sowerby), Hechingen-Beuren, Heiligenbach, Inopernabank, SMNS 70528/10. **(11)** *Mytiloceramus polyplocus* (Roemer), Jungingen, Mühlbächle, Rostrote Kalkbank, SMNS 70528/11. **(12)** *Oxytoma inaequivalvis* (Sowerby), Jungingen, Starzel river, Inopernabank, SMNS 70528/12. **(13)** *Pleuromya* cf. *uniformis* (Sowerby), Jungingen, Starzel river, Inopernabank, SMNS 70528/13. **(14)** Belemnite rostrum, Hechingen-Beuren, Heiligenbach, Calceolabank SMNS 70529. **(15)** *Asteracanthus personati* (Quenstedt), Zillhausen Member, Starzel river in Schlatt, SMNS 97005. Scale for 1, 2: 50 mm; for 3-14: 20 mm, for 15a, b: 20 mm.

5.1.2 "Comptum" Subzone (samples He19-13–14)

The stratigraphical significance of the ostracod assemblage from the "Comptum" Subzone is rather limited (8 species, represented by only 65 specimens). The assemblage is characterized by the extinction of the previously typical species *Aphelocythere pygmaea*, *Acrocythere pumila*, *Procytherura euglyphea*, *Proc. celtica*, *Eucytherura plumhoffi*, *Euc. foveolata*, *Euc*. sp. 1 Franz et al., *Metacytheropteron opalinum*, and *Cardobairdia tesakovae*. *Aphelocythere pygmaea* has its last appearance (very rare) in the claystones directly above the Comptumbank. Only *Cytherella apostolescui* appears for the first time, like in the Geisingen clay pit (Franz et al. 2018); the newly appearing species *Praeschuleridea punctulata*, *Kinkelinella* (*K*.) *fischeri*, *Kinkelinella* sp. 2 and *Ektyphocythere* aff. *anterocosta* are already known from older strata in Geisingen and some other sections.

Dominant species include *Praeschuleridea ventriosa*, *Pr. punctulata* and *Kinkelinella* (*K*.) *fischeri*.

5.1.3 Murchisonae Zone (samples He19-15–16)

The samples from the clays above the "Doppelbank" 20 + 21 yielded 126 specimens of 17 species, 12 of which were found in single specimens. Dominant species are *Praeschuleridea ventriosa*, *Pr. punctulata* and *Homocytheridea* sp. 1. Nine species are new; most important are *Homocytheridea* sp. 1, *Bythoceratina* (*Praebythoceratina*) sp. 1, *Eucytherura* sp. 3 Franz et al. and, to a minor degree, the very rare *Pleurocythere* sp. 1. The still undescribed Gen. et sp. indet. 10 Franz has its last appearance. *Homocytheridea* sp. 2, *Procytherura* aff. *serangodes*, *Aphelocythere* cf. *pygmaea*, *Pleurocythere* sp. 1 and Gen. et sp. indet. 12 were found only in single specimens in this assemblage.

Homocytheridea sp. 1 differs from *Homocytheridea* cf. *punctulata* from the Concavum Zone in the Geisingen clay pit. The stratigraphic distribution of *Homocytheridea* in the Upper Aalenian can be clarified only after investigation of further material.

5.1.4 Bradfordensis Zone, Bradfordensis Subzone (sample He19-17)

In this sample, we found 12 species (only 25 specimens), the majority of which are again represented by single specimens. Among the newly appearing species the solely abundant *Progonocythere scutula* (13 specimens) is particularly noteworthy. It was first described by Franz et al. (2018) from the Geisingen-Oolith (Gigantea Subzone). *Progonocythere scutula* and Gen. et sp. 9 Tesakova were observed in this sample only. A stratigraphical interpretation is not possible so far.

5.1.5 Bradfordensis Zone, Gigantea Subzone (samples He19-18–21)

The stratigraphical significance of this assemblage (35 species, represented by 169 specimens) is restricted. Eighteen species occur for the first time respectively reoccur in this part of the section: *Praeschuleridea ornata*, *Pr. ventriosa*, *Balowella catena*, *Cytherelloidea lordi*, *Pleurocythere kirtonensis* and rare *Kinkelinella levata* and *Eocytheridea elongata* in the uppermost sample. Dominant species are *Praeschuleridea ornata* and *Pr. ventriosa*, which alone account for > 22% of the total assemblage, *Cytheropterina bicuneata*, *Praeschuleridea punctulata* and *Balowella catena*. *Eucytherura michelseni*, *Eucyth*. sp. 3 Franz et al., *Cytherelloidea* cf. *catenulata* and Gen. et sp. indet. 9 have their last appearances in this section. *Cytherelloidea lordi*, *Pleurocythere kirtonensis*, *Aaleniella compressa* and *Eucytherura* sp. 5 Franz were found in this assemblage only.

As already observed in Geisingen (Franz et al. 2018) and Thanheim (Dietze et al. 2018), *Kinkelinella levata* – contrary to Ohmert (2004) – already occurs in the Bradfordensis Zone. The lower boundary of the Levata ostracod zone must therefore be significantly shifted downwards.

5.1.6 Concavum Zone (samples He19-21–28, Mue19-1, Ha19-1–3, Ro19-3–5)

The Concavum-Zone comprises the claystones immediately below and above the Inopernabank up to the Sowerbyi-Oolith. Since the claystones above the Rostrote Kalkbank are not exposed along the Heiligenbach creek, their basal part was sampled at the Mühlbächle creek in Jungingen and, for comparison purposes, at the Roschbach in Balingen-Zillhausen. The 14 samples obtained there show ostracod (and foraminifers) assemblages relatively rich in species and individuals. The upper half of these claystones and the basal Wedelsandstein Formation were sampled in the Hausterberg section. The claystones in this level are fine sandy and very poor in microfossils. In some samples only one foraminiferal and one ostracod species were found in small (foram.) to very small (ostr.) numbers.

This assemblage (including the samples from the Roschbach valley) comprises 2,365 specimens from 58 species, 34 of which appear for the first time in this section. Dominant species are *Cytherella apostolescui*, *Praeschuleridea ornata* and the newly appearing *Eocytheridea lacunosa* and *Camptocythere pusilla*. The still persisting *Praeschuleridea ventriosa*, *Pr. punctulata*, *Balowella catena*, *Cytheropterina bicuneata*, *Eucytherura eberti* and *Bythoceratina* (*Praebyth*.) sp. 1 are common as well. Of 34 species appearing here for the first time, the following ones are somewhat more common and useful for stratigraphic purposes (in the order of their first occurrence in this section): *Eocytheridea lacunosa*, *Plumhofficythere clavatoides*, *Kinkelinella* (*Kink*.) *adunca*, *Camptocythere pusilla*, *Pleurocythere ohmerti*, *Kinkelinella* (*Kink*.) sp. B Ohmert, *Cytheropterina crassicostata*, *Cyth. alacostata*, *Kinkelinella* (*Kink*.) cf. *sermoisensis*, *Praeschuleridea* cf. *subtrigona*, and *Minyocythere tuberculata*.

The two species of *Cytheropterina* are very conspicuous, but *Cytheropterina alacostata* is often represented by very small specimens.

Camptocythere pusilla, the index species of the Pusilla Ostracod Zone (Ohmert 2004), has been found here in

Zones	Subzones	Biohorizons	Localities
Concavum	Formosum	yet to be worked out	?Geisingen, Ringsheim, Wutach
	Concavum	*cavatum*	Zollernalb; ?Kappishäusern, ?Metzingen [Rieber 1963]
Bradfordensis	Gigantea	?	Zollernalb
		decipiformis	Geisingen
		?	Geisingen
		geisingensis	Geisingen, Öfingen
		gigantea sensu Contini	Geisingen, Wutach (condensed)
	Bradfordensis	yet to be worked out	Aalen, Kuchen, Geislingen, Wutach (condensed)
		staufensis	Swabian Alb, Wutach [Rieber 1963], Geisingen, Ringsheim
Murchisonae	Murchisonae	*discoidea*	Wochenberg [Rieber 1963]
		sehndensis	Wochenberg, Plettenberg, Gosheim [Rieber 1963]
	Haugi	*opalinoides*	Geisingen, Wutach, ?Aalen, Wochenberg [Rieber 1963]
Opalinum	"Comptum"	yet to be worked out	Aichelberg [Dietl 2013], Geisingen [Dietze et al. 2014]
		"comptum"	Swabian Alb, Wutach [Rieber 1963]
	Opalinum	*lineatum-"costosum"*	Middle Swabian Alb [Ohmert 1993], Zollernalb
		hansrieberi	Middle Swabian Alb [Dietze & Schweigert 2018], Zollernalb
		opaliniforme	Middle Swabian Alb [Ohmert 1993]
		misera	Wittnau [Ohmert 1993; non Schulbert 2001], Swabian Alb

Figure 26. Biohorizons in the Aalenian of SW Germany. The biohorizons recorded in the Zollernalb area are shaded in grey.

large numbers. The very noticeable *Plumhofficythere clavatoides*, which also occurs in Northern Germany (Plumhoff 1963; Luppold 2003) and England (Bate 1963b), is obviously limited to the Bradfordensis Zone (Gigantea subzone) and Concavum Zone and would therefore also have stratigraphic significance.

Eucytherura eberti sp. nov., which has been found in rare specimens from the uppermost Opalinum Zone upwards, has its acme at this level. A number of further, mostly small species appear here for the first time. Although they are partly very conspicuous (e.g., ? *Cytheropteron* sp. 1, *Eucytherura* sp. 10), they are rather unsuitable for stratigraphic purposes due to their scarcity. Additionally, some of these rare species occur earlier elsewhere. A range chart for the Achdorf Formation is given in Appendix 2.

Bajocian

5.1.7 Discites Zone (samples Ha19-4–6)

The appearance of *Kinkelinella* (*Ekt.*) *triangula* and *Progonocythere triangulata*, together with *Cytherelloidea* cf. *cadomensis* and rare *Fuhrbergiella horrida bicostata* in this assemblage (374 specimens) clearly indicates the base of the Triangula Ostracod Zone, Triangulata Ostracod Subzone (= Discites Zone; Ohmert 2004). All other of the 15 species persist from the Aalenian. *Praeschuleridea ornata*, *Progonocythere triangulata*, *Cytherella apostolescui* and *Cytherelloidea* cf. *cadomensis* are dominant. Nine of the 15 species, including the dominant and the zonal index species, were also found at this level in the Thanheim section (Dietze et al. 2019). In contrast to Ohmert (2004), *Kinkelinella* (*Ekt.*) *triangula* appears in the Hausterberg section directly at the base of the Lower Bajocian.

5.2 Ammonites

Aalenian

5.2.1 Opalinum Zone

Opalinum and **"Comptum" subzones:** The strata of the Opalinum Zone were not in the focus of this investigation. However, the Opalinum Subzone reaches at least up to the "Wasserfallschichten" in the area. About 8 m above the "Zopfplatten" of the Heiligenbach section the "Comptum" Subzone is verified by numerous small-sized ammonites of the *L*. "*comptum*" – *L*. *evolutum* group.

5.5.2 Murchisonae Zone

At present, we cannot confirm strata of this age with ammonites.

5.2.3 Bradfordensis Zone

Bradfordensis Subzone: Beds 20–22 in the Roschbach section and bed 2 of the Mühlbächle section belong to the Bradfordensis Subzone. Ammonites are *Brasilia bradfordensis* and *Staufenia staufensis*.

Gigantea Subzone: For the moment, we place the ammonite fauna of the Inopernabank bed into the uppermost Gigantea Subzone. The graphoceratid fauna of this bed itself is not diagnostic enough to decide definitely, if this bed should be placed in the youngest Gigantea Subzone (younger than *decipiformis* biohorizon) or in the oldest Concavum Subzone (older than *cavatum* biohorizon). However, the single *Planammatoceras* sp. is very close to some of the hammatoceratids from the *decipiformis* biohorizon (Gigantea Subzone) of Geisingen, but very different from the hammatoceratids of the *cavatum* biohorizon (Concavum Subzone). Hence, we tentatively assign these beds in the Gigantea Subzone. Ammonites: *Brasilia decipiens*, *Graphoceras cavatum*, *G.* cf. *caduciferum*, *G.* aff. *fallax*, *Ludwigella tenuis*, *L.* aff. *tenuis*, *L. attenuata*, *L. attracta*, *Planammatoceras* sp.

5.2.4 Concavum Zone

Concavum Subzone (*cavatum* horizon): The Calceolabank (Roschbach: Bed 28, Mühlbächle: Bed 14, Heiligenbach: Bed 45, Hanneswiesle: Bed 4) belongs to the *cavatum* biohorizon of the Concavum Subzone. The fauna is a mixture of *Brasilia* spp., the dominant *Graphoceras* spp. and transitional morphologies besides *Euaptetoceras infernense* sensu Buckman. Ammonites: *Brasilia decipiens*, *B.* cf. *decipiens*, *B.* aff. *decipiens*, *B.* cf. *decipiformis*, *Graphoceras cavatum*, *G.* cf. *cavatum*, *G.* cf. *concavum*, *G. fallax*, *G.* aff. *magnum*, *G. decorum*, *G. pulchrum*, *G. formosum*, *Ludwigella arcitenens*, *L. attracta*, *L. micra*, *L. cornu*, *Euaptetoceras* cf. *euaptetum*, *E. infernense* sensu Buckman, *E.* cf. *kochi*.

Formosum Subzone: There is no evidence for this subzone in the Zollernalb.

Bajocian

5.2.5 Discites Zone

The Sowerbyi-Oolith bed belongs to the Discites Zone (see Dietze et al. 2019).

Table 4. Number of species, genera and families in relation to zones and subzones. Indeterminable individuals were not considered. The maxima of the species within the zones are in bold. Indiv. = individuals.

Zone /Subzone	Heiligenbach							
	no. of indiv.	indiv. / sample	species / new		genera / new		families / new	
Discites-Ovale	374	125	15	4	9	1	7	1
Concavum	2572	**161**	**58**	**34**	**29**	**10**	**13**	**3**
Gigantea	169	42	35	18	20	6	9	1
Bradfordensis	25	25	12	5	7	1	5	
Murchisonae	126	63	17	9	11	2	7	
Comptum	65	33	8	1	6	2	4	1
Opalinum	360	28	**34**		15		**9**	
Total	**3691**		**109**		**38**		**15**	

6. Correlation

6.1 Ostracods (M. Franz)

As Plumhoff (1963: 59) already stated, species of the genera *Cytherella* and *Cytherelloidea* dominate in the Upper Aalenian of the Swabian Alb, while they are absent in NW Germany in sediments of the same age. Nevertheless, the correlation succeeds by means of the genera and species occurring at different frequencies in both parts of the basin as listed in Plumhoff (1963: 59). Additionally, *Plumhofficythere clavatoides* Luppold (= *Cytheridae*, n. gen. sp. nov. 1 in Plumhoff 1963) is now also known from several sections in SW Germany.

In the present study and in the Geisingen section, a total of 33 genera and species were identified which are also known from the English, Scottish and Irish Aalenian and Lower Bajocian. *Cytherella apostolescui*, *Cytherelloidea catenulata*, *Cyth. lordi*, *Cytheropterina cribra*, *Eocytheridea elongata*, *Eoc. lacunosa*, *Eucytherura liassica*, *Euc. michelseni*, *Euc. transversiplicata*, *Kinkelinella* (*Ekt.*) *triangula*, *Macrocypris aequabilis*, *M. liassica*, *Procytherura celtica*, *Proc. euglyphea*, *Proc. multicostata*, and many others indicate a marine connection between these two sedimentary basins across the Paris Basin.

6.1.1 Opalinum Zone

Of the 34 species detected in the Heiligenbach section in the upper part of the Opalinuston Formation, 21 species are restricted to the Opalinum Zone or occur here for the last time. In accordance with the Geisingen clay pit (Franz et al. 2018), these are, in the order of their first occurrence: *Aphelocythere pygmaea*, *Acrocythere pumila*, *Eucytherura plumhoffi*, *Eucytherura* sp. 1 Franz et al., Gen. et sp. indet. 3 Franz et al., *Eucytherura foveolata* sp. nov., *Cardobairdia tesakovae*, *Metacytheropteron opalinum*, Gen. et sp. indet. 4 Franz et al., *Procytherura* sp. 2 Franz et al., and *Procytherura celtica*.

The ostracod assemblage of the upper Opalinuston Formation, Zillhausen Subformation (Franz and Nitsch 2009) can be well correlated with neighbouring regions. Although the zonal index *Aphelocythere kuhni* is missing here, *Aphelocythere pygmaea*, *Acrocythere pumila* and *Metacytheropteron opalinum* are also indicative for the upper Opalinum Zone in the Western and Middle Swabian Alb (Dilger 1963; Franz et al. 2018), Northern Germany and Northern Switzerland – there additionally *Eucytherura plumhoffi* and *Cardobairdia tesakovae*.

6.1.2 Opalinum Zone ("Comptum" Subzone) to Murchisonae Zone

The stratigraphically insignificant ostracod faunal assemblage of the "Comptum" Subzone and Murchisonae Zone has little in common with previously studied sections of the Swabian Alb. According to Dilger (1963), only *Cytherella apostolescui* and *Cytheropterina bicuneata* are common in this section. Besides these two species Franz et al.

(2018) mentioned also *Praeschuleridea punctulata* and *Kinkelinella fischeri*. The composition of the ostracod assemblage in northern Germany is very different. According to Ainsworth (1986), *Cytherella apostolescui* is already present in the Toarcian of the Fastnet Basin (off Ireland).

6.1.3 Bradfordensis Zone

The ostracod assemblage of this part of the section shows good accordance with that of the Geisingen section with 15 common species. In contrast, the similarities with Dilger (1963) are limited to *Aphelocythere dilgeri* and *Cytherelloidea lordi*.

Progonocythere scutula, first described from the Geisingen Oolite (Gigantea Subzone; Franz et al. 2018: 78), occurs in the Heiligenbach section only in sample 17 (below the Staufensisbank), which presumably corresponds to the Bradfordensis Subzone. Due to the rarity of this species, a further stratigraphic interpretation is not possible.

The samples following higher up yielded *Balowella catena*, an index species of the Ohmerti-catena assemblage (Franz et al. 2018: 82). The second index species, *Pleurocythere ohmerti*, occurs here only above the Konglomeratbank, in the Concavum Zone.

6.1.4 Concavum Zone

Ohmert (2004) placed an ostracod assemblage with *Kinkelinella* (*Kink.*) *levata*, *Aphelocythere recta* and *Pleurocythere* cf. *kirtonensis* (= *Pleurocythere ohmerti*) from beds of the lower Discites Zone in the Pusilla ostracod zone (Concavum to Discites zones). The index species and additionally *Plumhofficythere clavatoides*, *Cytheropterina alacostata* and *C. crassicostata*, occur in the Zollernalb already in the Concavum Zone; *Kinkelinella* (*Kink.*) *levata* sporadically even in the uppermost Gigantea Subzone of the Bradfordensis Zone. Dilger (1963), who had summarized the interval from the Staufensisbank to the Sowerbyi-Oolith, also mentioned *Camptocythere pusilla* from the Balingen section (Zollernalb).

Apart from the zonal index species *Camptocythere pusilla*, *Plumhofficythere clavatoides* (Cytheridae, n. gen. sp. nov. 1 Plumhoff) is restricted to the Concavum Zone in northern Germany (Plumhoff 1963: 55). The latter occurs very rarely already in the Gigantea Subzone in Geisingen (Franz et al. 2018).

Reisdorf et al. (2016) and Tesakova (2017) did not mention any of the characteristic species of the Concavum Zone, which is a very thin interval in Northern Switzerland.

6.2 Ammonites

Herein we focus on the ammonites from the Inopernabank up to the Rostrote Kalkbank.

SW Germany: From the few data available it is most likely that the ammonites from the Inopernabank and the Rostrote Kalkbank are slightly younger compared to the ammonites from the *decipiformis* biohorizon of Geisingen (westernmost Swabian Alb). The few *Graphoceras* specimens from the Inopernabank are slightly more depressed and more involute compared to the "*Graphoceras*-morphology" of *B. decipiformis* (in a chronospecific sense as described in Dietze et al. 2014). Furthermore, *Euaptetoceras infernense* sensu Buckman – typical of the Concavum Subzone (Chandler and Sole 1996) – is unknown from the *decipiformis* biohorizon at Geisingen, where the highly variable *Bredyia diadematoides* and *Planammatoceras* spp. are the most common hammatoceratids; the latter was also recorded in the Inopernabank. Very close in depositional age to the Inopernabank and to the Calceolabank is the "Concava-Bank" around Metzingen and Kappishäusern (Middle Swabian Alb) (Rieber 1963). However, these outcrops and their ammonite content is still under investigation. Possibly the sections around Metzingen and Kappishäusern are slightly condensed.

The *cavatum* biohorizon (index species: *Graphoceras cavatum*; Calceolabank and Rostrote Kalkbank) is younger compared to the *decipiformis* biohorizon of Geisingen (Dietze et al. 2014) and younger than the ammonite faunas from the underlying Inopernabank and Konglomeratbank. The *decipiformis* biohorizon is characterised by smooth, large-sized *Brasilia decipiformis*, which occur only rarely in the *cavatum* biohorizon. The *Brasilia* fauna of the *cavatum* biohorizon consists of specimens with a smaller size, sometimes already showing the ribbing style of *Graphoceras*. The morphogenus *Graphoceras* is much more common in the *cavatum* biohorizon than in the *decipiformis* biohorizon, where most of the specimens belonging to the morphogenus *Graphoceras* are also less depressed. Variants of *Bredyia diadematoides* are abundant in the *decipiformis* biohorizon and not recorded in the *cavatum* biohorizon, where *Euaptetoceras infernense* sensu Buckman is common.

Ammonites of the Formosum Subzone occur in the "Bunte Mergel" and "Tonhorizont E1" of Ringsheim (Upper Rhine Valley) and in the Konglomeratbank/basal part of the Sowerbyi-Oolith near Achdorf (Wutach area). However, these beds are not yet subdivided into biohorizons.

SW England: The *decipiens* biohorizon (Bradfordensis Zone, Gigantea Subzone) is slightly older than the *cavatum* biohorizon of SW Germany, because therein occur *Graphoceras* and large-sized *Brasilia* (up to 0.4 m in diameter) in roughly equal numbers (Chandler 1997). The herein described *cavatum* biohorizon can be correlated with the *cavatum* biohorizon (Concavum Zone) of Dorset (Chandler 1997).

7. Additional macrofauna of the Upper Aalenian in the Zollernalb

Besides the ammonites described and discussed above, the macrofauna of the Achdorf Formation is mainly composed of bivalves. Only two species, *Gryphaea calceola* (Quenstedt, 1843) and *Inoperna sowerbyana* (d'Orbigny, 1850) are more abundant, especially the former, which oc-

curs in masses, but only in a few beds. *Gryphaea calceola* (Fig. 25: 1–4) was first described from the vicinity of Jungingen, which is hence considered the type locality. This small oyster is especially abundant in the name-bearing Calceolabank. The shells are embedded not in live position, but as isolated valves in a chaotic arrangement (Fig. 25: 1). In a few other beds only small-sized specimens occur (Fig. 25: 3, 4). Probably these small specimens did not reach the maximum size due to less favourable life conditions and thus represent ecophenotypes, very similar to Early and Middle Jurassic species of *Gryphaea* (e.g., Bayer et al. 1985). Despite their smaller size they undoubtedly belong to the same taxon and should not be confused – as Quenstedt (1843) did – with a superficially similar small oyster, *Ostrea calceola* Zieten, 1833, described from Upper Aalenian beds in eastern Swabia (Aalen-Wasseralfingen). The identity of the latter was checked by topotypic material in the SMNS collection. *Inoperna sowerbyana* (d'Orbigny, 1850) (Fig. 25: 5) was already mentioned by Quenstedt (1857, as *Modiola plicata*) from the vicinity of Jungingen. In the studied sections, it is restricted to the Inopernabank, which is why we here name the bed after this bivalve. *Inoperna* was probably a shallow endobenthic sediment stacker (Fürsich and Werner 1988), very similar in its life-style to *Pinna*, which is rarely recorded as well (Fig. 25: 6). Isolated calcitic valves of *Trigonia alemanica* Rollier, 1912 (Fig. 25: 7) occur in the Calceolabank and were probably washed out of the sediment during storm events. This observation corresponds to the chaotic embedding of the above mentioned *Gryphaea*. Epibenthic bivalves do not occur earlier than in the Lower Bajocian Sowerbyibank. They are represented by fragments of thick-shelled oysters (*Actinostreon* sp.) and limids (*Ctenostreon* sp.). Deeper endobenthic taxa such as *Pholadomya lirata* (Sowerby, 1818) (Fig. 25: 8), *Pholadomya fidicula* (J. de C. Sowerby, 1826) (Fig. 25: 9), *Goniomya literata* (Sowerby, 1819) (Fig. 25: 10), and *Pleuromya* cf. *uniformis* (Sowerby, 1813) (Fig. 25: 13), always preserved as steinkerns, are rare in the Upper Aalenian claystones.

Byssate bivalves are represented by isolated valves of *Mytiloceramus polyplocus* (Roemer, 1857), *Oxytoma inaequivalvis* (Sowerby, 1819) and the pectinids *Propeamussium pumilum* (Lamarck, 1819), *Chlamys textoria* (Schlotheim, 1820) and *Entolium corneolum* (Young & Bird, 1828). *Mytiloceramus polyplocus* (Fig. 25: 11) is a geographically wide-spread taxon, which was originally reported from the Aalenian of northern Germany. In the studied Aalenian sections of the Zollernalb, all records come from a single bed, the Rostrote Kalkbank (Mühlbächle, Starzel river near Killer), which is otherwise very poor in fossils. Possibly these bivalves lived attached to driftwood or empty ammonite shells and thus had a pseudoplanctic life-style. *Propeamussium pumilum* (Fig. 15: 1) is rare in the area, probably because of unfavourable environmental conditions. In contrast, it is extremely common in various sandstones of the coeval Eisensandstein Formation of eastern Swabia. *Chlamys textoria* and *Entolium corneolum* are stratigraphically long-ranging and geographically widespread taxa (Johnson 1984). In the studied sections, however, they have been only recorded by a few specimens. Other determinable molluscs comprise a single belemnite rostrum (Fig. 25: 14) and a poorly preserved nautiloid (*Cenoceras* sp.), both from the Heiligenbach section.

Crinoid remains were noticed in the field in some beds of the Zillhausen Member and in polished sections of the Onkoidbank bed. Among arthropods, in the Upper Aalenian claystones of the Zollernalb occasionally tanaidacean remains occur. Specimens preserved in claystones had been originally misidentified and described as tiny salamanders by F. v. Huene (see Schweigert and Etter 2008). A well-preserved new record comes from a microfossil sample below the Konglomeratbank in the Heiligenbach section and will be described in another context elsewhere.

Finally, a single tooth of *Asteracanthus personati* (Quenstedt, 1857) Fig. 25: 15) is the only vertebrate remain from our studied sections and outcrops. It was found in a bed of the Zillhausen Member of the Starzel river.

8. Conclusions

The consideration of small species results in a much higher diversity of the ostracod fauna of the Upper Aalenian in SW Germany than previously known. The Heiligenbach section and the Geisingen clay pit (Franz et al. 2018) yielded a total of 115 species from the Upper Aalenian (including the species 'incertae sedis'), 31 of which were recorded in both sections.

The uppermost Lower Aalenian is well characterized by the presence of *Aphelocythere pygmaea*, *Acrocythere pumila* and *Metacytheropteron opalinum*. *Eucytherura foveolata* and *Cardobairdia tesakovae* have also only been found in this part of the section so far. *Cytherella apostolescui* appears for the first time at the base of the Achdorf Formation. Higher up in the Achdorf Formation, especially from the Gigantea subzone on, several stratigraphically important species appear like *Balowella catena*, *Cytherelloidea lordi*, *Cytheropterina alacostata*, *Eucytherura eberti*, *Kinkelinella levata*, *Pleurocythere ohmerti*, *Procytherura multicostata*, and *Progonocythere scutula*.

Among the ostracod assemblages, cytherurids show the most striking development with the first appearance of five species in the Gigantea Subzone and 14 species in the Concavum Zone. During the same period the total number of genera increases from 7 (from 5 families) in the Bradfordensis Zone to 20 (9 families) in the Gigantea Subzone and 29 (13 families) in the Concavum Zone.

The variation within ammonites of the family Graphoceratidae in southwestern Germany reflects the evolution of Graphoceratidae from the *geisingensis* biohorizon via the *decipiformis* biohorizon (uppermost Bradfordensis Zone; see Dietze et al. 2014) to the here newly introduced *cavatum* biohorizon (basal Concavum Zone). The faunas gradually change in the successive biohorizons from the morphogenus *Brasilia* to the morphogenus *Graphoceras*, with numerous transitional forms and a gradual shift towards smaller, more involute and slender shells. In each biohorizon, the ammonites of the family Graphoceratidae

probably represent a single palaeobiospecies, the variation of which changes through time, whereas each morphospecies may range across several biohorizons. The integrative study of ammonite and ostracod faunas allows an excellent combination of both stratigraphic lines of evidence. This allows significantly improved correlations between sections and areas, where either ammonites or ostracods are absent or very rare.

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References

Ainsworth NR (1986) Toarcian and Aalenian Ostracoda from the Fastnet Basin, offshore south-west Ireland. Bulletin of the Geological Survey of Ireland 3: 277–336.

Ainsworth NR (1990) Uppermost Rhaetian to Lower Bajocian Ostracoda from the Porcupine, Slyne, Erris and Donegal basins, offshore west Ireland. Bulletin of the Geological Survey of Ireland 4: 168–200.

Ainsworth NR (1991) Stratigraphy of the Triassic, Lower Jurassic and Middle Jurassic (Aalenian) from the Fastnet Basin, offshore south-west Ireland. Marine and Petroleum Geology 8: 417–429. https://doi.org/10.1016/0264-8172(91)90064-8

Ainsworth NR, O'Neill M, Rutherford MM (1989) Jurassic and Upper Triassic biostratigraphy of the North Celtic Sea and Fastnet Basins. In: Batten DJ, Keen MC (Eds) Northwest European Micropalaeontology and Palynology. Ellis Horwood, Chichester, 44 pp.

Alexander CI (1929) Ostracoda of the Cretaceous of North Texas. University of Texas Bulletin 2907: 1–137.

Althoff W (1940) Die Ammonitenzonen der oberen Ludwigienschichten von Bielefeld. Palaeontographica A 92: 1–44.

Apostolescu V (1959) Ostracodes du Lias du Bassin de Paris. Revue de l'Institut Francais du Pétrole et Annales des Combustibles liquides 14(6): 795–826.

Arias C, Garcia-Frank A, Canales ML, Ureta S (2009) Ostracods from the global stratotype section for the base of the Aalenian stage, Jurassic, at Fuentelsaz section (Cordillera Ibérica, Spain). Rivista Italiana di Paleontologia e Stratigrafia 115: 209–232.

Baird W (1850) The natural history of the British Entomostraca. The Ray Society, London, 364 pp. https://doi.org/10.5962/bhl.title.1807

Ballent SC (1991) Ostrácodos del Jurásico medio (límite Aaleniano-Bayociano) en la Provincia del Neuquén, centro-oeste de Argentina. Revista Española de Micropaleontología 23(3): 21–56.

Ballent SC, Whatley R (2000) The distribution of the Mesozoic ostracod genus *Procytherura* Whatley: palaeogeographical implications with special reference to Argentina. Alcheringa 24(3): 229–242. https://doi.org/10.1080/03115510008619209

Ballent SC, Whatley RC (2009) Taxonomy and zoogeography of the Mesozoic cytherurid Ostracoda from West-Central Argentina. Palaeontology 52(1): 193–218. https://doi.org/10.1111/j.1475-4983.2008.00827.x

Bate RH (1963a) Middle Jurassic Ostracoda from North Lincolnshire. – Bulletin of the British Museum (Natural History) 8(4): 175–219.

Bate RH (1963b) Middle Jurassic Ostracoda from South Yorkshire. Bulletin of the British Museum (Natural History) 9(2): 21–46.

Bate RH (1964) Middle Jurassic ostracoda from the Millepore Series, Yorkshire. Bulletin of the British Museum (Natural History) 10(1): 1–33.

Bate RH (1965) Middle Jurassic ostracoda from the Grey Limestone Series, Yorkshire. Bulletin of the British Museum (Natural History) 11(3): 73–133.

Bate RH (1968) *Praeschuleridea ventriosa ventriosa* (Plumhoff) and *Paraschuleridea ornata* Bate [Ostracoda] from the Bajocian of N.E. England. Journal of Natural History 1968(2): 205–214. https://doi.org/10.1080/00222936800770841

Bate RH (1978) The Jurassic Part 2 (Aalenian to Bathonian). In: Bate RH, Robinson E (Eds) A stratigraphical index of British Ostracoda. Geological Journal, Special issues 8: 213–258.

Bate RH (2009) Middle Jurassic (Aalenian–Bathonian). In: Whittaker JE, Hart MB (Eds) Ostracods in British Stratigraphy. The Micropalaeontological Society, Special Publications. The Micropalaeontological Society, London, 199–233. https://doi.org/10.1144/TMS003.9

Bate RH, Coleman B (1975) Upper Lias ostracoda from Rutland and Huntingdonshire. Bulletin of the Geological Survey of Great Britain 55: 1–42.

Bayer U (1969) *Euaptetoceras* und *Eudmetoceras* (Ammonoidea, Hammatoceratidae) aus der concava-Zone (Ober-Aalenium) Süddeutschlands. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 133: 211–222.

Bayer U, Johnson ALA, Brannan J (1985) Ecological patterns in Middle Jurassic *Gryphaea*: The relationship between form and environment. Lecture Notes in Earth Sciences 1: 436–463. https://doi.org/10.1007/BFb0009855

Beisswenger H (1920) Beiträge zur Kenntnis der Schichten des Braunen Jura α–γ zwischen Kirchheim und Balingen. Dissertation Universität Tübingen [unpublished].

Bizon JJ (1960) Sur quelques ostracodes du Lias du Bassin Parisien. Revue de Micropaléontologie 2(4): 203–211.

Bodergat AM (1997) Les ostracodes marins du Jurassique Européen – Utilisation stratigraphique. In: Groupe française d'étude du Jurassique (Ed.) Biostratigraphie du Jurassique Ouest-Européen et Méditerranéen. Bulletin du Centre des Recherches Elf Exploration-Production, Mémoires 17: 197–223.

Bold WA van den (1960) Eocene and Oligocene ostracoda of Trinidad. Micropaleontology 6(2): 145–196. https://doi.org/10.2307/1484466

Boomer ID (1988) On *Ektyphocythere anterocosta* Boomer sp. nov. A Stereo-Atlas of Ostracod Shells 15: 93–96.

Boomer I, Ballent S (1996) Early–Middle Jurassic ostracod migration between the northern and southern hemispheres: further evidence for a proto Atlantic-Central American connection. Palaeogeography, Palaeoclimatology, Palaeoecology 121: 3–64. https://doi.org/10.1016/0031-0182(95)00049-6

Boomgaard WH (1948) Der Braunjura im Starzeltal. Neues Jahrbuch für Mineralogie, Geologie und Paläontologie Monatshefte Abt. B 1945–1948, 319–333.

Bradfield HH (1935) Pennsylvanian ostracoda of the Admore Basin, Oklahoma. Bulletins of American Paleontology 22(73): 1–173.

Brady GS (1868) A synopsis of the recent British Ostracoda. The Intellectual Observer 12: 110–130. https://doi.org/10.5962/bhl.title.84654

Brand E (1961) *Procytheridea triangula* n. sp. Brand. In: Brand E, Malz H (Eds) Ostracoden-Studien im Dogger, 3: Drei neue Procytheridea-Arten und *Ljubimovella* n. g. aus dem NW-deutschen Bajocien. Senckenbergiana Lethaea 42(1/2): 157–173.

Brand E (1990) Biostratigraphische Untergliederung des Ober-Bathonium im Raum Hildesheim, Nordwestdeutschland mittels Ostracoden und Korrelation ihrer Vertikalreichweiten mit Ammonitenzonen. Geologisches Jahrbuch A 121: 119–274.

Brand E, Malz H (1962) Ostracoden-Studien im Dogger, 4: *Fuhrbergiella* n. g. Senckenbergiana Lethaea 43(1): 1–39.

Brand E, Mönnig E (2009) Litho- und Biostratigraphie des Mittel-Jura (Dogger) in Bohrungen Norddeutschlands. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften 54: 5–73.

Buckman SS (1887–1907) A Monograph of the ammonites of the Inferior Oolite Series. Palaeontographical Society Monographs. The Palaeontographical Society, London, [ccixii +] 456 pp.

Cabral MC, Lord A, Boomer I, Loureiro I, Malz H (2014) *Tanycythere* new genus and its significance for Jurassic ostracod diversity. Journal of Paleontology 88(3): 519–530. https://doi.org/10.1666/13-127

Chandler RB (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.

Chandler RB (2019) A new ammonite faunal horizon in the Ovale Zone (Middle Jurassic, Lower Bajocian) and observations on the ammonite genus *Sonninia* at Coombe Quarry, Mapperton, near Beaminster, Dorset. Proceedings of the Geologists' Association 130: 772–791. https://doi.org/10.1016/j.pgeola.2019.10.004

Chandler RB, Callomon JH (2009) The Inferior Oolite at Coombe Quarry, near Mapperton, Dorset, and a new Middle Jurassic ammonite faunal horizon, Aa-3b, *Leioceras comptocostosum* n. biosp., in the Scissum Zone of the Lower Aalenian. Proceedings of the Dorset Natural History and Archaeological Society 130: 99–132.

Chandler RB, Dietze V, Auer W (2012) Die Graphoceratidae: *Leioceras* und seine Verwandten. Fossilien 2012/2: 110–119.

Chandler RB, Sole D (1996) The Inferior Oolite at East Hill Quarry, Bradford Abbas, Dorset. Proceedings of the Dorset Natural History and Archaeological Society 117: 101–108.

Contini D (1969) Les Graphoceratidae du Jura franc-comtois. Annales scientifiques de l'Université de Besançon, série 3, Géologie 7: 1–95.

Dépêche F (1985) Lias supérieur, Dogger, Malm. In: Oertli HJ (Ed.) Atlas des Ostracodes de France. Bulletin des Centres des Recherches Exploration-Production Elf-Aquitaine, Mémoires 9: 119–145.

Dietl G (2013) Der Braunjura am Fuß der Schwäbischen Alb. Fossilien, Sonderhefte 2013, 62 pp.

Dietze V, Rieber H, Auer W, Franz M, Schweigert G, Chandler RB, Rieter M, Chiarini R (2014) Aalenian (Middle Jurassic) ammonites and stratigraphy of the Geisingen clay pit (SW Germany). Palaeodiversity 7: 61–127.

Dietze V, Franz M, Kutz M, Waltschew A (2017a) Stratigraphy of the Middle Jurassic Sengenthal Formation of Polsingen-Ursheim (Nördlinger Ries, Bavaria, Southern Germany). Palaeodiversity 10: 49–95. https://doi.org/10.18476/pale.v10.a5

Dietze V, Rieber H, Wannenmacher N (2017b) Der *staufensis*-Horizont (Bradfordensis-Zone, Ober-Aalenium, Mittlerer Jura) am Plettenberg (westliche Schwäbische Alb, SW-Deutschland). Zitteliana 89: 235–252.

Dietze V, Schweigert G (2018) The *hansrieberi* biohorizon (Aalenian; Opalinum Zone) in the Opalinuston Formation of Donzdorf-Grünbach (Eastern Swabian Alb, Germany). Palaeodiversity 11: 29–57. https://doi.org/10.18476/pale.11.a4

Dietze V, Wannenmacher N, Franz M, Weis R (2019) Neue Erkenntnisse über die Wedelsandstein-Formation der Zollernalb (Schwäbische Alb, SW-Deutschland). Zitteliana 93: 47–81.

Dilger H (1963) Mikrofauna und Stratigraphie des Dogger beta Schwabens. Thesis, Universität Tübingen, 98 pp. [unpubl.]

Donze P (1975) *Tethysia*, nouveau genre d'ostracode bathyal du Jurassique supérieur – Crétacé inférieur mésogéen. Géobios 8(3): 185–190. https://doi.org/10.1016/S0016-6995(75)80037-4

d'Orbigny A (1850) Prodrome de paléontologie stratigraphique universelle des animaux mollusques et rayonnés. Masson, Paris, [IX + 394 +] 428 pp. https://doi.org/10.5962/bhl.title.62810

Erb H (1938) Die Geologie der Braun-Jura-Landschaft um Beuren bei Hechingen. Hohenzollerische Jahreshefte 5: 328–357.

Ernst M (1989) Bio- und Lithostratigraphie des Unter-Aalenium (Opalinumton) in der Tongrube von Feldberg bei Müllheim/Südbaden. Berichte der Naturforschenden Gesellschaft Freiburg i. Br. 77/78: 5–22.

Finger KL (1983) *Acrocythere michelseni*, a new name for *Acrocythere tricostata* Michelsen, 1975 (Ostracoda). Micropaleontology 28(1): 110–110. https://doi.org/10.2307/1485654

Fischer W (1961) Neue Arten der Ostracoden-Gattung *Polycope* Sars 1865 aus dem oberen Lias (Württemberg). Neues Jahrbuch für Geologie und Paläontologie, Monatshefte 1961(10): 497–501.

Fischer W (1962) Ostracoden der Gattungen *Monoceratina* Roth 1928, *Cytheropteron* G. O. Sars 1865 und andere im Lias zeta Schwabens. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 114(3): 333–345.

Franz M (1986) Vergleichende Ökologie und Fazies der Oolithhorizonte im Bajocium Südwestdeutschlands. PhD Thesis, Heidelberg University, 313 pp.

Franz M, Beher E, Dietl G (2014) The Bathonian and Early Callovian Ostracoda of Baden-Wuerttemberg, southern Germany. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 274(2/3): 149–185. https://doi.org/10.1127/0077-7749/2014/0431

Franz M, Ebert M, Stulpinaite R (2018) Aalenian – Early Bajocian (Middle Jurassic) ostracods from the Heiligenbach section near Hechingen, Swabian Alb (SW Germany). Palaeodiversity 11: 59–105. https://doi.org/10.18476/pale.11.a5

Franz M, Nitsch E (2009) Zur lithostratigraphischen Gliederung des Aalenium in Baden-Württemberg. LGRB Informationen 22: 123–146.

Franz M, Tesakova E, Beher E (2009) Documentation and revision of the index ostracods from the Lower and Middle Jurassic in SW Germany according to Buck (1954). Palaeodiversity 2: 119–167.

Fürsich FT, Werner W (1988) The Upper Jurassic Bivalvia of Portugal. Part I. Palaeotaxodonta and Pteriomorphia (Arcoida and Mytiloida). Comunicações dos Serviços Geológicos de Portugal 73: 103–144.

Géczy B (1967) Ammonoides jurassiques de Csernye, Montagne Bakony, Hongrie – Part II (excl. Hammatoceratidae). Geologica Hungarica, Series Palaeontologica 35: 1–413.

Gramann F (1963) *Liasina* n. gen. (Ostracoda) aus dem deutschen Lias. Geologisches Jahrbuch 82: 65–73.

Gründel J (1975) Zur Entwicklung der Trachyleberididae (Ostracoda) im Jura. Zeitschrift für Geologische Wissenschaften 3(3): 363–374.

Gründel J, Kozur H (1971) Zur Taxonomie der Bythocytheridae und Tricorninidae (Podocopida, Ostracoda). Monatsberichte der Deutschen Akademie der Wissenschaften zu Berlin 13(10/12): 907–937.

Hahn W (1975) Erläuterungen zu Blatt 7620 Jungingen. 1. Auflage, Geol. Kt. 1:25.000 Baden-Württemberg. Stuttgart (Landesvermessungsamt), 89 pp.

Harlton BH (1933) Micropaleontology of the Pennsylvanian Johns Valley shale of the Ouachita Mountains, Oklahoma, and its relationship to the Mississippian Caney Shaler. Journal of Paleontology 7(1): 3–29.

Henriques MH (1992) Biostratigrafia e Paleontologia (Ammonoidea) do Aaleniana em Portugal (Sector Setentrinal da Bacia Lusitaniana). Ph. D. Thesis. Centro de Geociencias da Universidade de Coimbra, Portugal, 301 + 7 pp.

Hiller D, Kunze T (1979) Der Braune Jura β (Ober-Aalenium) zwischen Nürtingen und Owen (Württemberg). Arbeiten aus dem Institut für Geologie und Paläontologie der Universität Stuttgart NF 74: 141–163.

Hoffmann G (1913) Stratigraphie und Ammoniten-Fauna des Unteren Doggers in Sehnde bei Hannover. Stuttgart, Schweizerbart, 202 pp.

Horn E (1909) Die Harpoceraten der Murchisonae-Schichten des Donau-Rhein-Zuges. Mitteilungen der Grossherzoglichen Badischen Geologischen Landesanstalt 6: 251–323.

Hornibrook N de B (1952) Tertiary and recent marine ostracoda of New Zealand. Their origin, affinities, and distribution. Palaeontological Bulletins, New Zealand Geological Survey 18: 1–82.

Howarth MK (2013) Treatise Online 57. Part L, Revised, Vol. 3B, Chapter 4: Psiloceratoidea, Eodoceratoidea, Hildoceratoidea, 1–139. https://doi.org/10.17161/to.v0i0.4441

Howe HvW, Laurencich L (1958) Introduction to the study of Cretaceous ostracoda. Louisiana State University Press, Baton Rouge, 536 pp.

Hyatt A (1867) The fossil cephalopods of the Museum of Comparative Zoology. Bulletin of the Museum of Comparative Zoology 1: 71–102.

Johnson ALA (1984) The palaeobiology of the bivalve families Pectinidae and Propeamussiidae in the Jurassic of Europe. Zitteliana 11: 3–235.

Jones TR (1849) A monograph of the Entomostraca of the Cretaceous Formation of England. Annual Volumes (Monographs) of the Palaeontographical Society 3(1): [I–IV,] 1–40. https://doi.org/10.1080/02693445.1850.12088362

Jones TR, Sherborn CD (1888) On some ostracoda from the Fullers-Earth oolite and Bradford clay. Proceedings of the Bath Natural History and Antiquarian Field Club 6(3): 249–278.

Kobler HU (1972) Geochemische, sedimentologische und ökologische Untersuchungen im Braunen Jura alpha (Opalinuston) der Schwäbischen Alb. Arbeiten aus dem Geologisch-Paläontologischen Institut der Universität Stuttgart NF 66: 134 pp.

Kochhann KGD, Bergue CT, Falahatgar M, Javidan M, Parent H (2015) Benthic foraminifera and Ostracoda from the Dalichai Formation (Aalenian–Bajocian) at Delma-Dareh, Alborz Mountains, northern Iran. Revista Brasileira de Paleontologia 18(1): 3–20. https://doi.org/10.4072/rbp.2015.1.01

Kovács Z (2009) Toarcian – Aalenian Hammatoceratinae (Ammonitina) from the Gerecse Mts (NE Transdanubian Range, Hungary). Fragmenta Palaeontologica Hungarica 27: 1–72.

Lamarck JPBA de (1819) Histoire naturelle des animaux sans vertèbres. Tome sixième, 1re partie. Déterville et Verdière, Paris, 232 pp.

Ljubimova PS (1955) Ostrakody Mezozoyskikh otlozheniy srednego Povolzhya i obshchego Syrta. Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Instituta (VNIGRI), novaya seriya 84: 3–189.

Lörcher E (1939) Die Stratigraphie von Braun-Jura (Dogger) β und Ober-α im südwestlichen Württemberg. Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg 95: 145–230.

Lord AR, Cabral MC, Danielopol DL (2020) Sieve-type normal pore canals in Jurassic ostracods: A review with description of a new genus. Acta Palaeontologica Polonica 65(X): 1–37. https://doi.org/10.4202/app.00632.2019

Luppold FW (2003) Neue und seltene Index-Foraminiferen und -Ostrakoden aus dem Jura NW-Deutschlands. Senckenbergiana lethaea 83(1/2): 15–37. https://doi.org/10.1007/BF03043303

Luppold FW (2012) Ostracod assemblages from the Middle Jurassic of NW Germany with special reference to the Sowerbyi ammonite Zone (Early Bajocian, Jurassic). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 266(3): 217–238. https://doi.org/10.1127/0077-7749/2012/0280

Malz H (1966) Zur Kenntnis einiger Ostracoden-Arten der Gattungen *Kinkelinella* und *Praeschuleridea*. Senckenbergiana Lethaea 47(4): 385–404.

Mandelstam MI (1956) Ostracoda. In: Kiparisova, Markovski, Radchenko (Eds) Materialy po Paleontologii. Novie semeystva I rody. Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatelskogo Geologicheskogo Instituta (VSEGEI), novaya seriya 12: 87–144.

Mandelstam MI (1959) Ostrakody iz otlozheniy Paleogena sredney Azii. Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Instituta (VNIGRI), novaya seriya 136: 442–543.

Martin GPR (1960) 3. Die Mikrofauna. In: Hoffmann K, Martin GPR (Eds) Die Zone des *Dactylioceras tenuicostatum* (Toarcien, Lias) in NW- und SW-Deutschland. Paläontologische Zeitschrift 34: 119–132. https://doi.org/10.1007/BF02987046

Morris PH (1983) Palaeoecology and stratigraphic distribution of Middle Jurassic ostracods from the Lower Inferior Oolite of the Cotswolds, England. Palaeogeography, Palaeoclimatology, Palaeoecology 41: 289–324. https://doi.org/10.1016/0031-0182(83)90092-5

Müller GW (1894) Ostracoden des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Fauna und Flora des Golfes von Neapel und der angrenzenden Meeres-Abschnitte 21: [I–VIII,] 1–404.

Müller GW (1912) Crustacea: Ostracoda. Das Tierreich 31: [I–XXXIII,] 1–434.

Neale JW (1960) Marine lower Cretaceous ostracoda from Yorkshire, England. Micropaleontology 6(2): 203–224. https://doi.org/10.2307/1484468

Oertli HJ (1957) Ostracodes du Jurassique supérieur du Bassin de Paris (sondage Vernon 1). Revue de l'institut francais du pétrole et annales des combustibles liquides 12(6): 647–695.

Oertli HJ (1959) Malm-Ostrakoden aus dem Schweizerischen Juragebirge. Denkschriften der Schweizerischen Naturforschenden Gesellschaft 83(Abh. 1): [I–IV,] 1–44.

Ohmert W (1981) Fossilfunde aus der Freiburger Umgebung. Der Aufschluss 32: 379–390.

Ohmert W (1993) Zur Entwicklung der Grammoceratinae – Leioceratinae an der Toarcium-Aalenium-Grenze Südwestdeutschlands. Geologische Blätter für Nordost-Bayern und angrenzende Gebiete 43: 143–166.

Ohmert W (1996) 3.5.6.3 Ostracoden. In: Geologisches Landesamt Baden-Württemberg (Ed.) Die Grenzziehung Unter-/Mitteljura (Toarcium/Aalenium) bei Wittnau und Fuentelsaz – Beispiele interdisziplinärer Zusammenarbeit. Informationen 8: 39–40.

Ohmert W (2004) Ammoniten-Faunen im tiefen Unter-Bajocium des Reutlinger Gebiets (mittlere Schwäbische Alb) [mit einem Beitrag zur Ostracoden-Stratigraphie]. Jahreshefte des Landesamts für Geologie, Rohstoffe und Bergbau in Baden-Württemberg 40: 9–141.

Plumhoff F (1963) Die Ostracoden des Oberaalenium und tiefen Unterbajocium (Jura) des Gifhorner Troges, Nordwestdeutschland. Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft 503: 1–100.

Quenstedt FA (1843) Das Flözgebirge Würtembergs. Tübingen (Laupp), [iv +] 558 pp.

Quenstedt FA (1856–1857) Der Jura. Stuttgart (Schweizerbart), [vi +] 842 pp.

Quenstedt FA (1886) Die Ammoniten des Schwäbischen Jura. 2. Der Braune Jura. Stuttgart (Schweizerbart), 441–672.

Reisdorf A, Hostettler B, Jaeggi D, Deplazes G, Bläsi H, Morard A, Feist-Burkhardt S, Waltschew A, Dietze V, Menkveld-Gfeller U (2016) Litho- and biostratigraphy of the 250 m-deep Mont Terri BDB-1 borehole through the Opalinus Clay and bounding formations, St-Ursanne, Switzerland. Mont Terri Project, Technical Report 2016-02, 59 pp.

Rieber A (1922) Die neuen Braun-Jura-Aufschlüsse bei Zillhausen im Vergleich mit den Nachbargebieten. Dissertation Universität Tübingen, 120 pp. [unpubl.]

Rieber A (1961) Drei neue Braunjura β-Profile in der Mittleren Alb. In: Einsele H, Seibold H (Eds) Die geologische Kartierung der Rohrgräben beim Bau der Bodensee-Fernwasserversorgung. Jahreshefte des geologischen Landesamtes Baden-Württemberg 4: 251–254.

Rieber H (1963) Ammoniten und Stratigraphie des Braunjura β der Schwäbischen Alb. Palaeontographica A 122: 1–89.

Roemer F (1857) Die jurassische Weserkette. Zeitschrift der Deutschen Geologischen Gesellschaft 9: 581–728.

Rollier L (1912) Fossiles nouveaux ou peu connus des terrains secondaires (mésozoiques) du Jura et de contrées environnantes. Mémoires de la Société Paléontologique Suisse: 2. partie: 38: 33–148.

Roth R (1928) Monoceratina: A new genus of ostracoda from the Pennsylvanian of Oklahoma. Journal of Paleontology 2(1): 15–19.

Sandoval J, Martinéz G, Ureta S (2020) Hammatoceratidae (Ammonitina) from the Upper Toarcian–Lowermost Bajocian (Jurassic) of the Betic Cordillera (Southern Spain). Palaeontographica A315, 4–6: 1–65. https://doi.org/10.1127/pala/2020/0092

Sanns M, Schweizer V (1987) Zur Fazies und Genese des Ober-Aalenium (Braunjura ß) der südwestlichen Schwäbischen Alb. Jahreshefte des Geologischen Landesamtes in Baden-Württemberg 29: 125–143.

Sars GO (1866) Oversigt af Norges marine ostracoder. Forhandlinger i videnskabs-selskabet i Christiania 1865: 1–130.

Sars GO (1888) Nye bidrag til Kundskaben om Middelhavets invertebratfauna: 4. Ostracoda mediterranea (sydeuropaeiske ostracoder). Archiv for Mathematik og Naturvidenskab 12: 173–324. https://doi.org/10.5962/bhl.title.10252

Sars GO (1923) An account of the crustacean of Norway with short descriptions and figures of all the species, vol. 9 (Ostracoda), parts 3–4: 33–72.

Sars GO (1925) An account of the crustacean of Norway with short descriptions and figures of all the species, vol. 9 (Ostracoda), parts 5–12: 73–208.

Sars GO (1926) An account of the crustacean of Norway with short descriptions and figures of all the species, vol. 9 (Ostracoda), parts 13–14: 209–240.

Schlotheim EF von (1820) Die Petrefactenkunde auf ihrem jetzigen Standpunkte durch die Beschreibung seiner Sammlung versteinerter und fossiler Überreste des Thier- und Pflanzenreichs der Vorwelt erläutert. Gotha (Becker'sche Buchhandlung), [LXI +] 437 pp.

Schmierer T (1925) Blatt Hechingen (Bodelshausen) Nr. 3640. Erläuterungen zur Geologischen Karte von Preußen und benachbarten deutschen Ländern. Preußische Geologische Landesanstalt, Berlin, 68 pp.

Schmierer T (1926) Blatt Thanheim (Balingen). Nr. 3648. Erläuterungen zur Geologischen Karte von Preußen und benachbarten deutschen Ländern. Preußische Geologische Landesanstalt, Berlin, 64 pp.

Schmidt M (1933) Blatt Mössingen (Nr. 109). Erläuterungen zur geologischen Spezialkarte von Württemberg. Württembergisches Statistisches Landesamt, Stuttgart, 184 pp.

Schulbert C (2001) Die Ammonitenfauna und Stratigraphie der Tongrube Mistelgau bei Bayreuth (Oberfranken). Beihefte zu den Berichten der Naturwissenschaftlichen Gesellschaft Bayreuth e. V. 4: 1–20.

Schweigert G, Etter W (2008) On the true nature of the supposed urodelan amphibian *Boomgaardia* v. Huene, 1948 from the Middle Jurassic of SW Germany – a tanaidacean! – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 248: 123–127. https://doi.org/10.1127/0077-7749/2008/0248-0123

Sheppard LM (1981) Middle Jurassic Ostracoda from Southern England and Northern France. PhD Thesis, University of London, [XVII +] 214 pp. [unpublished]

Sowerby J (1812–1822) The Mineral Conchology of Great Britain. Meredith, London 1(1): 9–32 (1812); 1(2): 33–96 (1813); 1(3): 97–178 (1814); 179–236 (1815); 2(1): 1–28 (1815); 2(2): 29–116 (1816); 2(3): 117–194 (1817); 2(4): 195–239 (1818); 3(1): 1–40 (1818); 3(2): 41–98 (1819); 3(3): 99–126 (1820); 3(4): 127–186; 4(1): 1–16 (1821); 4(2): 17–104 (1822).

Sowerby J de C (1822–1845) The Mineral Conchology of Great Britain. Meredith, London, 4(3): 105–114 (1822); 4(4): 115–151 (1823); 5(1) 1–64 (1823); 5(2): 65–138 (1824); 5(3): 139–171 (1825);

6(1): 1–86 (1826); 6(2): 87–156 (1827); 6(3): 157–200 (1828); Preface to general indices: 239–250 (1835); Alphabetical index to vol.1–6: 1–11 (1840); 7(1): 1–8 (?1840); 7(2): 9–16 (1841): 7(3): 17–24 (1843); 7(4): 25–56 (1844); 7(5): 57–80 (1846).

Spath LF (1936) On Bajocian ammonites and belemnites from eastern Persia (Iran). Palaeontologica Indica. Memoirs of the Geological Survey of India. New series 22, Memoir 3: 1–21.

Stahlecker R (1926) Brauner Jura und Tektonik im Kirchheim-Uracher Vulkangebiet. Neues Jahrbuch für Mineralogie, Geologie und Paläontologie. Beilage-Band 54: 157–258.

Stahlecker G (1934) Stratigraphie und Tektonik des Braunen Jura im Gebiet des Stuifen und Rechberg. Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg 90: 59–121.

Swain FM (1952) Ostracoda from wells in North Carolina, part 2: Mesozoic ostracoda. United States Geological Survey professional paper 234 B: [I–III,] 59–93. https://doi.org/10.3133/pp234B

Sylvester-Bradley PC (1948) Bathonian ostracods from the Boueti bed of Langton Herring, Dorset. Geological Magazine 85(4): 185–204. https://doi.org/10.1017/S001675680007309X

Tesakova EM (2017) Biostratigraphie du Jurassique moyen des sondages Benken et Schlattingen-1 (Nord de la Suisse) établie sur la base de la répartition des ostracodes. NAGRA NAB 17–41, 79 pp.

Triebel E (1950) *Camptocythere*, eine neue Ostracoden-Gattung aus dem Dogger Norddeutschlands. Senckenbergiana 31(3/4): 197–208.

Triebel E (1951) Einige stratigraphisch wertvolle Ostracoden aus dem höheren Dogger Deutschlands. Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft 485: 87–101.

Triebel E, Bartenstein H (1938) Die Ostracoden des Deutschen Juras – 1: Monoceratina-Arten aus dem Lias und Dogger. Senckenbergiana 20(6): 502–518.

Triebel E, Klingler W (1959) Neue Ostracoden-Gattungen aus dem deutschen Lias. Geologisches Jahrbuch 76: 335–371.

Tröster J (1987) Biostratigraphie des Obertoarcium und der Toarcium/Aalenium-Grenze der Bohrungen Weiach, Beznau, Riniken und Schafisheim (Nordschweiz). Eclogae geologicae Helvetiae 80(2): 431–447.

Ureta Gil S (1983) Bioestratigrafia y Paleontologia (Ammonitina) del Aaleniense en el sector noroccidental de la Cordillara Iberica. Unpublished Ph. D. Thesis, Universidad Complutense de Madrid, [VIII +] 452 pp.

Whatley RC (1970) Scottish Callovian and Oxfordian Ostracoda. Bulletin of the British Museum (Natural History), Geology 19(6): 299–358.

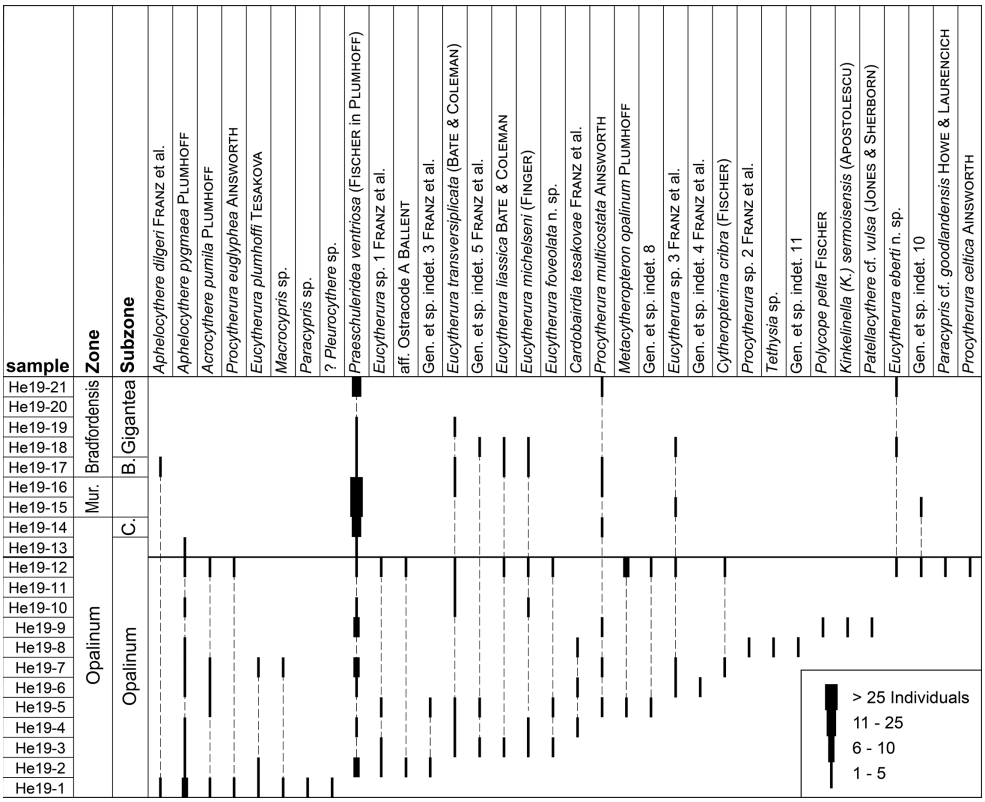
Whittaker JE, Hart MB (2009) Ostracods in British Stratigraphy. The Micropalaeontological Society, Special Publications, London [The Geological Society], 485 pp.

Wienholz E (1967) Neue Ostracoden aus dem norddeutschen Callov. Freiberger Forschungshefte, Reihe C (Paläontologie) 213: 23–51.

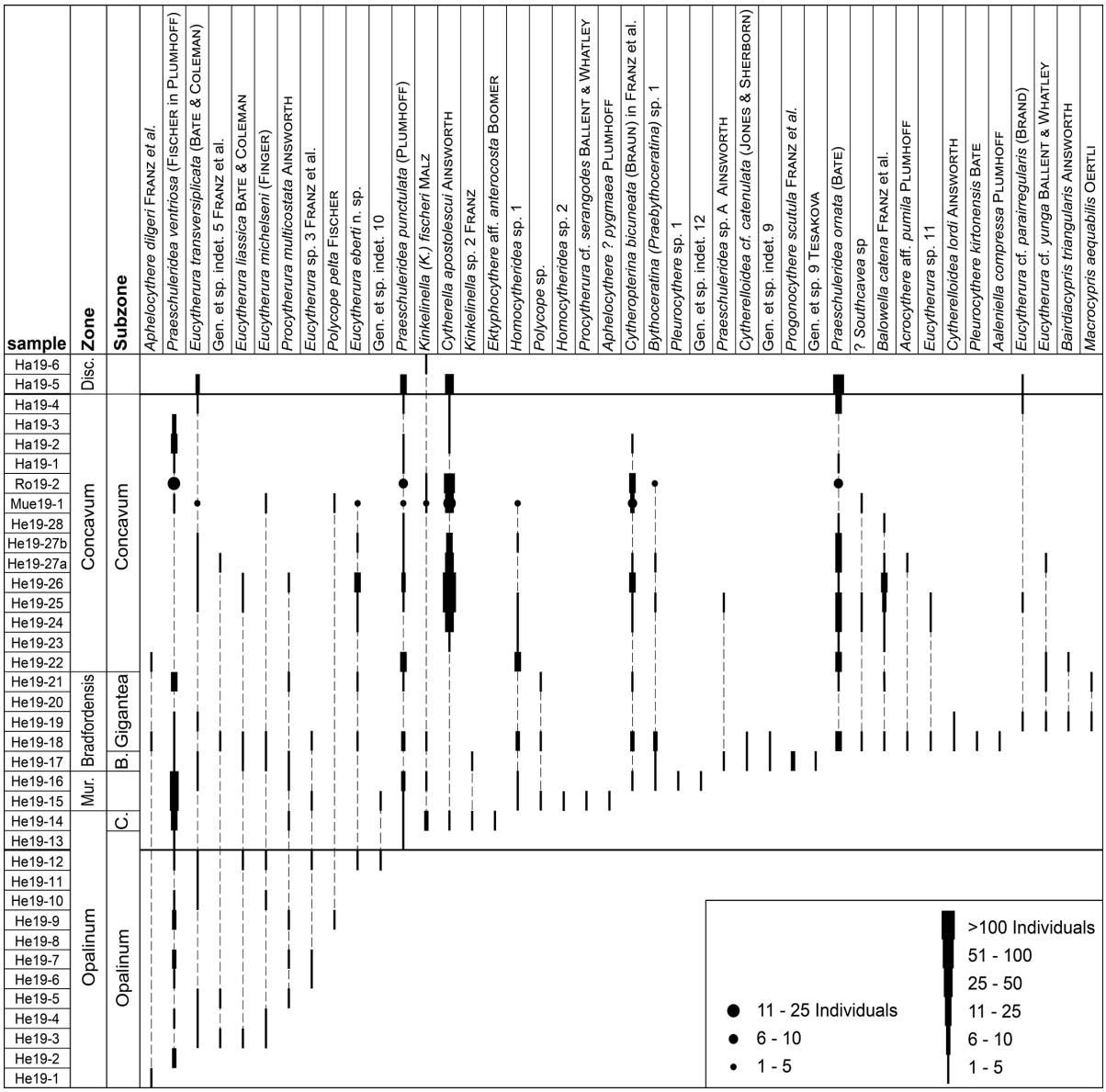
Young G, Bird J (1828) A geological survey of the Yorkshire coast: describing the strata and fossils occurring between the Humber and the Tees, from the German Ocean to the plain of York. Whitby [published by the authors].

Zieten CH von (1830–1833) Die Versteinerungen Württembergs. Stuttgart (Schweizerbart), 102 pp.

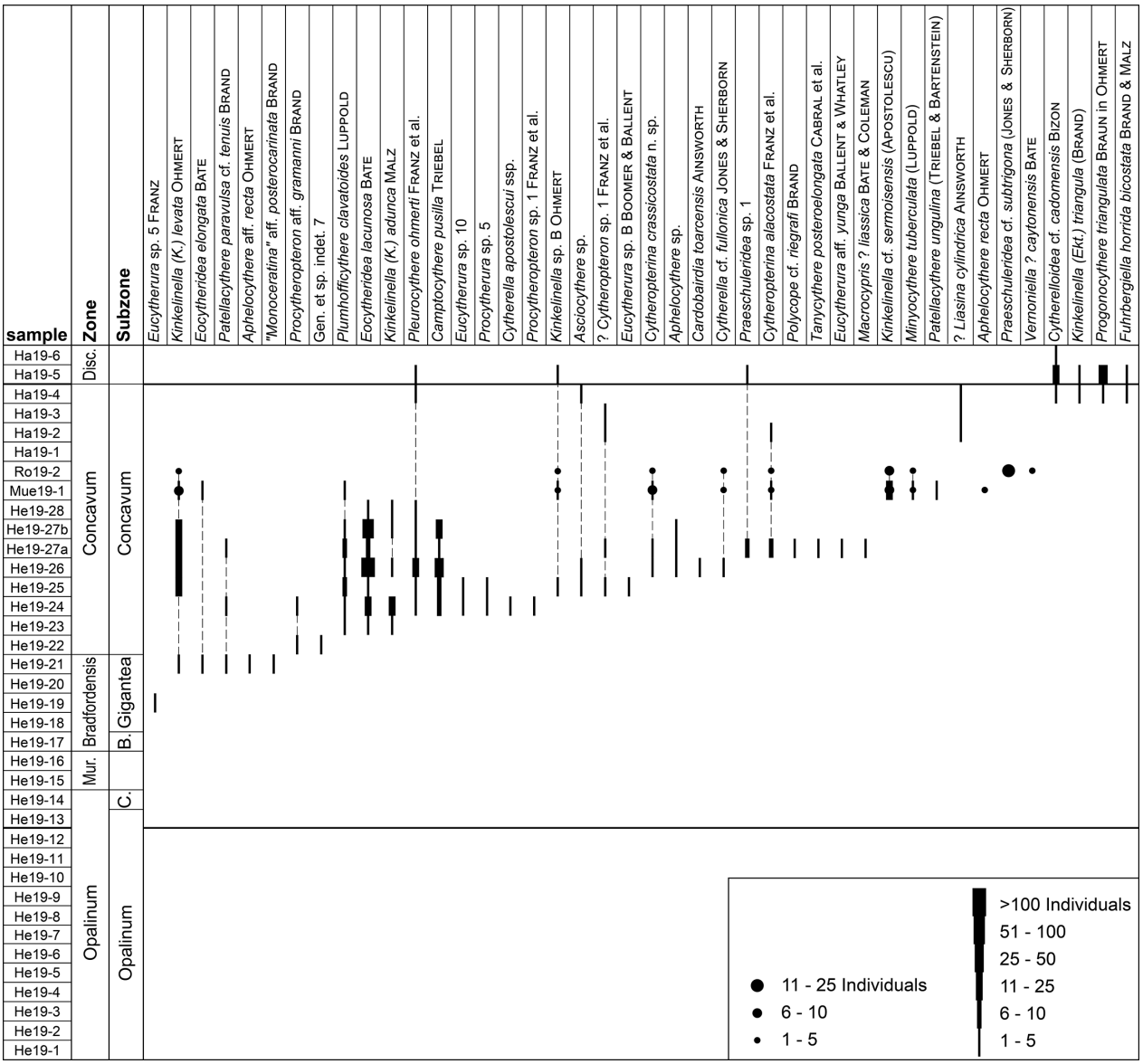
Appendices



Appendix 1. Range chart of all taxa in the Opalinuston Formation determined to the specific level. Single representatives of a genus are also listed, even when the species in unkown.



Appendix 2. Range chart of all taxa in the Achdorf Formation determined to the specific level. Species persisting from the Opalinuston Formation are also shown.



Appendix 2. Continued.

Addendum

After submission of the original draft of this manuscript, the "Comptum" Subzone of the Opalinum Zone has been renamed Bifidatum Subzone, and the number of distinguished biohorizons in the Opalinum Zone (Opalinum and Bifidatum subzones) (Fig. 26) has remarkably increased (see Dietze V, Gräbenstein S, Franz M, Schweigert G, Wetzel A (2021) The Middle Jurassic Opalinuston Formation (Aalenian, Opalinum Zone) at its type locality near Bad Boll and adjacent outcrops (Swabian Alb, SW Germany). Palaeodiversity 15: 14–113, published online 05 March 2021). These changes could not be included in the present paper and have to be considered.