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The *hansrieberi* biohorizon (Aalenian; Opalinum Zone) in the Opalinuston Formation of Donzdorf-Grünbach (Eastern Swabian Alb, Germany)

Volker Dietze & Günter Schweigert

Abstract

The lithostratigraphy and ammonite fauna of the Early Aalenian Opalinuston Formation (Zillhausen Member) at Donzdorf-Grünbach is described. A new chronospecies of *Leioceras*, *L. hansrieberi*, is erected. It characterizes the *hansrieberi* biohorizon of the Opalinum Subzone (Opalinum Zone). The macroconchs of *L. hansrieberi* represent the largest specimens hitherto described within the genus *Leioceras*. In addition, the associated macrofauna is described which allows to draw some conclusions on the palaeoecology of this locality.

Keywords: Opalinum Zone, Aalenian, ammonites, biostratigraphy, palaeoecology.

1. Introduction

At a thickness of approximately 100 metres, the Opalinuston Formation is the thickest lithostratigraphical unit in the Middle Jurassic of southwestern Germany and adjacent Switzerland. This thickness is remarkable, as it represents only a single ammonite subzone, the Opalinum Subzone of the Lower Aalenian Opalinum Zone, indicating comparatively very high rates of sedimentation during a short time interval. The Opalinuston Formation crops out in the northern foreland of the Swabian Alb. Formerly the claystones were exploited in several clay pits of brickyards (Hechingen-Schlatt, Heiningen, Essingen). Nowadays these brickyards are abandoned and almost only natural outcrops in small gorges or temporary outcrops still exist. The best areas in the Swabian Jurassic to study the Opalinuston Formation are the vicinities of Bad Boll and Donzdorf (Fig. 1). The lower part of the formation can be studied in the still open clay pit of Weilen unter den Rinnen near Schömberg. The Opalinuston Formation is divided lithostratigraphically into the clay-rich Teufelsloch Member below and the more silty/sandy Zillhausen Member above (Franz & Nitzsch 2009). In older regional literature, the Zillhausen Member is also known as "Wasserfallschichten". Modern biostratigraphical details of the Opalinuston Formation based on ammonites have been reported in discussions in regard to the designation of the Aalenian Stage GSSP (Ohmert 1993). After the ratification of a global stratotype for the Aalenian (Cresta et al. 2001) it appeared that basal parts of the Opalinuston Formation are still Late Toarcian in age, lacking *Leioceras opalinum*. Comments on the biostratigraphical subdivision of higher parts of this formation have been presented by Ohmert (2003, with references therein).

Following description of the higher part of the Teufelsloch Member of the Opalinuston Formation exposed at Donzdorf-Hochdorf (Dietze & Schweigert 2016) we continue with descriptions of the fauna of this formation in the Swabian Jurassic. In this study, we focus on the lower part of the Zillhausen Member at Donzdorf-Grünbach (Fig. 1). Two sections have been studied, which are located less than 2 kilometres away from each other, and provide a good composite profile (Fig. 2). At Donzdorf-Hochdorf the upper part of the Teufelsloch Formation was temporarily exposed during road constructions. In that part of the section, ammonites and bivalves are preserved with their aragonitic shells. In contrast, a natural exposure in the Lauter stream at Donzdorf-Grünbach exposes the lower part of the Zillhausen Member directly overlying the Teufelsloch Member. In the latter section, the aragonitic shells of ammonites and of some bivalves are completely replaced by brownish calcite.

2. Previous studies

Previously Engel (1908) cited the occurrence of well-preserved macrofossils in the upper part of the Opalinuston Formation at Grünbach (now part of the township of Donzdorf), particularly abundant specimens of the infaunal bivalve *Scaphotrigonia navis*. Rieber (1963, pl. 8, figs. 2, 3) and Hegele (1995, fig. 4) illustrated a specimen of the rare Tethyan guide ammonite *Tmetoceras* cf. *scissum* (Benecke). This specimen is now stored in the collection of the Staatliches Museum für Naturkunde Stuttgart (SMNS 70327; Fig. 6). Another small *Tmetoceras* cf. *scissum* from Grünbach was illustrated in Geyer & Gwinner (1964, pl. 7, fig. 3). A further specimen is on display in the

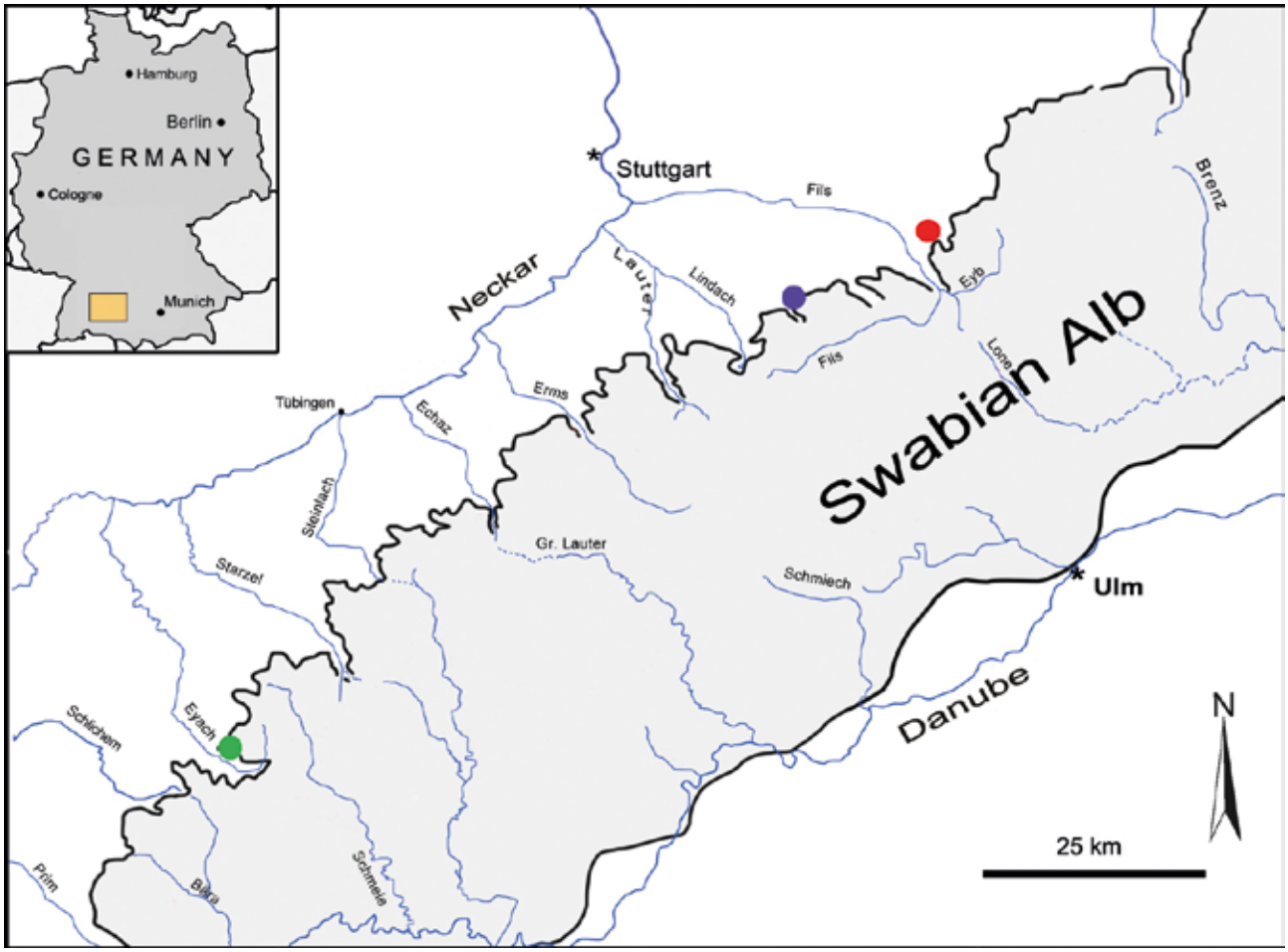


Fig. 1. Location of important outcrops of the lower Aalenian Opalinuston Formation. Red point: Donzdorf-Grünbach, violet point: Bad Boll, green point: Balingen-Zillhausen.

permanent exhibition of the Engel-Museum in Göppingen-Jebenhausen and a fragmentary example is in the private collection of W. Dangelmaier (Lauterstein-Nenningen). Hegele (1992, 2009) illustrated various ammonites, bivalves and decapod crustaceans from Grünbach.

3. Material and geological setting

During recent years numerous ammonites have been collected bed-by-bed in the vicinity of Grünbach. The different preservational states of this material, which results from an upwardly increasing sand content of the claystones, allows us to place these specimens confidently in their horizons of occurrence. The bulk of fossils in private and public collections labelled "Grünbach" come from the higher part of Bed 1 (Fig. 2). Besides ammonites this bed yields well-preserved specimens of *Scaphotrigonia navis*, other endobenthic bivalves and decapod crustaceans, which made this locality well-known among fossil-hunters. However, ammonites have not been the focus of their sampling activities, because in most specimens from Grünbach the phragmocone is missing or at least strongly compressed, and only the body chambers are three-dimensionally preserved. The ammonites from Bed 1 are generally preserved with brownish calcitic shells.

For the construction of a factory building in Grünbach (see Engel 1908) the Lauter stream was artificially diverted into a new streambed (pers. comm. W. Dangelmaier). Until several decades ago, the lower concretionary limestone layer (Bed 2) formed a small waterfall. It was easy to dig there for fossils during summertime, when the water level was low. However, more recently the deposits of the stream accumulated and formed a thick pebble bed so that the water level is now permanently above Bed 2. As a result, this well-known location is now inaccessible. Only two small landslides located further downstream allowed us to measure the section around Bed 1

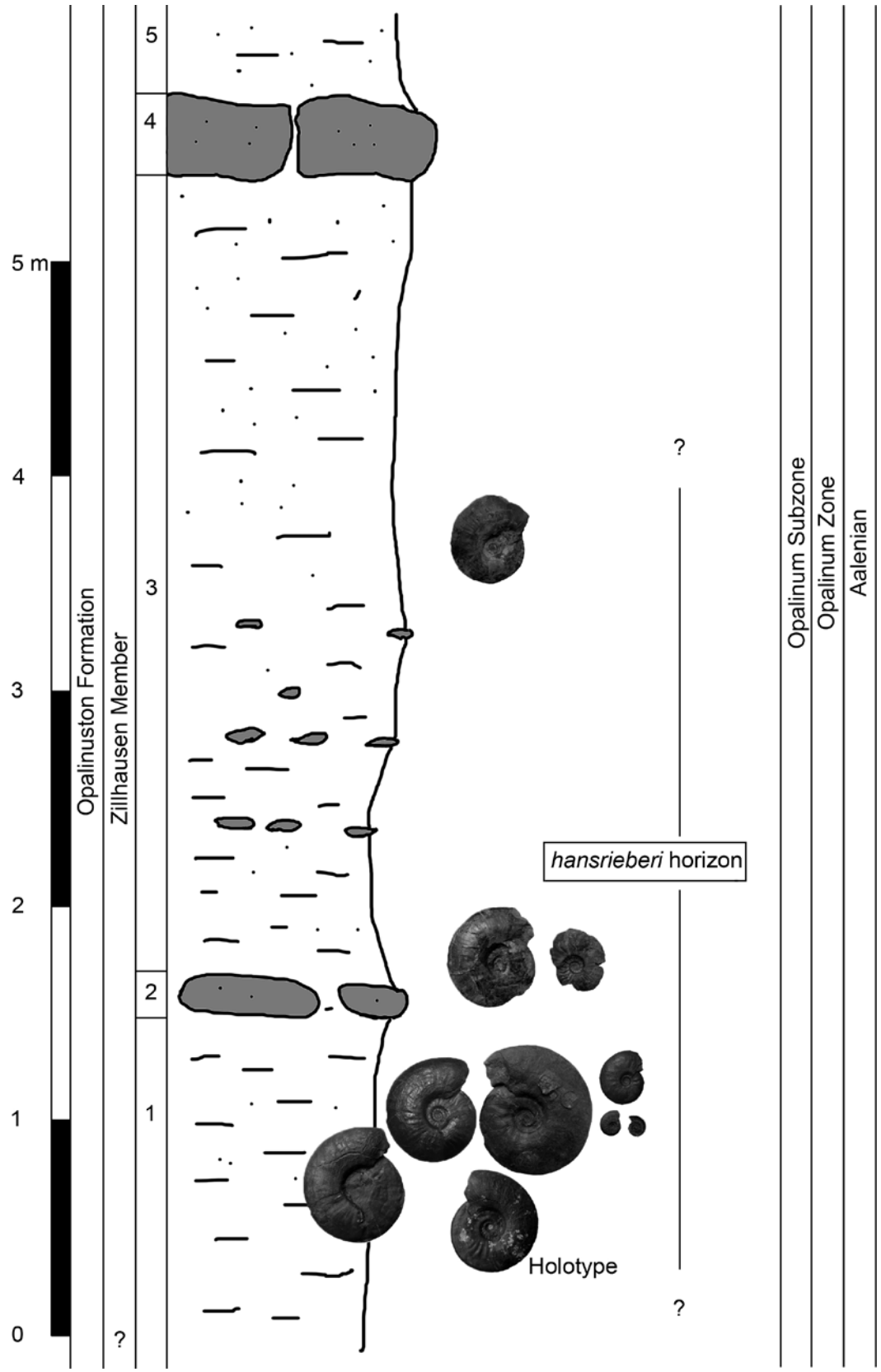


Fig. 2. Section in the lower part of the Zillhausen Member (Opalinuston Formation, Lower Aalenian) of Donzdorf-Grünbach.

and to make additional ammonite and bivalve collections from this level.

The illustrated specimens of this study are housed in the collection of the Stuttgart Natural History Museum (acronym: SMNS).

4. Lithostratigraphic section

4.1. Opalinuston Formation

Teufelsloch Member

Isolated outcrops of the Teufelsloch Member occur along the meandering Lauter stream between the village Grünbach and the small town Donzdorf. We could not record any ammonites there; only some remains of bivalves with white aragonitic shells occurred. The transition from the Teufelsloch Member to the overlying Zillhausen Member is well-marked by a shift from white aragonitic to brown calcitic shells. This change of preservation is caused by an upwardly increasing sand content of the claystones (Andalib 1970). The exact transition is not exposed along the Lauter stream, but it must be located somewhere around the bridge at the western margin of the village Grünbach. This is suggested by the find of a bivalve with aragonitic shell only a few meters downstream of the location of the bridge by W. Dangelmaier.

Zillhausen Member (Fig. 2)

Bed 1 (ca. 1.5 m of this bed was observed when the water level was low):
Grey to brownish, slightly sandy micaceous claystone, with laminated appearance in the uppermost 0.15 m. Ammonites and bivalves with brown calcitic shells are abundant in the uppermost 0.5–0.6 m; occasionally they occur until 1 m below the top of Bed 1. The highest abundance is located ca. 0.2–0.3 m below Bed 2.

Bed 2 (0.15–0.2m):
Grey, firm, slightly sandy bed with limestone concretions (0.2–0.5 m in diameter) weathering with a reddish-brown crust. In former years, this calcareous bed had formed a small waterfall.

Bed 3 (3.7 m):
Calcareous marls, becoming upwards more and more sandy, contain a well-marked limestone concretion layer (thickness ca. 0.05 m) ca. 0.7 m above Bed 2, a second layer with flat limestone concretions ca. 1.1–1.2 m above Bed 2, and a third layer with rare concretions ca. 1.6–1.7 m above Bed 2. Slightly crushed leioceratids and trigoniid bivalves preserved with calcitic shells occur within the basal 0.2 m of Bed 3 (Pl. 7, Figs. 1–3). Internal moulds of body chambers of relatively large-sized leioceratids occur rarely in the interval between ca. 1.7–3 m above the basis of Bed 3 (Pl. 8, Figs. 1–4).

Bed 4 (0.3 m):
Firm, continuous bed of calcareous sandstone; no fossils were recorded. Above follow sandy calcareous marlstones (Bed 5), the thickness of which is unknown.

5. Description of the ammonite fauna

Remarks: More than 99% of all ammonites are represented by the genus *Leioceras*. In macroconchs only the body chamber is three-dimensionally preserved, whereas the phragmocone is either more or less compressed (e.g., Pl. 2, Figs. 1, 2) or totally missing (e.g., Pl. 1, Figs. 1, 8). In contrast, the microconchs are preserved with a three-dimensional phragmocone and their body chamber is compressed or missing (Pl. 1, Figs. 4–7, 9–13). We can present at the moment no explanation for this different preservation of the microconchs and macroconchs, respectively.

Besides the Teufelsloch gorge near Bad Boll (Fig. 1), which is the type locality of the Teufelsloch Member, the Lauter streambed in Grünbach is the only locality of the Opalinuston Formation from which specimens of the Tethyan ammonite *Tmetoceras scissum* (Figs. 4–6) have been recorded.

Abbreviations: D – diameter; Uw – umbilical width; Wh – whorl height; Wb – whorl breadth; SMNS – Staatliches Museum für Naturkunde Stuttgart, Germany.

Family Graphoceratidae Buckman, 1905

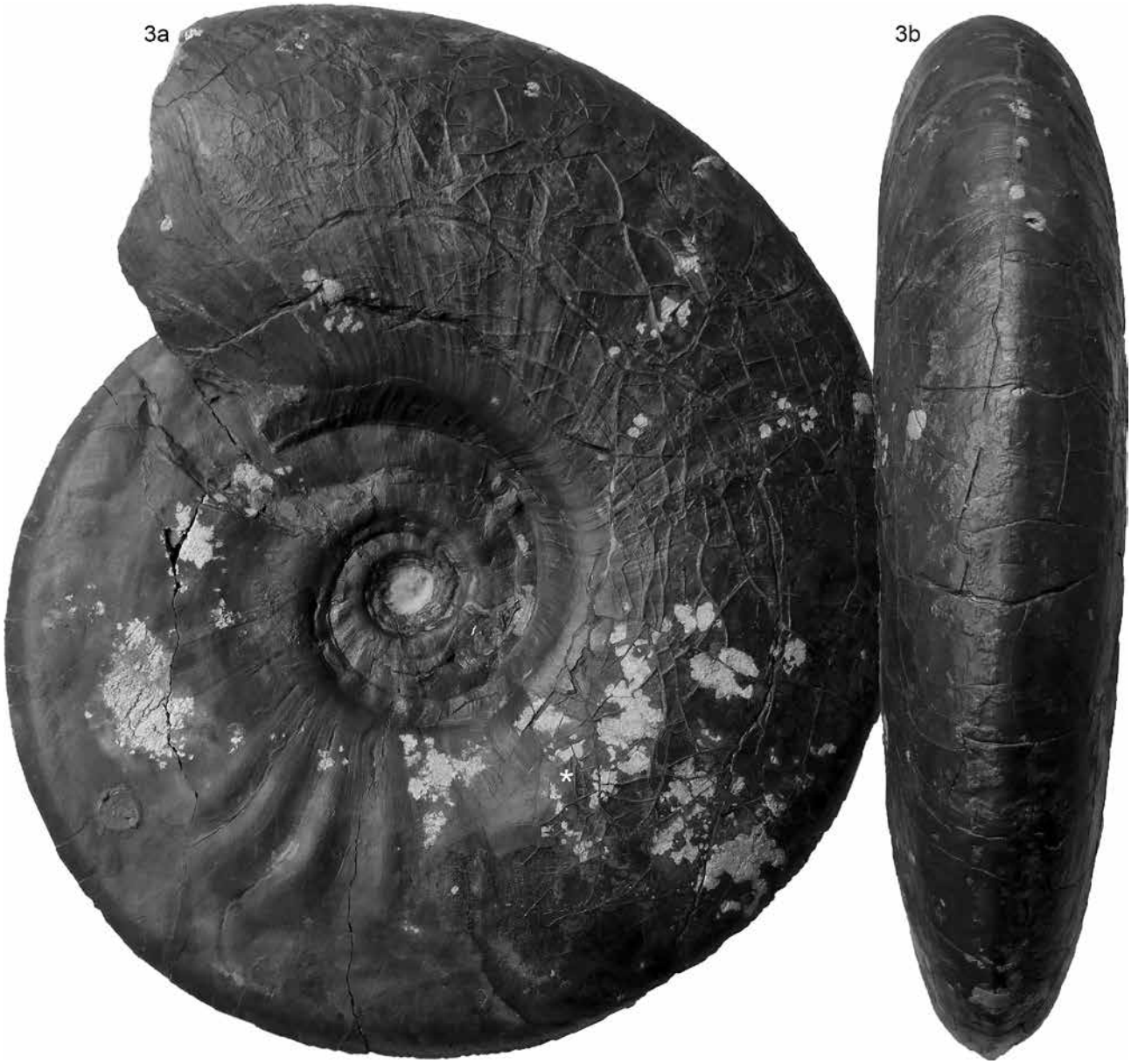
Subfamily Leioceratinae Spath, 1936

Genus *Leicoceras* Hyatt, 1867

Type species: *Nautilus opalinus* Reinecke, 1818.

Leioceras hansrieberi n. sp.
Figs. 3a, b; Pls. 1–3, ?4, 5–8

? 1878 *Ludwigia opalina* Reinecke, sp. – Bayle, pl. 80, fig. 1.
? 1887 *Ammonites opalinus*. – Quenstedt, pp. 444, 447, pl. 55, figs. 11, 18 only.
? 1887 *Ammonites opalinus* cf. *costosus*. – Quenstedt, p. 447, pl. 55, fig. 19.
1925 *Lioc. opalinum*. – Gropper, profile I.
? 1935 *Ludwigia opalina* Rein. – Dorn, p. 65, pl. 28, fig. 1.
1939 *Ludwigia (Leioc.) opalina*. – Lörcher, p. 180.
1963 *Leioceras opalinum*. – Rieber, p. 9.
1967 *Leioceras opalinum* (Rein.). – Kobler, pp. 11, 12, 22–24, 84, 85, 87, 88.
1972 *Leioceras opalinum* (Rein.). – Kobler, pp. 12, 13.
1984 *Leioceras opalinum* (Reinecke). – Hönig, p. 43, pl. 2, fig. 1 [left figure].
1992 *Leioceras opalinum* (Rein.). – Hegele, p. 346, fig. on p. 341 bottom right.
?1992 *Leioceras opalinum* (Rein.). – Hegele, p. 345, fig. on p. 348 top left.
1993 *Leioceras (Leioceras) partitum* (Buckman). – Ohmert, p. 156, text-fig. 2, pl. 15, figs. 5, 6.



Figs. 3a, b. *Leioceras hansrieberi* n. sp. [M], holotype. Opalinuston Formation, Zillhausen Member, bed 1, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon; ca. 1.0 m below top of bed 1, SMNS 70408/2 [leg. V. DIETZE]. Ammonite depicted in natural size. Beginning of body chamber is marked by an asterisk.

1993 *Leioceras (Cypholioceras) opaliniforme* (BUCKMAN). – OHMERT, pp. 155, 157, fig. 2.
1993 *Leioceras (Leioceras) opalinum*. – OHMERT, p. 156, fig. 2.
?1995 *Leioceras opalinum* (REIN.). – HEGELE, p. 96, fig. top left.
2013 *Leioceras*. – DIETL, p. 11, fig. 11.
2016 *Leioceras opaliniforme* (BUCKMAN). – DIETZE & SCHWEIGERT, p. 71, pl. 3, figs. a, b.
?2016 *Leioceras costosum* (QUENSTEDT). – DIETZE & SCHWEIGERT, p. 71, pl. 4, figs. a, f.
?2016 *Leioceras* cf. *costosum* sensu QUENSTEDT. – DIETZE & SCHWEIGERT, p. 7, pl. 4, fig. e.
2016 *Leioceras opalinum* (REINECKE). – DIETZE & SCHWEIGERT, p. 71, pl. 4, figs. b–d, g.

E t y m o l o g y : After our friend and colleague Prof. Dr. HANS RIEBER, who was the first researcher to describe extensively the Aalenian ammonites and strata of southwestern Germany.

H o l o t y p e : Specimen illustrated on Figs. 3a, b (SMNS 70408/2).

T y p e l o c a l i t y : Donzdorf-Grünbach (see Fig. 1).

Type horizon: Bed 1 (see Fig. 2) (*hansrieberi* horizon).

Material studied: > 150 specimens.

Occurrences in Southern Germany: Zillhausen Member, in many stream gorges in the foreland of the eastern and middle Swabian Alb (e.g., Weilerstoffel near Schwäbisch Gmünd, Donzdorf-Grünbach, Krähbach near Winzingen, Hohenstaufen-Hohrein, Weiler in den Bergen, Teufelsloch, Mühlbach and Riesbach near Bad Boll, Rotensteigbach near Weilheim), and in the foreland of the western Swabian Alb (e.g., Zillhausen, Hausen am Tann).

	D [mm]	Uw [mm]	Wh [mm]	Wb [mm]
Figs. 3a, b (HT) SMNS 70408/2	163	44	69	35
Pl. 5, Figs. 1, 2 SMNS 70408/15	200	52	83	31
Pl. 2, Figs. 1, 2 SMNS 70408/4	182	55	69	36
Pl. 4, Figs. 1, 3 SMNS 70408/8	170	44	71	34
Pl. 7, Figs. 2, 3 SMNS 70408/2	160	42	67	28
Pl. 3, Figs. 5, 6 SMNS 70408/7	153	35	67	29
Pl. 6, Figs. 2, 4	144	-	-	27
Pl. 1, Figs. 1, 8 SMNS 70408/1	132	-	59	28
Pl. 6, Figs. 1, 3 SMNS 70408/16	126	35	51	25
Pl. 7, Fig. 1 SMNS 70408/19	105	25	47	-
Pl. 1, Figs. 2, 3 SMNS 70408/5	104	27	44	20
Pl. 3, Figs. 1, 2 SMNS 70408/6	85	27	43	16
Pl. 3, Figs. 3, 4 SMNS 70408/9	73	14	35	13
Pl. 4, Fig. 2 SMNS 70408/3	67	20	29	-

Diagnosis: Large-sized species of *Leioceras* with slightly fastigate venter resembling a gothic arch and a broadened cross-section in the adult stage. Venter of body chamber fastigate to broadly rounded. Shell covered with delicate falcoid hair-ribs. Flanks with wavy bunchings of lirae. Microconchs have stronger sculpture than macroconchs.

Description of the holotype: The holotype is preserved with a calcitic replacement shell (Figs. 3a, b). The body chamber is three-dimensionally preserved with parts of the aperture. The phragmocone is diagenetically slightly compressed. The length of body chamber equals approximately a half whorl. The keeled venter at the beginning of the body chamber becomes broadly rounded towards the aperture. The maximum width is located slightly above mid-flank. The steep umbilical wall flattens towards the aperture. The umbilical edge is rounded, flanks are convex. Towards the aperture the cross section with the fastigate venter becomes more and more rounded. The hair-ribs are crossing the venter forming an arch with weak elevations in short distances probably due to short growth interruptions. On the flanks the sinuous hair-ribs become weaker ventrally and cross the venter in a straight way. The wavy bead sculpture on mid-flank is best discernible in the last portion of the phragmocone.

Variation: The biggest of all studied specimens (Pl. 5, Figs. 1, 2) exhibits typical shallow wavy beads on the last part of the phragmocone. However, in that specimen both the phragmocone and body chamber are laterally compressed, which is why we did not select this otherwise perfect specimen as holotype. The venter at the end of the body camber is still slightly fastigate. Another big specimen (Pl. 2, Figs. 1–2) shows a three-dimensionally preserved body chamber, preserved with the aperture. Length of the body chamber equals approximately a half whorl, the phragmocone is diagenetically compressed. The high-oval cross section at the beginning of the body chamber is slender and becomes much thicker towards the aperture. The shell exhibits fine, falcoid hair-ribs. In another specimen (Pl. 1, Figs. 1, 8) the wavy bead sculpture persists until the beginning of the body chamber. The venter is fastigate, and the umbilical wall is rather steep. Most likely that specimen is not adult. The specimens of Pl. 3, Figs. 5, 6 and Pl. 6, Figs. 2, 4 correspond to the most abundant morphology within the chronospecies *L. hansrieberi*. This concerns the adult size, strength of the wavy sculpture and the shape of the venter. In both specimens the fine hair-ribs are especially well discernible, and in Pl. 3, Figs. 5–6 the aperture is nearly perfectly preserved. Despite of its somewhat more rounded venter, the specimen of Pl. 6, Figs. 1, 3 is still typical. The latter three specimens and the specimen of Pl. 3, Figs. 3, 4 are juveniles. In a remarkably narrow juvenile with a lanceolate cross section and a pointed venter (Pl. 3, Figs. 1, 2) the hair-ribs are perfectly preserved. Wavy beads on the flanks are characteristic. A relatively small specimen (Pl. 1, Figs. 2, 3) shows an egression of the body chamber with decreasing whorl height and a rounded venter; therefore, it seems to be adult. At mid-flank the hair-ribs form nodular bundles.

Two specimens of different size have a very unusual ribbing style. In the smaller one (Pl. 4, Fig. 2) the strong primaries divide at mid-flank into strong, densely spaced secondaries with numerous intercalatory ribs. Hair-ribs are not discernible. The bigger one (Pl. 4, Figs. 1, 3) shows a dense bead sculpture, which weakens gradually on the body chamber. At the end of the body chamber the venter is well-rounded. It is still unclear whether these specimens represent extreme variants of *L. hansrieberi* or if they belong to another coeval leioceratid genus and species.

The abovementioned specimens all come from Bed 1, whereas the following specimens come from Bed 3. An internal mould with some remains of the shell (Pl. 7, Figs. 2, 3) exhibits a narrow cross-section with a fastigate, slightly rounded keel even on its body chamber. It's well discernible suture line shows a wide trifid lateral lobe; this suture line fits well with the "*opalinus*-Typus" of Ohmert (1993). A phragmocone with the beginning of the body chamber (Pl. 7, Fig. 1) is unusually coarse-ribbed and recalls the morphology of *L. uncinatum* (Buckman), a morphotype, which becomes more abundant in younger beds. Its wide bifid lateral lobe corresponds better to the "*Cypholioceras*-Typus" of Ohmert (1993). Specimens from the middle part of Bed 3 which are preserved as internal moulds exhibit a keeled (Pl. 8, Figs. 1, 3) or rounded venter (Pl. 8, Figs. 2, 4), respectively. The suture line of the specimen illustrated on Pl. 8, Figs. 1, 3 differs from all types distinguished by Ohmert (1993), therefore the taxonomic value of the suture line has to be questioned. Rieber (1963, and personal communication to V.D.) observed in some specimens of Graphoceratidae trifid resp. bifid lateral lobes on

the different flanks of the same specimen). However, we cannot exclude pathogenic suture lines in those cases.

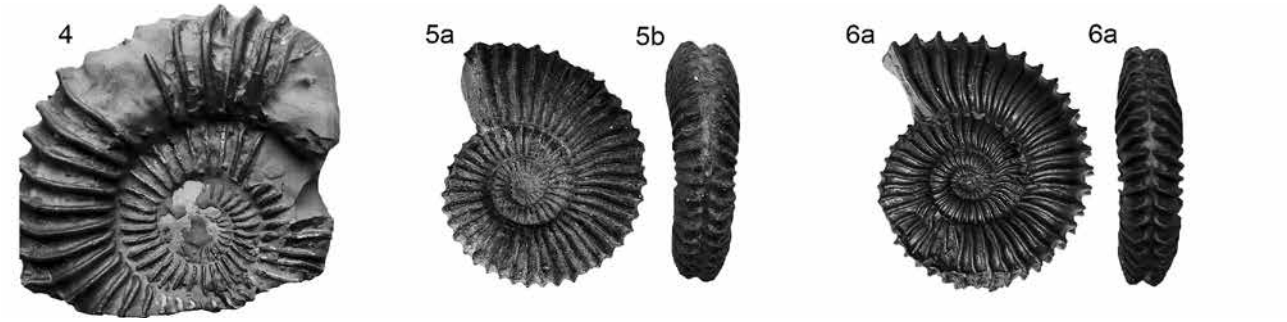
Microconchs are preserved as uncompressed phragmocones lacking their body chamber (Pl. 1, Figs. 4–7, 9–13). These specimens with a high-lanceolate cross section exhibit an acute keel. They correspond to the morphospecies *L. partitum* (Buckman) as already stated by Ohmert (1993, pl. 15, figs. 5, 6).

Comparisions: None of the nominal taxa of *Leioceras* introduced in literature comes from beds corresponding exactly to the *hansrieberi* biohorizon; hence, we decided to introduce a new chronospecies for the material from Grünbach. *L. opalinum* (Reinecke), *L. opaliniforme* (Buckman), *L. subglabrum* (Buckman), *L. renovatum* (Buckman) and *L. plicatum* (Buckman) differ from *L. hansrieberi* n. sp. in their much smaller adult size and the lack of beads on the flanks. Stratigraphically these taxa are older than *L. hansrieberi*. The type horizon of *L. opalinum* is located at the very base of the Aalenian; all other mentioned taxa come from the *opaliniformis* horizon (or *opaliniformis* hemera, respectively). Further taxa introduced by Buckman such as *L. thompsoni*, *L. uncum*, *L. uncinatum*, *L. plicatellum*, *L. plectile*, *L. partitum*, *L. lineatum*, *L. grave* as well as *L. bifidatum* come from the British Scissum Bed, which corresponds at Burton Bradstock approximately with the Comptum Subzone of south-western Germany; an exact correlation is beyond the scope of this work. The various morphospecies described from the Scissum Bed represent younger chronospecies, which differ morphologically from *L. hansrieberi* n. sp. in their smaller adult sizes and a significantly higher percentage of widely umbilicate and coarse-ribbed variants. Only *L. grave* is morphologically close to *L. hansrieberi*, but differs from the latter by lacking beads on the flanks.

Remarks: It remains uncertain whether the specimens illustrated by Contini (1969) as *Leioceras (Cypholioceras) opaliniforme* Buckman (pl. 6, figs. 8, 9) are coeval with *L. hansrieberi* n. sp., because there is no means to make an exact correlation. For this reason why we did not include them in the synonymy of *L. hansrieberi*. Moreover, the *L. (C.) opaliniforme* specimens illustrated by Contini (1969) are very badly preserved. His *L. (C.) lineatum* specimens, however, are smaller than *L. hansrieberi* n. sp. and differ in their whorl sections, which show a less rounded venter. Our previous determinations of leioceratids from the uppermost fossiliferous bed with aragonitic shells and of one specimen with a brown calcitic shell from Donzdorf-Hochdorf as *L. opaliniforme, L. opalinum* and *L.* [cf.] *costostum* (see Dietze & Schweigert 2016, pls. 3, 4) were based on a purely morphospecific concept. These beds can also be assigned now to the *hansrieberi* biohorizon and this is why we tentatively included these specimens in our synonymy of *L. hansrieberi*. According to our observations the shape of the venter alone is neither diagnostic for species nor for generic discrimination. In the younger chronospecies *Leioceras comptocostosum* there is even greater variability (see Chandler & Callomon 2009). Extreme morphologies of the venter in *L. hansrieberi* (e.g., Figs. 3a, b; Pl. 1, Figs. 1, 8; Pl. 1, Figs. 2, 3; Pl. 3, Figs. 1, 2) are linked by numerous transitions (see Pl. 2, Figs. 1, 2; Pl. 4, Figs. 1, 3; Pl. 6, Figs. 1, 3). The rounded venter seems to be individually developed at different stages of the adult body chamber. Morphotypes with a more fastigate venter predominate in the material from Donzdorf-Grünbach. The same is true for the brown calcitic shells from the Zillhausen Member in the Teufelsloch and Riesbach gorges near Bad Boll. In contrast, leioceratid specimens in aragonitic preservation from slightly deeper beds in the latter two sections show predominantly rounded venters, but no further differences are recognizable. Approximately 2 m above the uppermost "Wasserfallbank" large-sized leioceratids occur in both localities. In these populations, all transitions concerning their ventral aspects are observed.

6. Remarks on the genus *Tmetoceras* Buckman, 1892

In the Jurassic of Swabia, the Tethyan ammonite genus *Tmetoceras* is very rare. As mentioned in the introduction, it is long-known to occur in the upper part of the Opalinuston Formation, the Zillhausen Member. Further, still unpublished records come from the late Toarcian Jurensismergel Formation and from the late Aalenian Achdorf Formation. The records from the Zillhausen Member have been traditionally identified as *Tmetoceras scissum* (Benecke). However, all studied specimens are either incomplete (Fig. 4) or juvenile (Figs. 5, 6) specimens. Therefore, their specific identification is somewhat doubtful.



Figs. 4–6. *Tmetoceras* cf. *scissum* (Benecke).; Opalinuston Formation, Zillhausen Member, bed 1, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon. Fig. 4: after rock matrix and preservation from the uppermost 0.5 m of bed 1, SMNS 70407 [ex coll. C. F. Allmendinger]. Figs. 5a, b: after rock matrix and preservation from the uppermost 0.5 m of bed 1, SMNS 18859 [illustrated in Dietl (1977, pl. 1, fig. 3)]. Figs. 6a, b: ca. 0.3 m below top of bed 1 [pers. comm. K.-H. Veit], SMNS 70327 [illustrated in Rieber (1963, pl. 8, figs. 2, 3) and Hegele (1995: 95, fig. 4; ex coll. K.-H. Veit).
Ammonites in depicted in natural size. Beginning of body chamber is marked by an asterisk.

7. Biostratigraphy and correlation

The *hansrieberi* biohorizon is assigned to the Opalinum Subzone of the Opalinum Zone (Lower Aalenian). The illustration of a remarkably large-sized *Leioceras* from calcareous sandstones in the upper part of the Opalinuston of Niedermirsberg (? an equivalent of the "Wasserfallbänke" of Swabia) in Dorn (1935, pl. 28, fig. 2) may indicate the presence of the *hansrieberi* horizon in northern Franconia. In Switzerland the "*opalinum-lineatum*-Horizont" in the central Swiss Jura correlates approximately with the *hansrieberi* biohorizon (see Christ 1999). The *hansrieberi* horizon is either coeval or slightly younger than the French "horizon à *opaliniforme*" (Contini et al. 1997). However, it must be older than the "horizon à *lineatum*" of Contini et al. (1997), because the diversification within *Leioceras* morphologies recorded from this level (e.g. with *L.* "*comptum*" and *L. uncinatum* [=? *lineatum-costostum*-Horizont sensu Ohmert]) is not seen in the *hansrieberi* horizon. Hence, the *hansrieberi* horizon must be younger than the *opaliniformis* hemera, from which Buckman (1887–1909) described specimens mainly from Haresfield (Cotswolds, S England), but older than his *scissi* hemera of Burton Bradstock in Dorset (see Callomon & Chandler 1994). In conclusion, the *hansrieberi* horizon represents an intermediate age between the *opaliniforme* and *lineatum* horizons (Chandler & Callomon 2009). The *Leioceras* fauna of the *lineatum* horizon in S Dorset is slightly smaller in size and exhibits relatively more coarsely ribbed forms compared to the *Leioceras* fauna of the *hansrieberi* horizon.

8. The macrofauna of the *hansrieberi* horizon at Grünbach

Apart from ammonite shells, which are the predominant invertebrate fossils of the macrofauna at Grünbach, several other molluscs and invertebrates have been recorded. A representative sample is documented on Plates 9 and 10. Among the molluscs there are mostly infaunal bivalves, the other are byssate or cemented on secondary hardgrounds. The most common bivalve recorded from Grünbach is the trigoniid *Scaphotrigonia navis* (Lamarck) (Pl. 9, Figs. 1, 2). This primarily infaunal bivalve is usually preserved with both valves still closed, suggesting an *in situ* preservation. However, some of these specimens must have been exhumed from the sediment as indicated by occasional overgrowth with small oysters (Pl. 9, Fig. 2). At Grünbach, other common infaunal bivalves are represented by the nuculid *Palaeonucula hammeri* (Defrance) (Pl. 9, Fig. 6) and an indetermined lucinid (Pl. 9, Fig. 7). The latter was traditionally identified as "*Lucina plana* Zieten" in the collections, but this determination is definitely incorrect due to a significantly differing outline of the shell, especially concerning the position of the umbo. The large-sized *Gervillia pernoides* Deslongchamps (Pl. 9, Fig. 4) was probably attached to secondary hardgrounds. Further infaunal bivalves have been recorded by very few or single specimens only: *Pleuromya* sp. (Pl. 9, Fig. 5), *Goniomya angulifera* Sowerby (Pl. 9, Fig. 10), and *Pholadomya triquetra* Agassiz (Pl. 9, Fig. 13). Both the sediment stacker *Pinna* sp. (Pl. 9, Fig. 3) and the byssate pteriid *Oxytoma* sp. (Pl. 9, Fig. 9) are recorded by single specimens. Oysters and byssate pectinids settled on various secondary hardgrounds. The only gastropod within the association of Grünbach is a poorly preserved specimen of the infaunal *Turritelloidea opalina* (Quenstedt) (not illustrated). Besides ammonites there are few other nektonic molluscs such as the belemnites *Acrocoelites conoideus* (Oppel) (Pl. 9, Fig. 11) and *Acrocoelites quenstedti* (Oppel) (not illustrated) and the nautiloid *Ligeiceras jurense* (Quenstedt) (Pl. 9, Fig. 14; Pl. 10). In contrast to ammonite shells the latter exhibit overgrowth with oysters, pectinids and the serpulid *Dorsoserpula conformis* (Goldfuss). It is unclear whether the nautiloid shells were settled upon during life or post mortem. A mass occurrence of the same serpulid was recorded on both sides of a platy lithoclast (not illustrated) thus indicating that it must have been turned around. These records fill the strange stratigraphical gap in the fossil record of serpulids in the Lower Aalenian of south-western Germany (Parsch 1956). Typical epibenthic soft-bottom dwellers are only represented by an ahermatypic coral of the genus *Thecocyatus* (Pl. 9, Fig. 12).

Small calcareous concretions sometimes contain incomplete remains of decapod crustaceans, namely of the erymid lobster *Eryma* cf. *bedeltum* (Quenstedt) (Pl. 9, Fig. 16) and the glypheid lobster *Glypheopsis solitaria* (Oppel) (Pl. 9, Fig. 15). The incomplete preservational state of these crustaceans suggests they are ecdysis moults.

The rich infauna reported here from Grünbach points to a well-oxygenated clayey substrate. Occasional currents or storm events washed out parts of the infauna as well as lithoclasts which had formed during early diagenesis. Bigger shells and other firm substrates were used as secondary hardgrounds. Despite the occurrence of lobsters their burrows have not been recorded at place. Possibly the moults of the lobsters were washed in from elsewhere.

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Plate 1

(**1–13**): *Leioceras hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 1, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
1–3, 8: [M]. 1, 8: ca. 0.6 m below top of bed 1, SMNS 70408/1 [leg. V. Dietze]. 2–3: ca. 0.3 m below top of bed 1 [pers. comm. K.-H. Veit], SMNS 70408/5 [ex coll. K.-H. Veit].
4–7, 9–13: [m]; after rock matrix and preservation from topmost 0.5 m of bed 1. 4–5: SMNS 70408/14. 6–7: SMNS 70408/13. 9–10: SMNS 70408/11. 11: SMNS 70408/12. 12–13: SMNS 70408/10.
Ammonites are depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 2

(**1–2**): *Leioceras hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 1, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon; 0.6 m below bed 2, SMNS 70408/4 [leg. V. DIETZE].
Ammonite depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 3

(**1–6**): *Leioceras hansrieberi* n. sp. [M], Opalinuston Formation, Zillhausen Member, bed 1, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
1, 2: after rock matrix and preservation from topmost 0.5 m of bed 1, SMNS 70408/6 [ex coll. H. HONEGGER].
3, 4: ca. 0.3 m below top of bed 1 [pers. comm. K.-H. VEIT], SMNS 70408/9 [ex coll. K.-H. VEIT].
5, 6: ca. 0.3 m below top of bed 1 [pers. comm. K.-H. VEIT], SMNS 70408/7 [ex coll. K.-H. VEIT].
Ammonites are depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 4

(**1–3**)*: Leioceras* ?*hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 1, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
1, 3: after rock matrix and preservation from topmost 0.5 m of bed 1, SMNS 70408/8 [ex coll. M. Tüskes],
2: after rock matrix and preservation from the uppermost 0.5 m of bed 1, SMNS 70408/3 [ex coll. E. Bernt].
Ammonites are depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 5

(**1, 2**): *Leioceras hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 1 (ca. 0.3 m below top, pers. comm. K. JENNE), Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon. SMNS 70408/15 (leg. R. FLAIG, ex coll. K. JENNE).
Ammonite depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 6

(**1–4**): *Leioceras hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 1 (after matrix and preservation from topmost 0.5 m), Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
1, 3: SMNS 70408/16 [ex coll. E. BERNT];
2, 4: SMNS 70408/17 [ex coll. M. TÜSKES].
Ammonites are depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 7

(**1–3**): *Leioceras hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 3 (0–0.2 m above base of bed 3), Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
1: SMNS 70408/19 (leg. M. Grupp).
2, 3: SMNS 70408/18 [ex coll. K.-H. Veit].
Ammonites are depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 8

(**1–4**): *Leioceras hansrieberi* n. sp., Opalinuston Formation, Zillhausen Member, bed 3 of Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
1, 3: ca. 2.2 m above base of bed 3, SMNS 70408/21.
2, 4: ca. 1.8 m above base of bed 3, just above 3rd concretion layer (Fig. 1), SMNS 70408/22 [leg. V. DIETZE].
Ammonites are depicted in natural size. Beginning of body chamber is marked by an asterisk.

Plate 9

Invertebrate fauna of the Opalinuston Formation, Zillhausen Member, of Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon.
(**1, 2**) Infaunal bivalve *Scaphotrigonia navis* (Lamarck). Note small cemented oyster attached to the specimen of Fig. 2 [Fig. 1, SMNS 70442/1, ex coll. K.-H. Veit; Fig. 2, SMNS 70442/2, ex coll. G. & U. Bayer].
(**3**) Byssate sediment stacker bivalve *Pinna* sp., SMNS 70442/3 [ex coll. K.-H. Veit].
(**4**) Byssate bivalve *Gervillia pernoides* Deslongchamps with two cemented oysters, SMNS 70442/4 [ex coll. K.-H. Veit].
(**5**) Infaunal bivalve *Pleuromya* sp., SMNS 70442/5 [ex coll. K.-H. Veit].
(**6**) Infaunal nuculid bivalve *Palaeonucula hammeri* (Defrance), SMNS 70442/6 [ex coll. K.-H. Veit].
(**7**) Undetermined infaunal bivalve of the family Lucinidae, SMNS 70442/7 [ex coll. K.-H. Veit].
(**8**) Undetermined byssate pectinid bivalve, SMNS 70442/8 [ex coll. G. & U. Bayer].
(**9**) Byssate bivalve *Oxytoma* sp., SMNS 70442/9 [ex coll. K.-H. Veit].
(**10**) Infauna bivalve *Goniomya angulifera* Sowerby, SMNS 70442/10 [ex coll. K.-H. Veit].
(**11**) Belemnite rostrum *Acrocoelites conoideus* (Oppel), SMNS 70442/11 [ex coll. K.-H. Veit].
(**12**) Solitary coral *Thecocyatus* sp. in two views, SMNS 70442/12 [ex coll. K.-H. Veit].
(**13**) Infaunal bivalve *Pholadomya triquetra* Agassiz, SMNS 70442/13 [ex coll. K.-H. Veit].
(**14**) Nautiloid *Ligeiceras jurense* (Quenstedt) with numerous attached serpulids *Dorsoserpula conformis* (Goldfuss), SMNS 70442/14 [ex coll. G. & U. Bayer].
(**15**) Glypheid lobster *Glypheopsis solitaria* (Oppel), SMNS 70442/15 [ex coll. G. & U. Bayer].
(**16**) Erymid lobster *Eryma* cf. *bedeltum* (Quenstedt), SMNS 70442/16 [ex coll. G. & U. Bayer].
Scale bar equals 50 mm.

Plate 10

Large-sized specimen of the nautiloid *Ligeiceras jurense* (QUENSTEDT), with cemented shells of oysters (O) and a pectinid bivalve (P) as well as serpulids (S) and a tiny bryozoan colony (B). Zillhausen Member, Donzdorf-Grünbach; Lower Aalenian, Opalinum Zone, Opalinum Subzone, *hansrieberi* horizon, SMNS 70442/17 [ex coll. K.-H. VEIT]. Scale bar equals 100 mm.