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Monograph

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The ammonoids from the *Gattendorfia* Limestone of Oberrödinghausen (Early Carboniferous; Rhenish Mountains, Germany)

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Abstract. The railway cutting near Oberrödinghausen at the northern margin of the Rhenish Mountains is the cardinal section for the investigation of Early Tournaisian (Early Carboniferous; Mississippian) ammonoids. The ammonoids from the Hangenberg Limestone (= *Gattendorfia* Limestone) of this and neighbouring outcrops are revised here, using the historical collections as well as undescribed new material. The ammonoid assemblages are composed of a total of 67 species, which occur in four successive ammonoid zones. The assemblages are composed of predominant prionoceratids (Order Goniatitina) with the twenty genera *Mimimitoceras* (two species), *Globimitoceras* (one species), *Paragattendorfia* (two species), *Kornia* (three species), *Stockumites* (eleven species), *Acutimitoceras* (two species), *Costimitoceras* (one species), *Nicimitoceras* (four species), *Imitoceras* (one species), *Voehringerites* (one species), *Gattendorfia* (eight species), *Zadelsdorfia* (two species), *Kazakhstania* (one species), *Gattenpleura* (one species), *Weyerella* (three species), *Hasselbachia* (three species), *Paprothites* (five species), *Pseudarietites* (three species), *Rodingites* (two species), *Paralytoceras* (one species) as well as subordinate eocanitids (Order Prolecanitida) with the genera *Eocanites* (eight species) and *Nomismocanites* (one species). The new genera *Rodingites* gen. nov. and *Nomismocanites* gen. nov. as well as the new species *Mimimitoceras perditum* sp. nov., *Kornia fibula* sp. nov., *Kornia acia* sp. nov., *Stockumites parallelus* sp. nov., *Stockumites voehringeri* sp. nov., *Acutimitoceras ucatum* sp. nov., *Acutimitoceras paracutum* sp. nov., *Imitoceras initium* sp. nov., *Gattendorfia rhenana* sp. nov., *Gattendorfia bella* sp. nov., *Gattendorfia valdevoluta* sp. nov., *Gattendorfia schmidti* sp. nov., *Gattendorfia corpulenta* sp. nov., *Gattendorfia immodica* sp. nov., *Zadelsdorfia oblita* sp. nov., *Weyerella lenis* sp. nov., *Hasselbachia erronea* sp. nov., *Paprothites beckeri* sp. nov., *Paprothites kullmanni* sp. nov., *Eocanites delicatus* sp. nov. and *Nomismocanites raritas* gen. et sp. nov. are described from Oberrödinghausen. *Mimimitoceras mina* sp. nov., *Stockumites marocensis* sp. nov., *Zadelsdorfia zana* sp. nov. and *Kazakhstania kana* sp. nov. are newly named for material from the Anti-Atlas of Morocco.

Keywords. Ammonoida, Carboniferous, Early Tournaisian, *Gattendorfia* Limestone, Rhenish Mountains.

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Introduction

Historical review

The railway cutting near Oberrödinghausen in the Hönne Valley (northern Rhenish Mountains) is the most productive locality for Early Tournaisian (earliest Carboniferous) ammonoids worldwide. It is still the standard section of the earliest Carboniferous ammonoid stratigraphy. So far, 45 species have been reported from the Hangenberg Limestone (= *Gattendorfia* Limestone) of this single outcrop (Vöhringer 1960; Korn 2006). The famous site dates back to the construction of the Hönnetal railway line between 1909 and 1912 and was probably first described by Hermann Schmidt (1924). In his monographs on the Devonian–Carboniferous boundary ammonoids from the Rhenish Mountains, Schmidt (1924, 1925) already listed eight species (assigned by him to the genera *Aganides*, *Gattendorfia*, *Pseudarietites* and *Protocanites*) from this outcrop.

In the late 1920s and early 1930s, Otto H. Schindewolf intensely studied the outcrop and accumulated large fossil collections. While he published some of the results on the Late Devonian Wocklum Limestone (= *Wocklumeria* Limestone) (Schindewolf 1937), his collection of ammonoids from the Hangenberg Limestone (= *Gattendorfia* Limestone) was destroyed during the bombing of Berlin in World War II. Only parts of the trilobite, brachiopod, bivalve and coral collections survived, which are now kept in the collection of the Geologische Bundesanstalt, Berlin-Spandau, in the Museum für Naturkunde, Berlin and in the Senckenberg Museum Frankfurt a. M. Some specimens of these other animal groups were published by Richter & Richter (1951), Paul (1954), Weyer (1981b, 2001), Bartzsch & Weyer (1982) and Mottequin *et al.* (2019).

Schindewolf became the head of the palaeontological department at the University of Tübingen in 1947 and at the beginning of the 1950s commissioned the doctoral student Eugen Vöhringer to re-examine the outcrop for the earliest ammonoids of the Carboniferous. The result of this study was published in a magnificent monograph (Vöhringer 1960), in which he separated 45 species and subspecies, which were assigned to six genera (*Imitoceras*, *Costimitoceras*, *Gattendorfia*, *Pseudarietites*, *Karagandoceras*, *Protocanites*). Vöhringer's monograph had difficulties in gaining acceptance because of its putatively extensive splitting, although this criticism was apparently never published in a paper. Nevertheless, this monograph can be considered a benchmark for the description of Palaeozoic ammonoids, as it incorporated ontogeny, conch geometry, shell ornament and suture line into a comprehensive concept.

After the study by Vöhringer (1960), the Oberrödinghausen outcrop was re-visited a number of times for the study of various microfossil groups such as conodonts (Voges 1959, 1960; Ziegler 1971; Kaiser *et al.* 2017) and miospores (Paproth & Streel 1970; Higgs & Streel 1984). The ammonoid record from the outcrop was used in articles that dealt with the faunal change from the Devonian into the Carboniferous (Korn 1986, 1993, 1994, 2000, 2006; Luppold *et al.* 1994; Sprey 2002; Korn & Weyer 2003; Ebbighausen & Korn 2007; Korn *et al.* 2013; Kaiser *et al.* 2016; Klein 2016; Klein & Korn 2016) or the analysis of some particular species (Weyer 1981a; Korn & Vöhringer 2004; Becker *et al.* 2021), however without including extensive new collections.

In the early 1990s, DW spent some time in the outcrop to sample material from the Hangenberg Limestone before this part of the outcrop was covered or partially destroyed by the nearby cement plant. The material that was collected in this field session amounts to more than 800 ammonoid specimens, all collected strictly bed-by-bed. Although many of these ammonoid specimens are small and hence difficult to identify, they provide a rich source of data for the study of the ammonoid recovery after the Hangenberg Event, which is regarded as one of the important mass extinction events in Earth history (Walliser 1984, 1996; House 1985b, 1989; Kaiser *et al.* 2016). Here, we describe this collection together with a revision of the ammonoids known so far from this important locality. Additionally, some species from the Anti-Atlas previously attributed to Central European species are renamed here.

The railway cutting outcrop of Oberrödinghausen

Geographic position

The outcrop of interest is located on the northern flank of the Remscheid-Altena anticline and is one of several sections along the strike between Hagen in the west and Oberrödinghausen in the east (Schmidt 1924; Luppold *et al.* 1994; Becker *et al.* 2021) (Fig. 1). It is one of several outcrops on both sides of the Hönne valley, which are arranged from west to east:

(1) Small temporary outcrop at a forestry road, immediately west of the railway line (DK 1977 Coll.).

(2a) Western side of the railway cutting. Vöhringer (1960) obviously collected most of his material from this exposure; a photograph of the outcrop was provided by him (Vöhringer 1960: pl. 7) (re-illustrated here in Fig. 2). As a result of intensive sampling, the outcrop is practically exploited; only strongly weathered, almost completely decalcified material remained.

(2b) Eastern side of the railway cutting. A subordinate part of the Vöhringer Collection comes from this exposure. Small outcrops were temporarily accessible in the 1970s and early 1990s and were sampled by DK and DW. Unfortunately, these outcrops are now completely covered or destroyed due to the construction activity of the nearby cement factory.

(3) Road cutting on the east side of the Hönne valley. The section was re-opened by DK and DW in 2000 and is no longer accessible. Its lithological succession is similar to that of the railway cutting, but it yielded only a small number of well-preserved ammonoids (Korn & Weyer 2003).

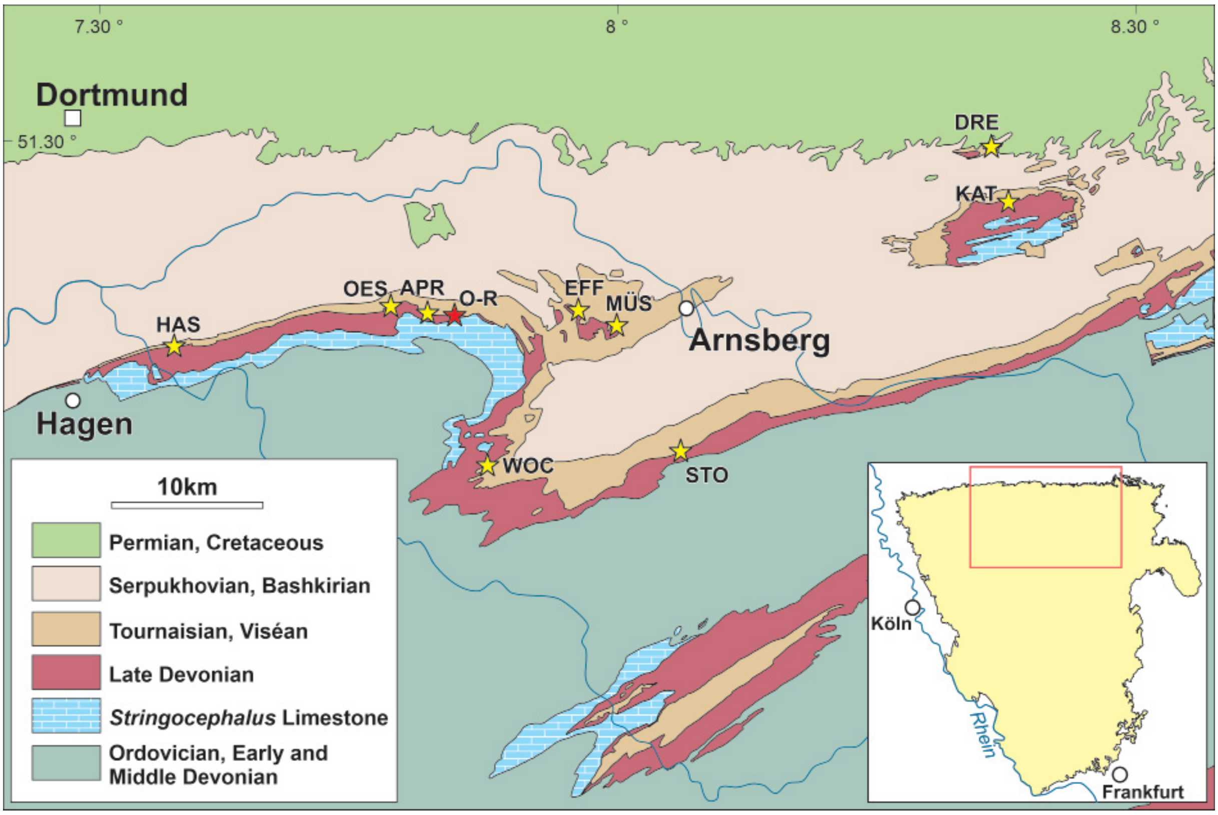

Fig. 1. The geographic position of the Oberrödinghausen railway cutting section and other Devonian–Carboniferous boundary sections at the northern margin of the Rhenish Mountains east of the Rhine. Abbreviations: APR = Apricke; DRE = Drewer; EFF = Effenberg; HAS = Hasselbachtal; KAT = Kattensiepen; MÜS = Müssenberg; OES = Oese; O-R = Oberrödinghausen; STO = Stockum; WOC = Wocklum.

(4) Temporary outcrop at a forestry road, 50 metres east of the Hönne valley road. The outcrop was already known to Denckmann (1903) but is no longer visible.

Lithological succession

The Early Tournaisian Hangenberg Limestone has a thickness of between 1.40 and 3.00 m at the northern margin of the Rhenish area (Schmidt 1924; Luppold *et al.* 1994; Korn & Weyer 2003); only at Oberrödinghausen it is very fossiliferous and yielded rich ammonoid assemblages throughout the section. Compared to the neighbouring sections (e.g., Hasselbachtal, Oese and Apricke), it is the one with the least amount of shale and thus might have occupied a somewhat elevated bathymetric position (Schmidt 1924; Paproth & Streel 1982; Becker *et al.* 1984, 1993; Becker 1988, 1996; Becker & Paproth 1993; Bless *et al.* 1993; Luppold *et al.* 1994; Korn & Weyer 2003; Korn *et al.* 2010c). A detailed subdivision was already undertaken by Vöhringer (1960), who, however, combined some separable horizons that were sampled more precisely by DW during the investigations in 1993 and 1994.

In the Oberrödinghausen railway cutting, the Hangenberg Limestone has a thickness of 1.45 metres (Fig. 2) and was subdivided by Vöhringer (1960) in six individual beds (beds 1 to 6 in descending order), of which bed 3 was subdivided by him into smaller units (beds 3a to 3e in descending order). Vöhringer stated that he also divided bed 5 in subunits, but the ammonoids from this bed were largely

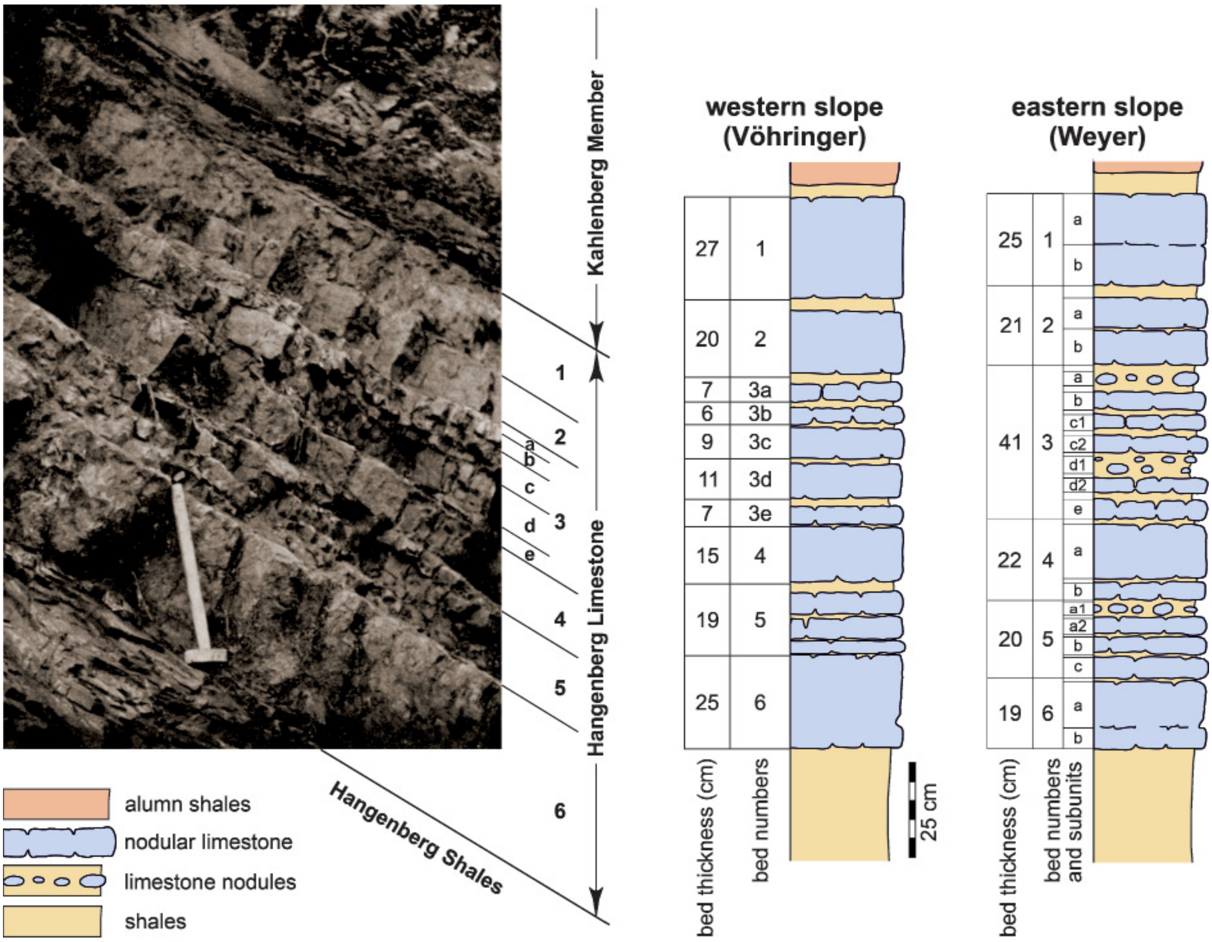

Fig. 2. The Hangenberg Limestone at the western slope of the Oberrödinghausen railway cutting section (reproduced from Vöhringer 1960) and the lithological succession of the Hangenberg Limestone after Vöhringer and the field work by DW.

binned together by him. During the investigations by DW in 1993 and 1994, several of the beds were sampled by using a finer resolution, e.g., for beds 2, 3c, 3d, 4, 5 and 6 (Korn & Weyer 2003).

All limestone horizons show a similar lithology and carbonate facies. It is a dark-grey nodular limestone with micritic matrix and varying biogenic content, in which the ammonoids play the predominant role. The fossil content diametrically correlates to some extent with the thickness of the individual layers; while the thin horizons of layer 3 are very rich in fossils, the lowest layer (layer 6), which is the thickest, has a much lower fossil content.

Ammonoid biostratigraphy

The great importance of the Oberrödinghausen outcrop for the ammonoid biostratigraphy across the Devonian–Carboniferous boundary was already recognised very early in its research history. With the publication of ammonoid descriptions by Schmidt (1924, 1925) and extensive field work by Schindewolf, it had been recognised that this outstanding outcrop plays an important role in the biostratigraphic definition of the Devonian–Carboniferous boundary. For this reason, the section was proposed and accepted as a global reference for this boundary at the Second Carboniferous Congress in Heerlen in 1935 (Jongmans & Gothan 1937; Paeckelmann & Schindewolf 1937).

Since the detailed investigation by Vöhringer (1960), the outcrop of Oberrödinghausen has been known as by far the best section worldwide with regard to the ammonoid succession across the Devonian–

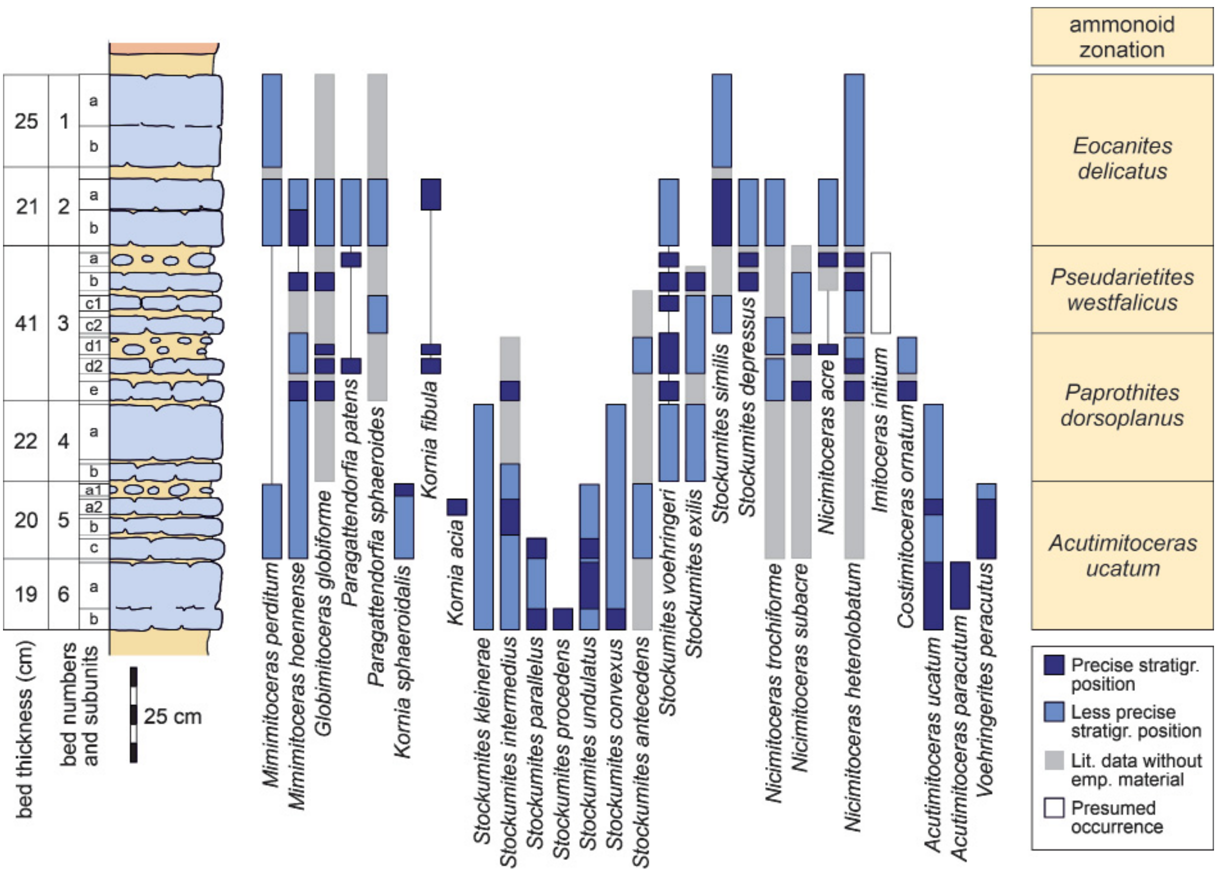

Fig. 3. The lithological succession of the Hangenberg Limestone in the Oberrödinghausen railway cutting section with the occurrence of the ammonoid species of the family Prionoceratidae Hyatt, 1884 and the ammonoid zonation.

Carboniferous boundary. Although it has not been surpassed by any other section since, it did not play a significant role in the 1980s during the search for a global stratotype for the boundary between the two periods. The reason for this was the uncertainty regarding the base of the Hangenberg Limestone in this outcrop; the absence of the so-called "Stockum Fauna" with prionoceratids but without representatives of the family Gattendorfiidae (Schmidt 1924; Korn 1984) and the absence of the conodont "*Protognathodus* fauna" known from Stockum (Ziegler 1969) were considered to be indicative of a stratigraphic gap (e.g., Paproth & Streel 1984; Bless *et al.* 1993). In the section of the adjacent Oberrödinghausen 1 borehole, Van Steenwinkel (1984) found a layer with lithoclasts at the base of the lowermost bed of the Hangenberg Limestone; this was interpreted as a sign of erosion directly in the range of the conodont-defined Devonian–Carboniferous boundary. The postulated presence of the "Stockum ammonoid" level (with the *Protognathodus* conodont fauna) in the basal parts of limestone bed 6 (Walliser & Alberti 1979) was an error.

In correlating the section at Wocklum with other sections in the Rhenish Mountains, Hartenfels *et al.* (2022) still advocated the view that the basal part of bed 6 (bed 6b) of Oberrödinghausen belongs to the "Upper Stockum Interval" and thus to the latest Devonian according to the currently valid boundary definition. However, the finding of *Gattendorfia rhenana* sp. nov. in this bed does not support such a classification, but rather an earliest Carboniferous age.

At present, we know that the Hangenberg Limestone of the Oberrödinghausen railway section also includes a gap at its top. Above the highest limestone bed 1, there occur another 5–10 cm of shales below

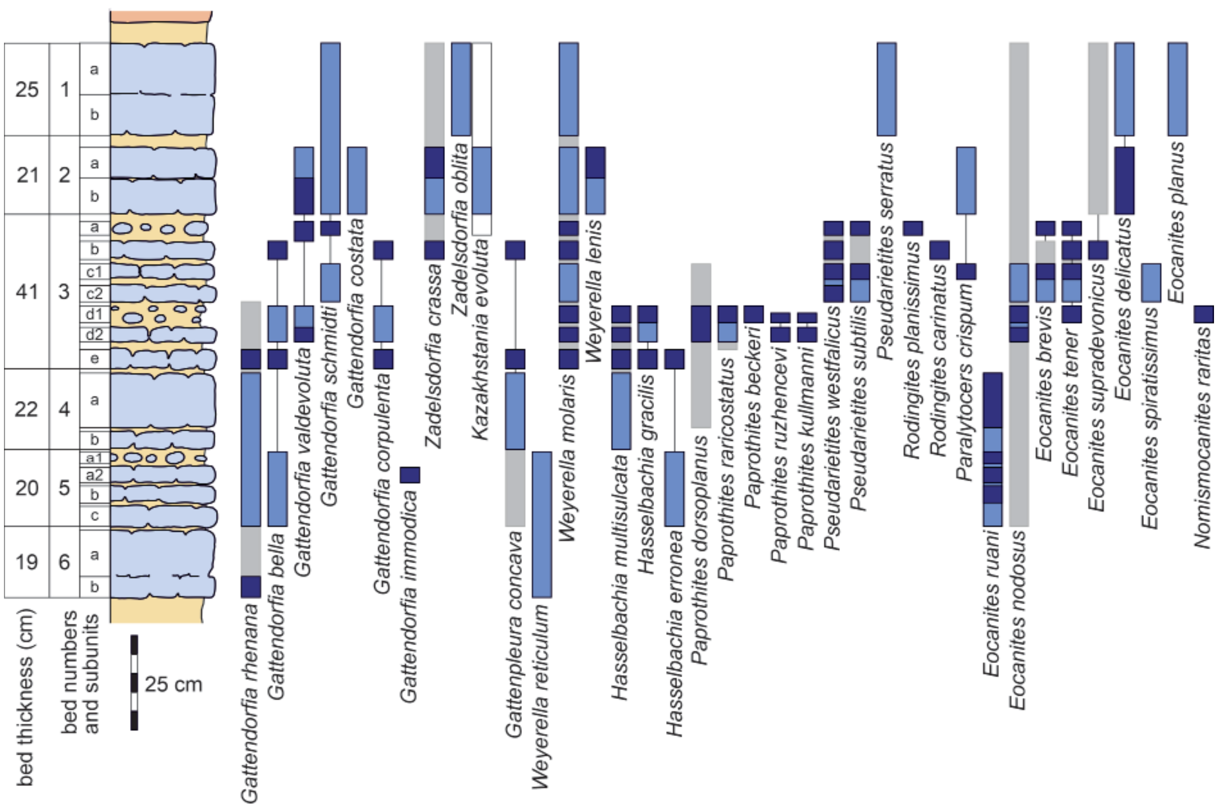

Fig. 4. The lithological succession of the Hangenberg Limestone in the Oberrödinghausen railway cutting section with the occurrence of the ammonoid species of the families Gattendorfiidae Bartzsch & Weyer, 1987 and Prolecanitidae Hyatt, 1884. For explanation of the colours used, see Fig. 3.

the base of the Middle Tournaisian Kahlenberg Member of Korn (2006); which were mostly completely neglected but mentioned by Voges (1960) and Korn & Weyer (2003).

It is possible to subdivide the Hangenberg Limestone into small biostratigraphic units based on the occurrence of the ammonoid species (Figs 3–4). Vöhringer (1960) separated two zones, each containing two subzones (Fig. 5). Korn (1993) suggested raising them to the biozone level. A finer zonation would be possible (Klein 2016; Klein & Korn 2016), but was not proposed because of possible difficulties in correlation with less fossiliferous neighbouring sections. We continue to use this stratigraphic scheme here because it has proven to be practicable over the past decades. A finer subdivision would be problematic, because almost every single layer contains new ammonoid species. This would lead to no gain because a robust correlation with other sections would no longer be possible. Due to nomenclatural changes, however, it is necessary to change two of the four zone names.

The four ammonoid zones, which must be regarded as regional zones for the Rhenish Mountains, are defined as follows, in ascending order for the Hangenberg Limestone:

Acutimitoceras ucatum Zone – The zone corresponds to the "Subzone des *Imitoceras acutum*" of Vöhringer (1960) and includes beds 6 and 5. Vöhringer had not distinguished subunits in these beds; therefore, the precise range of the species that he described from these beds is not known. However, it is particularly interesting to know whether the basal bed 6 already contains the characteristic ammonoids of the "*Gattendorfia* Stufe". With the new collections, five species have been recorded in the lowest part of bed 6 (bed 6b), namely *Stockumites parallelus* sp. nov., *S. convexus*, *S. procedens*, *Acutimitoceras ucatum* sp. nov. and *Gattendorfia rhenana* sp. nov. However, it can be considered certain that the species *Stockumites kleinerae*, *S. intermedius* and *S. parallelus* also occur in this bed, because they are known from the Stockum Limestone of Stockum and the time equivalent horizon at Müssenberg as well as from higher parts of the Hangenberg Limestone of Oberrödinghausen. The occurrence of *Gattendorfia* in the lowest bed of Oberrödinghausen can be regarded as evidence that no time equivalent of the Stockum Limestone is present here.

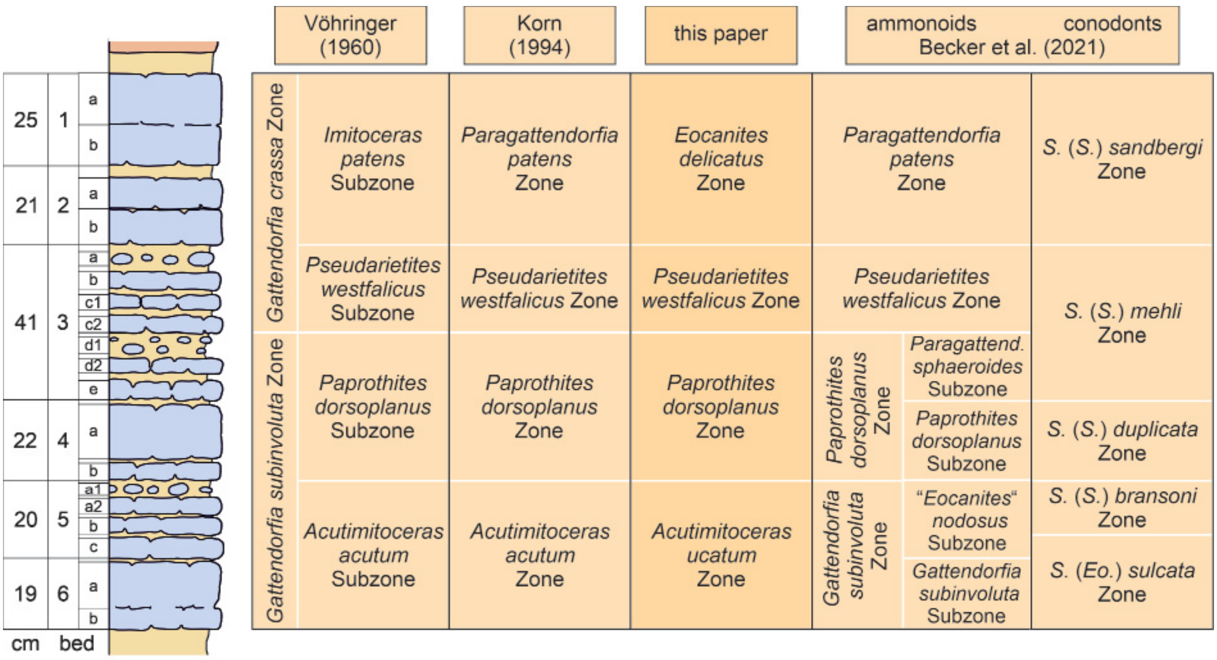

Fig. 5. Correlation of the ammonoid stratigraphy schemes of the Hangenberg Limestone and correlation to the conodont stratigraphy.

The range charts (Figs 3–4) show that the species spectrum changes between beds 6 and 5; but also here are clear statements difficult because Vöhringer did not assign the specimens from bed 5 to one of the four subunits. According to the empirical data, *Voehringerites peracutus* already starts in the lowest subunit (bed 5c), *Eocanites ruani* in bed 5b and the two rare species *Kornia acia* and *Gattendorfia immodica* sp. nov. in bed 5a2.

Becker *et al.* (2021) named this zone *Gattendorfia subinvoluta* Zone and distinguished two subzones. Bed 6 should represent the *Gattendorfia subinvoluta* Subzone and bed 5 the "*Eocanites*" *nodosus* Subzone (probably meaning *Eocanites ruani*). The latter subzone should also be characterised by the lowest occurrence of *Voehringerites peracutus*, *Nicimitoceras trochiforme*, *N. subacre* and *N. heterolobatum*. It must be noted, however, that no material of the three species of *Nicimitoceras* is available from bed 5; all available specimens are from beds above bed 4.

Paprothites dorsoplanus Zone – This zone is a total range zone characterised by the name-giving species and the other species of the genus *Paprothites*. It includes beds 4, 3e, 3d2 and 3d1 at Oberrödinghausen. It should be noted that bed 4 is rather poor in fossils and no *Paprothites* material is available from this bed. However, it can be assumed that the reference by Vöhringer (1960), to the occurrence of *P. dorsoplanus* in bed 4, actually refers to this easily recognisable species. Other species that probably have the lowest occurrence in bed 4 are *Stockumites exilis*, *S. voehringeri* and *Hasselbachia multisulcata*. *Gattendorfia corpulenta* sp. nov., *Weyerella molaris* and *Hasselbachia gracilis* appear to enter in bed 3e.

As with the zone previously described, Becker *et al.* (2021) proposed a subdivision of this zone, including a lower *Paprothites dorsoplanus* Subzone (containing bed 4) and an upper *Paragattendorfia sphaeroides* Subzone (beds 3e and 3d). Applying this scheme would mean that the main occurrence of *Paprothites dorsoplanus* is not in the subzone named after it, but in a bed from which no specimen is apparently currently available. All available, more than 70 specimens of the species from Oberrödinghausen are from bed 3d.

Another weakness in this scheme is the choice of *Paragattendorfia sphaeroides* as the index for the second subzone. There are only three specimens of this species available from beds 3c and 2. It is not certain whether the reference by Vöhringer (1960) to the occurrence of the species in bed 3e is correct or whether he has included specimens of *Kornia fibula* sp. nov.

Pseudarietites westfalicus Zone – The *Pseudarietites westfalicus* Zone is a total range zone, which corresponds to the range of the name-giving species. In the section of Oberrödinghausen it corresponds to beds 3c, 3b and 3a and is thus only slightly more than 20 cm thick. In addition to the species of *Pseudarietites*, *Stockumites depressus* and *Zadelsdorfia crassa* also start in this zone.

Eocanites delicatus Zone – The *Eocanites delicatus* Zone replaces the "Subzone des *Imitoceras patens*" of Vöhringer (1960), because the index species is very rare and apparently already occurs in older beds (3d, 3a) in the new collections. For beds 2 and 1 in the Oberrödinghausen section, the new zone name is therefore proposed here.

Neighbouring outcrops

Further sections with ammonoids in the Hangenberg Limestone in the neighbourhood of Oberrödinghausen at the northern Rhenish Mountains (Fig. 1) have been repeatedly described beginning with Schmidt (1924); later, these sections were reviewed by Luppold *et al.* (1994) and Becker *et al.* (2021). Here, we list the most important of these sections (from west to east):

Hasselbachtal – A number of ammonoid species are known from the Hasselbachtal section (Figs 6–8), which gained importance as an auxiliary stratotype section for the Devonian–Carboniferous boundary (Becker *et al.* 1984; Becker 1988; Becker & Paproth 1993; Becker 1996; Korn *et al.* 2010c). Korn & Weyer (2003) gave detailed descriptions of the lithological succession of the section and reviewed its research history. The section received particular attention because the geochronological dating of the tuffite layers, one of which (bed 79) at the base of the Hangenberg Limestone provided numerical ages for this period boundary (Claoué-Long *et al.* 1992, 1993; Trapp *et al.* 2004a, 2004b).

The Hasselbachtal section is characterised by a lower carbonate content than the Oberrödinghausen section. Solid limestone beds are almost missing in the Hangenberg Limestone and the individual carbonate layers reach a thickness of only 8 cm.

The fossil content of the Hasselbachtal section is much lower when compared with Oberrödinghausen. Nevertheless, it is possible to document the principal stratigraphic succession of the ammonoid assemblages. This applies mainly to the middle part of the Hangenberg Limestone, which shows a succession of the genera *Paprothites* and *Pseudarietites*.

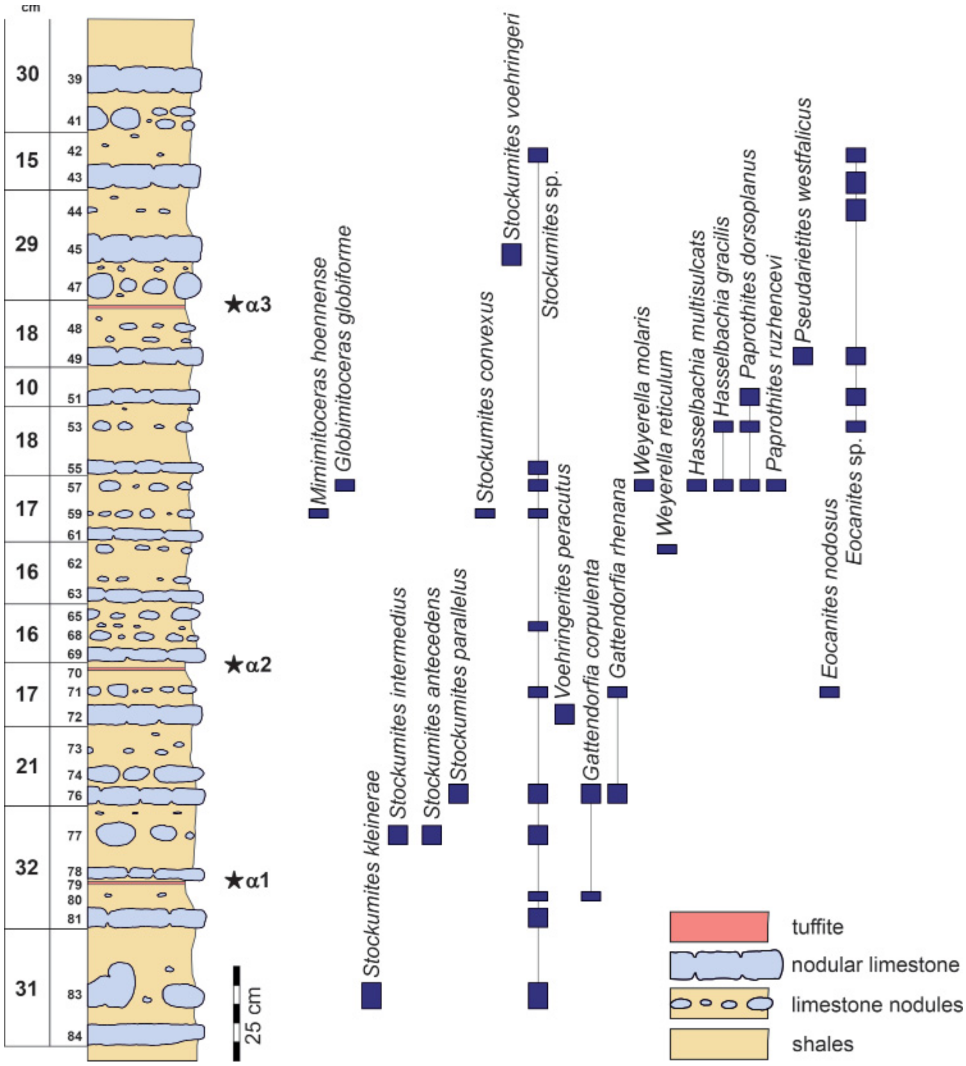

Fig. 6. The lithological succession of the Hangenberg Limestone in the Hasselbachtal section with the occurrence of the ammonoid species.

Oese – Geographically and lithologically, the Oese section is located between Hasselbachtal and Oberrödinghausen. This means that the carbonate content of the sediments has led to some more compact layers in the upper part of the Hangenberg limestone, but in the lower and middle part there are largely nodular layers. This section also yielded ammonoid assemblages (Figs 9–10), which come mainly from the middle part of the succession (Ziegler 1971; Becker *et al.* 1993; Korn & Weyer 2003).

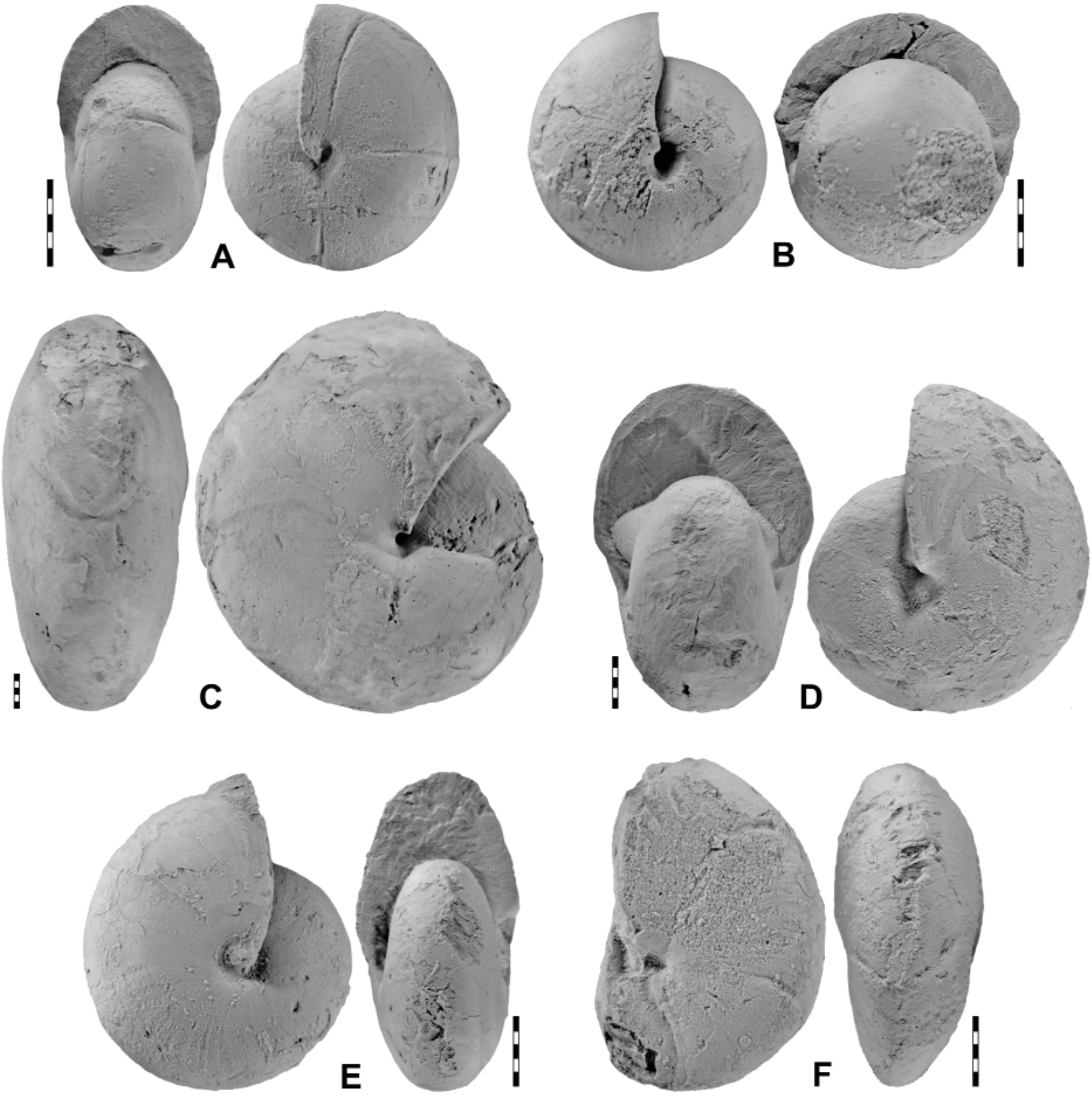

Fig. 7. Early Tournaisian representative ammonoids of the family Prionoceratidae from the Hasselbachtal section, all Weyer 1993–1994 Coll. **A**. *Mimimitoceras hoennense* Korn, 1993, specimen MB.C.5241.2 from bed 59. **B**. *Globimitoceras globiforme* (Vöhringer, 1960), specimen MB.C.5240.7 from bed 57. **C**. *Stockumites voehringeri* sp. nov., paratype MB.C.5235.1 from bed 46. [Illustrated by Korn & Weyer (2003, pl. 1 figs 1–2) as *Acutimitoceras* cf. *intermedium*.] **D**. *Stockumites intermedius* (Schindewolf, 1923), specimen MB.C.5248.1 from bed 77. **E**. *Stockumites convexus* (Vöhringer, 1960), specimen MB.C.5241.1 from bed 59. **F**. *Stockumites parallelus* sp. nov., paratype MB.C.5247.2 from bed 57. (Illustrated by Korn & Weyer 2003: pl. 2 figs 6–7, as *Acutimitoceras subbilobatum*.) Scale bar units = 1 mm.

Apricke – The section of Apricke shows a lithological succession very similar to the Hasselbachtal section with a Hangenberg Limestone largely built up of nodular carbonate layers (Korn & Weyer 2003). Species diverse ammonoid collections are not yet known from Apricke.

Wocklum – The classic outcrop above the weir at the Borke rivulet has become known as the eponym for the ammonoid genera *Wocklumeria* and *Parawocklumeria* as well the *Wocklumeria* Stufe (or Wocklum Stufe) of the traditional Late Devonian subdivision. However, it also includes a complete section of the Hangenberg Limestone, but this is poor in macrofossils (Luppold *et al.* 1994). Becker *et al.* (2016b) and Hartenfels *et al.* (2022) presented a revised account of the section; in the latter the Wocklum section was proposed as a global stratotype for the Devonian–Carboniferous boundary.

Hangenberg, Effenberg, Müssenberg – Outcrops in the vicinity of Hangenberg, Effenberg and Müssenberg show the Hangenberg Limestone with a higher carbonate content than the sections between Hasselbachtal and Wocklum. Ammonoids are mainly known from Müssenberg (Korn 1981, 1984, 1990, 2005; Clausen *et al.* 1990; Luppold *et al.* 1994), but these come largely from a single layer in the lower part of the succession and contain an assemblage in which genera of the family Gattendorfiidae are missing. This occurrence can be correlated with the Stockum Limestone.

Stockum – The Devonian–Carboniferous boundary section at Stockum occupies a special position among the boundary sections in the Rhenish Mountains. It is largely composed of clastic sediments and contains few carbonate layers. The outcrop has become famous for the Stockum Limestone;

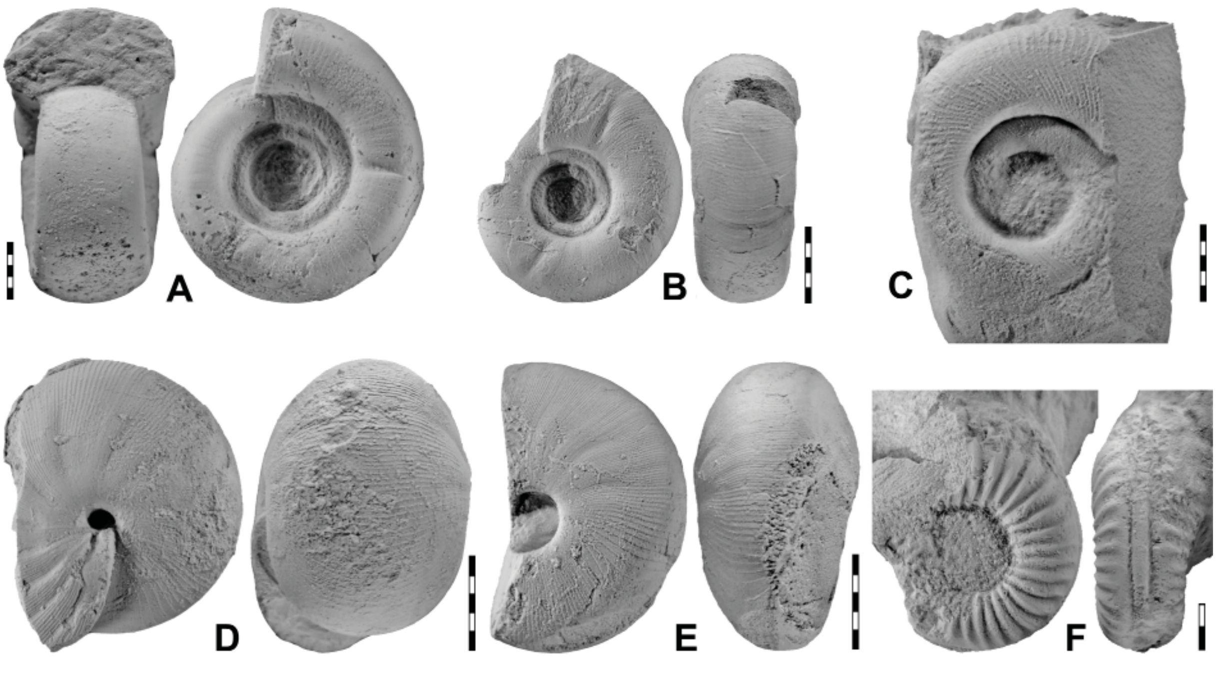

Fig. 8. Early Tournaisian representative ammonoids of the family Gattendorfiidae from the Hasselbachtal section, all Weyer 1993–1994 Coll. **A**. *Gattendorfia rhenana* sp. nov., paratype MB.C.5244.1 from bed 71. (Illustrated by Korn & Weyer 2003: pl. 2 figs 10–11, as *Gattendorfia subinvoluta*.) **B**. *Weyerella molaris* (Vöhringer, 1960), specimen MB.C.5240.8 from bed 57. **C**. *Weyerella reticulum* (Vöhringer, 1960), specimen MB.C.5242.1 from bed 62. **D**. *Hasselbachia multisulcata* (Vöhringer, 1960), specimen MB.C.5240.1 from bed 57. **E**. *Hasselbachia gracilis* (Vöhringer, 1960), specimen MB.C.5240.5 from bed 57. **F**. *Pseudarietites westfalicus* Schmidt, 1924, specimen MB.C.5236.1 from bed 49. Scale bar units = 1 mm.

these are dark grey carbonatic lenticular bodies, which yielded an ammonoid assemblage consisting of representatives of the family Prionoceratidae, but lack species of the family Gattendorfiidae (Korn 1984). This peculiarity was already recognised and discussed by Vöhringer (1960: 188). His assumption that the "Stockum Fauna" is stratigraphically a little older than the assemblages from Oberrödinghausen was later confirmed by the examination of the conodonts (Ziegler 1969; Alberti *et al.* 1974; Clausen *et al.* 1994). The Stockum assemblage has not been recorded at Oberrödinghausen; the lowest part of the basal bed 6 at Oberrödinghausen already yielded specimens of *Gattendorfia*. However, the Stockum occurrence lost its exclusivity as many sections of the Hangenberg Limestone in the Rhenish Mountains (Korn 1981; Clausen *et al.* 1990; Korn *et al.* 1994; Luppold *et al.* 1994; Korn & Weyer 2003) and its equivalents in Thuringia (Pfaffenberg Member of the Gleitsch Formation, Löhma Member of the Göschitz Formation) (Bartzsch *et al.* 1999, 2002) start with the "Stockum ammonoid fauna" of the *Stockumites prorsus* Zone.

Drewer – The Devonian–Carboniferous boundary section at Drewer is one of the most important sections representing this time interval. It has been intensively studied in terms of both the lithological-facial and the faunal succession; a summary of the research history has been provided by Becker *et al.* (2016a).

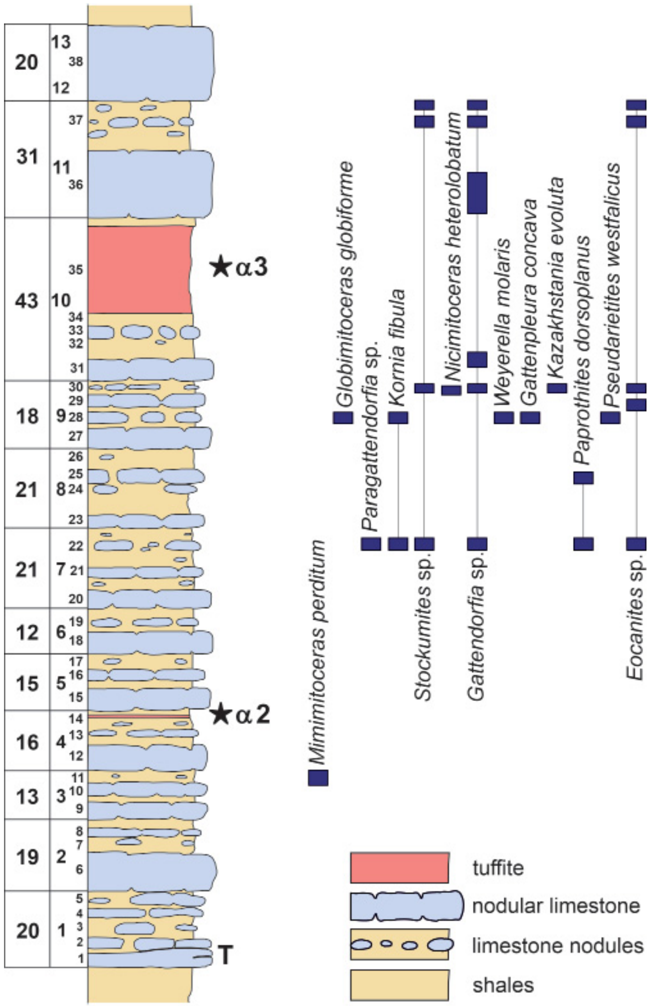

Fig. 9. The lithological succession of the Hangenberg Limestone in the Oese section with the occurrence of the ammonoid species.

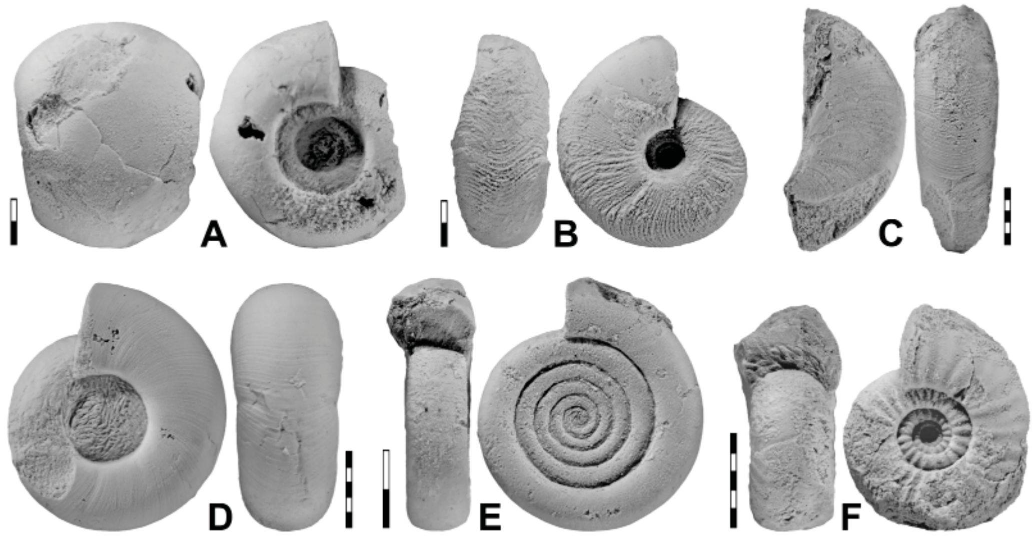

Fig. 10. Early Tournaisian representative ammonoids from the Oese section, all Weyer & Korn 2000 Coll. **A**. *Paragattendorfia* sp., specimen MB.C.5262.8 from bed 22. **B**. *Stockumites* sp., specimen MB.C.5262.9 from bed 22. **C**. *Gattenpleura concava* (Vöhringer, 1960), specimen MB.C.5260.1 from bed 28. **D**. *Weyerella molaris* (Vöhringer, 1960), specimen MB.C.5260.2 from bed 28. **E**. *Kazakhstania evoluta* (Vöhringer, 1960), specimen MB.C.5258.1 from bed 30. **F**. *Paprothites dorsoplanus* (Schmidt, 1924), specimen MB.C.5262.1 from bed 22. Scale bar units = 1 mm.

The unit of the Hangenberg Limestone is very similar to some sections in the vicinity of Oese and Wocklum; it is largely composed of thin (up to about 10 cm thick) nodular limestone layers and shales with intercalated limestone nodules (Clausen & Leuteritz 1984; Clausen *et al.* 1989; Korn *et al.* 1994).

A special feature of the Drewer outcrop is the lateral difference between the individual sections, which are probably caused by synsedimentary slumping events (Clausen & Leuteritz 1984; Walliser 1996). The most complete is section WB (Korn *et al.* 1994; Clausen & Korn 2008), in which the Hangenberg Limestone already starts at a time equivalent level of the Stockum Limestone. Furthermore, it is the only outcrop known so far in the Rhenish Mountains, from where three-dimensionally preserved ammonoids from the Hangenberg Black Shale are known (Korn 1991). A disadvantage of the locality is the tectonic deformation and the sometimes strong silicification of the fossils, which are only rarely well preserved.

Material and methods

The Vöhringer collection

Eugen Vöhringer had assembled, over several years in the 1950s, a rich collection on which he based his doctoral thesis (Vöhringer 1960). It is no longer known how many specimens he had in total for his study; for many species he stated the number of specimens available to him, but for some only that he had "numerous". However, it can be estimated that he studied more than 1000 specimens. Unfortunately, only the described and illustrated specimens were given to the collection of the Geological-Palaeontological Institute of the University of Tübingen; these are about 175 specimens in total. This means that even for the species newly introduced by Vöhringer, no further paratypes were deposited in addition to the illustrated specimens. This situation unfortunately precludes the study of intraspecific variation of some of the species.

Like contemporary doctoral students working with macrofossils at the University of Tübingen, Vöhringer had no professional support in mechanically extracting the specimens from the rock. The semi-professional preparation resulted in damage to many fossils. This is especially true for the visualisation of suture lines in the dorsal whorl zone of several specimens; grinding was sometimes too deep and caused inaccurate suture line images and also supposedly high apertures. Morphometric data can only be obtained with caution in some of these specimens.

In 2002, Vöhringer himself donated remains of his private collection to the Museum für Naturkunde, Berlin. This collection consists of about 180 specimens of various ammonoid species, most of which are poorly preserved. Almost all specimens are well labelled with the bed number and the indication from which side of the railway cut they originate. More than 60 of these specimens have already been sectioned by Vöhringer, but remained unused in his monograph. Among them, *Zadelsdorfia crassa* is well represented in this collection, and a number of specimens have been used to study the ontogeny of the internal whorls (Korn & Vöhringer 2004).

The Weyer collection

In 1993 and 1994, DW revisited the outcrop in the railway cutting to take bed-by-bed samples. At that time, only the eastern side of the outcrop was temporarily accessible when parts of the outcrop became opened during the construction work of the neighbouring cement factory. The restricted outcrop conditions only allowed the sampling of a relatively small amount of rock, much smaller than that available to Vöhringer. The western side of the railway cut already was no longer accessible to sample due to the almost complete weathering of the limestone.

The Weyer collection contains more than 800 ammonoid specimens, most of which are rather small and fragmentary. However, it is a complete collection, i.e., every ammonoid specimen was recorded, and therefore the percentage abundance of taxa of genus and species rank can be estimated. All specimens were collected in the most detailed stratigraphic resolution, with some of the strata summarised by Vöhringer (1960) being subdivided into smaller subunits.

Other collections

The Museum für Naturkunde at Berlin houses material from some other collectors of the Oberrödinghausen railway cutting. The oldest of these collections was assembled by Hermann Schmidt (1924, 1925), who probably was the first to sample this locality. The type material of the species described by him is stored in the collection of the Geologische Bundesanstalt, Berlin-Spandau and the Geoscience Centre, Göttingen.

DK visited the outcrop in the late 1970s and collected 60 specimens from a temporary outcrop on the eastern side of the railway cutting. At the same time, he collected a few specimens from a small outcrop in a slope about 25 metres west of the railway.

Method of description

We describe the species based on the original type material and new material from the Oberrödinghausen railway cutting. This is to complement earlier studies (Schmidt 1924, 1925; Vöhringer 1960; Korn 1994) by presenting diagrams of ontogenetic development and photographs of well-preserved specimens. A total amount of more than 900 specimens are available for study (Table 1).

Additionally, the time equivalent material from the Anti-Atlas of Morocco and monographically described by Bockwinkel & Ebbighausen (2006) and Ebbighausen & Bockwinkel (2007) was re-studied by us with special focus on the putative occurrences of species named previously in Central Europe.

Table 1 (continued on next page). The number of specimens available from Oberrödinghausen and neighbouring localities for the species described here.

Mimimitoceras perditum sp. nov.	18 specimens
Mimimitoceras hoennense Korn, 1993	9 specimens
Globimitoceras globiforme (Vöhringer, 1960)	10 specimens
Paragattendorfia patens (Vöhringer, 1960)	5 specimens
Paragattendorfia sphaeroides Weyer, 1972	3 specimens
Kornia sphaeroidalis (Vöhringer, 1960)	2 specimens
Kornia fibula sp. nov.	10 specimens
Kornia acia sp. nov.	3 specimens
Stockumites kleinerae (Korn, 1984)	12 specimens
Stockumites intermedius (Schindewolf, 1923)	37 specimens
Stockumites parallelus sp. nov.	11 specimens
Stockumites procedens (Korn, 1984)	1 specimen
Stockumites undulatus (Vöhringer, 1960)	8 specimens
Stockumites convexus (Vöhringer, 1960)	17 specimens
Stockumites antecedens (Vöhringer, 1960)	3 specimens
Stockumites voehringeri sp. nov.	79 specimens
Stockumites exilis (Vöhringer, 1960)	6 specimens
Stockumites similis (Vöhringer, 1960)	11 specimens
Stockumites depressus (Vöhringer, 1960)	6 specimens
Acutimitoceras ucatum sp. nov.	11 specimens
Acutimitoceras paracutum sp. nov.	2 specimens
Costimitoceras ornatum Vöhringer, 1960	4 specimens
Nicimitoceras trochiforme (Vöhringer, 1960)	4 specimens
Nicimitoceras subacre (Vöhringer, 1960)	6 specimens
Nicimitoceras acre (Vöhringer, 1960)	7 specimens
Nicimitoceras heterolobatum (Vöhringer, 1960)	23 specimens
Imitoceras initium sp. nov.	1 specimen
Voehringerites peracutus (Vöhringer, 1960)	23 specimens
Gattendorfia rhenana sp. nov.	10 specimens
Gattendorfia bella sp. nov.	5 specimens
Gattendorfia valdevoluta sp. nov.	5 specimens
Gattendorfia schmidti sp. nov.	9 specimens
Gattendorfia costata Vöhringer, 1960	1 specimen
Gattendorfia corpulenta sp. nov.	13 specimens
Gattendorfia immodica sp. nov.	1 specimen
Zadelsdorfia crassa (Schmidt, 1924)	50 specimens
Zadelsdorfia oblita sp. nov.	3 specimens
Kazakhstania evoluta (Vöhringer, 1960)	2 specimens
Gattenpleura concava (Vöhringer, 1960)	6 specimens
Weyerella molaris (Vöhringer, 1960)	132 specimens
Weyerella reticulum (Vöhringer, 1960)	6 specimens
Weyerella lenis sp. nov.	2 specimens
Hasselbachia multisulcata (Vöhringer, 1960)	20 specimens
Hasselbachia gracilis (Vöhringer, 1960)	11 specimens
Hasselbachia erronea sp. nov.	5 specimens
Paprothites dorsoplanus (Schmidt, 1924)	82 specimens

Table 1 (continued). The number of specimens available from Oberrödinghausen and neighbouring localities for the species described here.

Paprothites raricostatus (Vöhringer, 1960)	4 specimens
Paprothites beckeri sp. nov.	1 specimen
Paprothites ruzhencevi Korn & Weyer, 2003	45 specimens
Paprothites kullmanni sp. nov.	4 specimens
Pseudarietites westfalicus Schmidt, 1924	51 specimens
Pseudarietites subtilis Vöhringer, 1960	7 specimens
Pseudarietites serratus Vöhringer, 1960	2 specimens
Rodingites planissimus (Vöhringer, 1960)	1 specimen
Rodingites carinatus (Vöhringer, 1960)	1 specimen
Paralytoceras crispum (Tietze, 1870)	3 specimens
Eocanites ruani Bartzsch, Korn & Weyer, 2003	9 specimens
Eocanites nodosus (Schmidt, 1925)	25 specimens
Eocanites brevis (Vöhringer, 1960)	13 specimens
Eocanites tener (Vöhringer, 1960)	20 specimens
Eocanites spiratissimus (Schindewolf, 1926)	3 specimens
Eocanites supradevonicus (Schindewolf, 1926)	1 specimen
Eocanites delicatus sp. nov.	23 specimens
Eocanites planus (Schindewolf, 1926)	2 specimens
Nomismocanites raritas sp. nov.	1 specimen

The description of the material largely follows the scheme and terminology, which was proposed by Korn (2010) and Klug *et al.* (2015) for Palaeozoic ammonoids (Fig. 11). The terminology of the suture line follows Korn *et al.* (2003b), meaning that a difference between an A-mode (goniatitic) and U-mode (prolecanitic and thus also ceratitic) sutural ontogeny, as proposed by Schindewolf (1929), is not accepted. The sutural elements described here are therefore external (E), adventive (A), lateral (L), umbilical (U) and internal (I) lobes for both the goniatitid and prolecanitid ammonoids (Fig. 11).

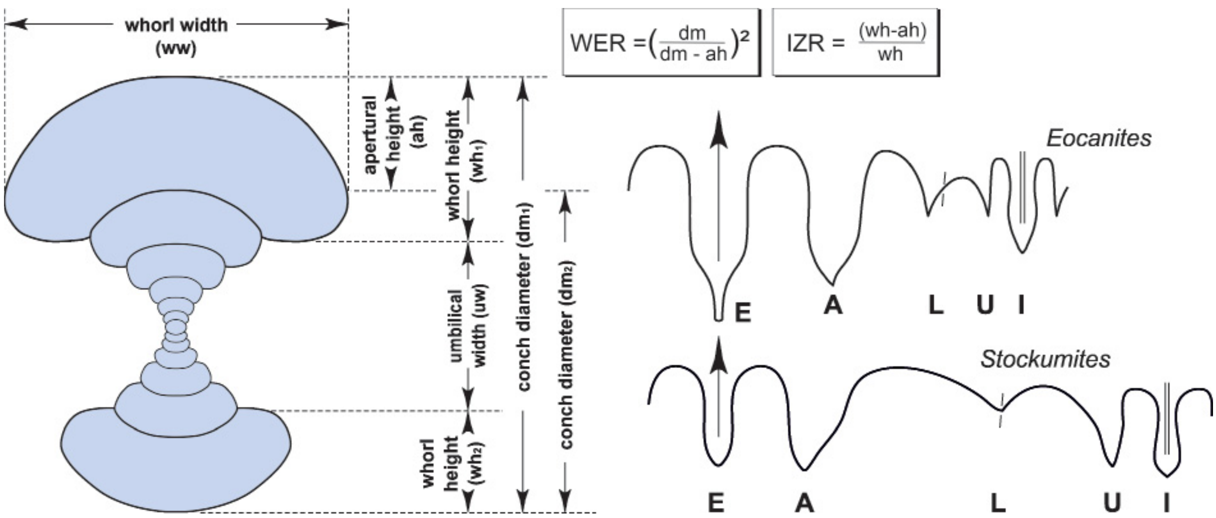

Fig. 11. The morphological terms used in the description of the ammonoid conchs and suture lines.

Abbreviations used in the species descriptions

ah = apertural height
dm = conch diameter
IZR = imprint zone rate
uw = umbilical width
WER = whorl expansion rate
wh = whorl height
ww = whorl width

Abbreviations of the host institutions of the studied specimens

BGR = Bundesanstalt für Geologie und Rohstoffe, Geowissenschaftliche Sammlungen Berlin
GPIT = Geological-Palaeontological Institute of the University of Tübingen
GZG = Geowissenschaftliches Zentrum, Museum, Sammlungen & Geopark, Göttingen
MB.C. = Cephalopod collection of the Museum für Naturkunde, Berlin
SMF = Senckenberg Museum, Frankfurt am Main
SNSB BSPG = Bayerische Staatssammlung für Paläontologie und Geologie, München

Results

Order Goniatitida Hyatt, 1884
Suborder Tornoceratina Wedekind, 1914

Superfamily **Prionoceratoidea** Hyatt, 1884

[nom. transl. Bogoslovsky (1971: 94), pro Prionocerae Hyatt, 1884; nom. correct. Kullmann (2009: 2), pro Prionocerataceae]

Diagnosis

Superfamily of the suborder Tornoceratina with discoidal to globular, primarily involute conchs without coarse ornament. Many modifications of the conch shape during ontogeny and phylogeny; advanced forms may possess a wide umbilicus and may bear a coarse ornament. Basic suture line with the elements E A L I, development of supplementary external, adventive, lateral and umbilical lobes occur in various lineages. Ornament primarily with growth lines only; ribs are developed in some lineages. Growth lines have a convex course in the early forms, but there are trends toward biconvex growth lines in many lineages (after Korn & Klug 2002).

Included families

Prionoceratidae Hyatt, 1884; Cheiloceratidae Frech, 1897; Sporadoceratidae Miller & Furnish, 1957; Praeglyphioceratidae Ruzhencev, 1957; Maximitidae Ruzhencev, 1960; Gattendorfiidae Bartzsch & Weyer, 1987.

Family **Prionoceratidae** Hyatt, 1884

[nom. correct. Bogoslovsky (1971: 180), pro Prionocerae Hyatt, 1884]

Diagnosis

Family of the superfamily Prionoceratoidea with the sutural formula E A L U I or (E_1 E_m E_1) A L U I in some advanced forms; adventive lobe deep, V-shaped or lanceolate and pointed, only rarely blunt; the lateral lobe has a position on the umbilical seam. Conch in the juvenile stage usually subinvolute, in some lineages subevolute or evolute; adult stage usually involute, but subinvolute in some genera. Shell ornament with fine to coarse growth lines, mostly without ribs.

Included subfamilies

Prionoceratinae Hyatt, 1884; Imitoceratinae Ruzhencev, 1950; Karagandoceratinae Librovitch, 1957; Voehringeritinae Bartzsch & Weyer, 1988; Acutimitoceratinae Korn, 1994; Balviinae Korn in Korn & Klug, 2002.

Subfamily **Prionoceratinae** Hyatt, 1884

[nom. transl. Bartzsch & Weyer (1988a: 136), pro Prionocerae Hyatt, 1884]

Diagnosis

Subfamily of the family Prionoceratidae with the sutural formula E A L U I, adventive lobe V-shaped or lanceolate, pointed. Conch in the juvenile stage usually subinvolute, rarely subevolute; adult stage involute or subinvolute. Coiling rate usually very low or low (WER = 1.40–1.75). Shell ornament with fine to coarse growth lines, without ribs.

Included genera

Prionoceras Hyatt, 1884; *Haugiceras* Cossmann 1900 [synonym of *Prionoceras*]; *Postprolobites* Wedekind, 1913 [synonym of *Prionoceras*]; *Paragattendorfia* Schindewolf, 1924; *Cunitoceras* Weyer, 1972 [problematic genus]; *Mimimitoceras* Korn, 1988; *Globimitoceras* Korn, 1993; *Rectimitoceras* Becker 1996 [synonym of *Mimimitoceras*]; *Kornia* Ebbighausen & Bockwinkel, 2007.

Morphology

The species of the subfamily Prionoceratinae are characterised by a simple conch geometry; the conch is sometimes discoidal but more often pachyconic to globular with a nearly closed or closed umbilicus and almost always a very low or low coiling rate. This morphology is shared by the two main genera *Prionoceras* and *Mimimitoceras* (e.g., Korn *et al.* 2014, 2015). Another common feature of the two genera are the shell constrictions, which are present in all species at least in the early stage of ontogeny. Almost all species have a shell ornament consisting only of growth lines; these almost always have a convex course on the flank and form a broad, shallow ventral sinus.

The suture line also shows little variation. It consists of the basic elements E A L U I; the shape of the external and adventive lobe varies between species. Usually, species with a discoidal conch show a narrower, sometimes lanceolate external lobe, while in globular species it is often broader and V-shaped. A deviation from this rule, however, is *Globimitoceras* with a globular conch but a very narrow external lobe.

Ontogeny

The species of the subfamily underwent a comparatively simple ontogenetic development; this means that the morphology of juveniles and adults does not differ markedly. Conch allometry is usually weakly developed; the ontogenetic trajectories (Korn 2012) are often monophasic with a simple decrease of the ww/dm ratio, for example. These simple ontogenetic trajectories are mainly caused by the small width of the umbilicus in the juvenile stage. Therefore, the whorl profiles are rather similar at all growth stages and range from C-shaped to horseshoe-shaped. Only the trend towards more slender conchs that is present in most Palaeozoic ammonoids is evident.

Phylogeny

The Prionoceratinae are the ancestral subfamily of the family Prionoceratidae and thus of all post Devonian ammonoids. The prionoceratids of the Famennian formed only one previously known side branch, the subfamily Balviinae with its paedomorphic conchs (Korn 1992a, 1995a, 1995b) is distinguished by divergent morphologies. Several side branches formed in the earliest Carboniferous.

The most successful of these is the subfamily Acutimitoceratinae, described in more detail below. Less successful side branches are the genera *Globimitoceras*, *Kornia* and *Paragattendorfia*, all of them restricted to the Early and Middle Tournaisian, but apparently extinct without descendants.

Stratigraphic occurrence

The subfamily Prionoceratinae has its main distribution in the middle and late Famennian, where several species can be used as index species (Korn *et al.* 2014, 2015) and help to establish a stratigraphic scheme that complements the clymeniid-based zonation. According to current knowledge, the Prionoceratinae are one of the few ammonoid lineages that survived the Hangenberg Event at the Devonian–Carboniferous boundary (Korn 1986, 1993, 2000; Becker 1993; Kullmann 2000). In contrast to the "failed survivors", the cymaclymeniids, which survived the biocrisis with few forms but became extinct shortly afterwards (Korn 1990; Korn *et al.* 2004), the evolution of the prionoceratids is, in contrast to the cymaclymeniids, not a "dead clade walking" (Jablonski 2002), but the evolution of a group with a very successful radiation in the Early Carboniferous. However, this successful radiation was caused by flourishing of the subfamily Acutimitoceratinae, while the genera of the Prionoceratinae have only a short stratigraphic range, apparently restricted to the early and middle Tournaisian. The late Tournaisian record of the problematic species *Cunitoceras schindewolfi* Weyer, 1972 in the Harz Mountains requires confirmation.

Geographic occurrence

The Prionoceratinae are a subfamily with an almost global distribution in the Middle and Late Famennian; in the Early and Middle Tournaisian the distribution is significantly restricted. The most important occurrences in Europe are in the Rhenish Mountains (Vöhringer 1960; Korn 1994; Korn & Weyer 2003), Franconia (Schindewolf 1923; Korn 1994), Thuringia (Weyer 1977), questionably the Harz Mountains (Schindewolf 1951), Silesia (Dzik 1997), the Carnic Alps (Korn 1992b) and the Montagne Noire (Becker & Weyer 2004; Korn & Feist 2007). Early Carboniferous species are also known from the Anti-Atlas (Bockwinkel & Ebbighausen 2006), the South Urals (Popov 1975), Guizhou (Ruan 1981), Karaganda (Librovitch 1940) and (questionably) Michigan (Winchell 1862; Miller & Garner 1955).

Genus ***Mimimitoceras*** Korn, 1988

Type species

Mimimitoceras trizonatum Korn, 1988; original designation.

Diagnosis

Genus of the subfamily Prionoceratinae with a discoidal to globular conch; umbilicus in the early juvenile stage slightly opened in most of the species and usually rapidly closing during the early whorls. External lobe usually V-shaped in globular species and lanceolate in discoidal species. Shell constrictions accompanied by an apertural shell bulge in the early and middle growth stage, internal shell thickenings usually cause deep steinkern constrictions throughout ontogeny.

Included species

Species lists including the Devonian species of the genus were published several times (Korn 1994; Korn & Klug 2002; Korn *et al.* 2015). The following Carboniferous species of *Mimimitoceras* are known from:

Central Europe (Schindewolf 1923; Korn 1992b, 1993): *Postprolobites varicosus* Schindewolf, 1923; *Mimimitoceras crestaverde* Korn, 1992; *Mimimitoceras hoennense* Korn, 1993; *Mimimitoceras perditum* sp. nov.

North Africa (Bockwinkel & Ebbighausen 2006): *Mimimitoceras mina* sp. nov.

Remarks

Mimimitoceras was revised with the description of Devonian North African material by Korn *et al.* (2015). The genus occurs in late Famennian ammonoid assemblages with numerous species; only two species are known so far from the basal Carboniferous Hangenberg Limestone of the Rhenish Mountains.

Mimimitoceras is easily distinguished from the other genera of the subfamily Prionoceratinae by the presence of a bulging radial ridge in front of the shell constrictions (Korn 1988c). This bulge is usually not present throughout ontogeny; the shell constrictions may disappear in the adult stage. In some stratigraphically older species, such as *M. lineare* (Münster, 1839) from the Late Famennian *Clymenia laevigata* Zone, they may be restricted to the juvenile stage. Based on this very minor variation, which rather describes a difference between species, Becker (1996) proposed the genus *Rectimitoceras*.

Mimimitoceras perditum sp. nov.
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Figs 12–15; Tables 2–3

Imitoceras varicosum – Vöhringer 1960: 122, pl. 2 fig. 1, text-fig. 4.
Mimimitoceras varicosum – Korn 1992a: 33; 1994: 22, text-figs 19a, c, 20c–d, 21f, 22c, 64e–f. — Becker 1996: 35, pl. 1 figs 4–5. — Sprey 2002: 52, text-fig. 17a. — Korn & Weyer 2003: text-fig. 14a.

Diagnosis

Species of *Mimimitoceras* with a conch reaching about 90 mm diameter. Conch thinly globular and subinvolute juvenile stage (ww/dm ~0.90; uw/dm ~0.20 at 2 mm dm), thinly pachyconic and involute in the adult stage (ww/dm ~0.60 at 45 mm dm); umbilicus closed at 8 mm dm. Whorl profile depressed in all stages up to 50 mm dm; coiling rate very low or low (WER ~1.50) up to 20 mm dm, thereafter slowly increasing to 1.75. Ornament with fine and sharp, narrow-standing growth lines with nearly linear course in the subadult stage but weakly convex course in the adult stage. Weak shell constrictions with nearly straight course up to 20 mm dm; adult stage only with internal shell thickenings. Suture line with very narrow, lanceolate external lobe and very narrow, symmetric, V-shaped adventive lobe.

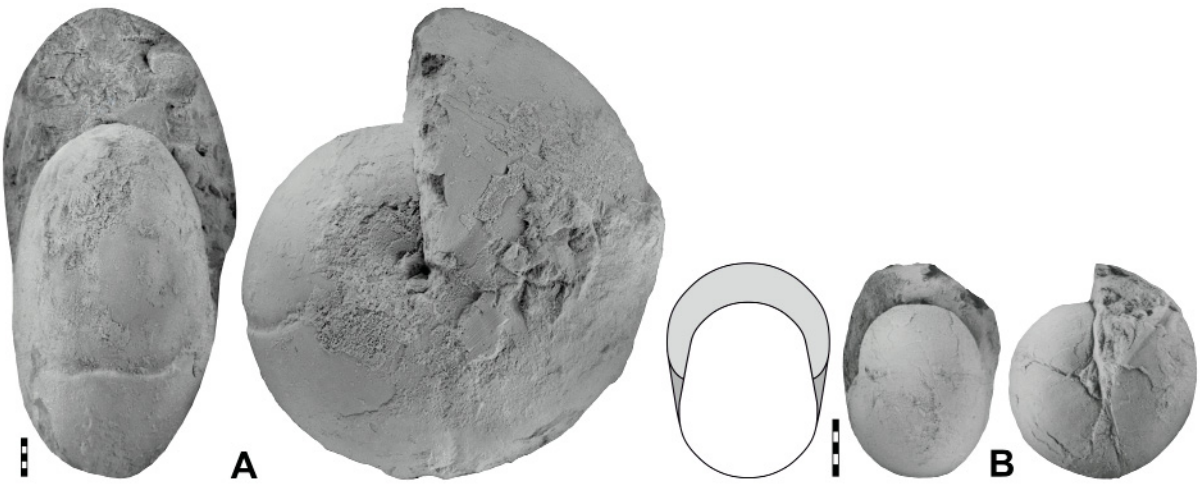

Fig. 12. *Mimimitoceras perditum* sp. nov., from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Holotype GPIT-PV-63861 from bed 2. **B**. Paratype GPIT-PV-63864 from bed 2. Scale bar units = 1 mm.

Etymology

From the Latin '*perditum*' = 'lost, hopeless'; named after the position of the species near the extinction of the clade.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by Korn (1994: text-fig. 19a), re-illustrated here in Fig. 12A; GPIT-PV-63861.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; GPIT-PV-63863, GPIT-PV-64013 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63864, GPIT-PV-63873 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63862 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; MB.C.31051.1–2 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31052.1–3 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; MB.C.31053 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; MB.C.31054.1–3 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1982 Coll.; MB.C.31055 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, upper part; Weyer 1993–1994 Coll.; MB.C.31056 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 11; Weyer & Korn 2000 Coll.; MB.C.5263.

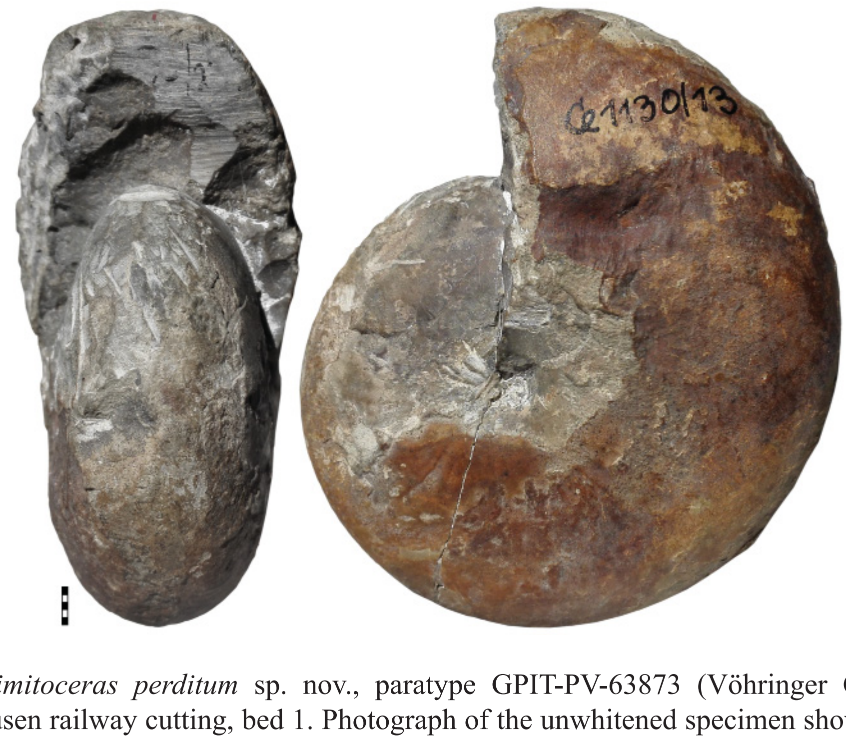

Fig. 13. *Mimimitoceras perditum* sp. nov., paratype GPIT-PV-63873 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 1. Photograph of the unwhitened specimen showing exemplary the often poorly preserved shell surface of the material from Oberrödinghausen. Scale bar units = 1 mm.

Description

Holotype GPIT-PV-63861 is a fairly well-preserved internal mould with 62 mm diameter. It has a thickly discoidal conch morphology (ww/dm = 0.52) and a closed umbilicus (Fig. 12A). The conch is widest near the rounded umbilical margin; from there the flanks slowly converge towards the broadly rounded venter. The coiling rate is low (WER = 1.70). The internal mould shows two constrictions 90 degrees apart. Remains of the shell show delicate growth lines with weakly biconvex course and a shallow shell constriction without an apertural shell bulge.

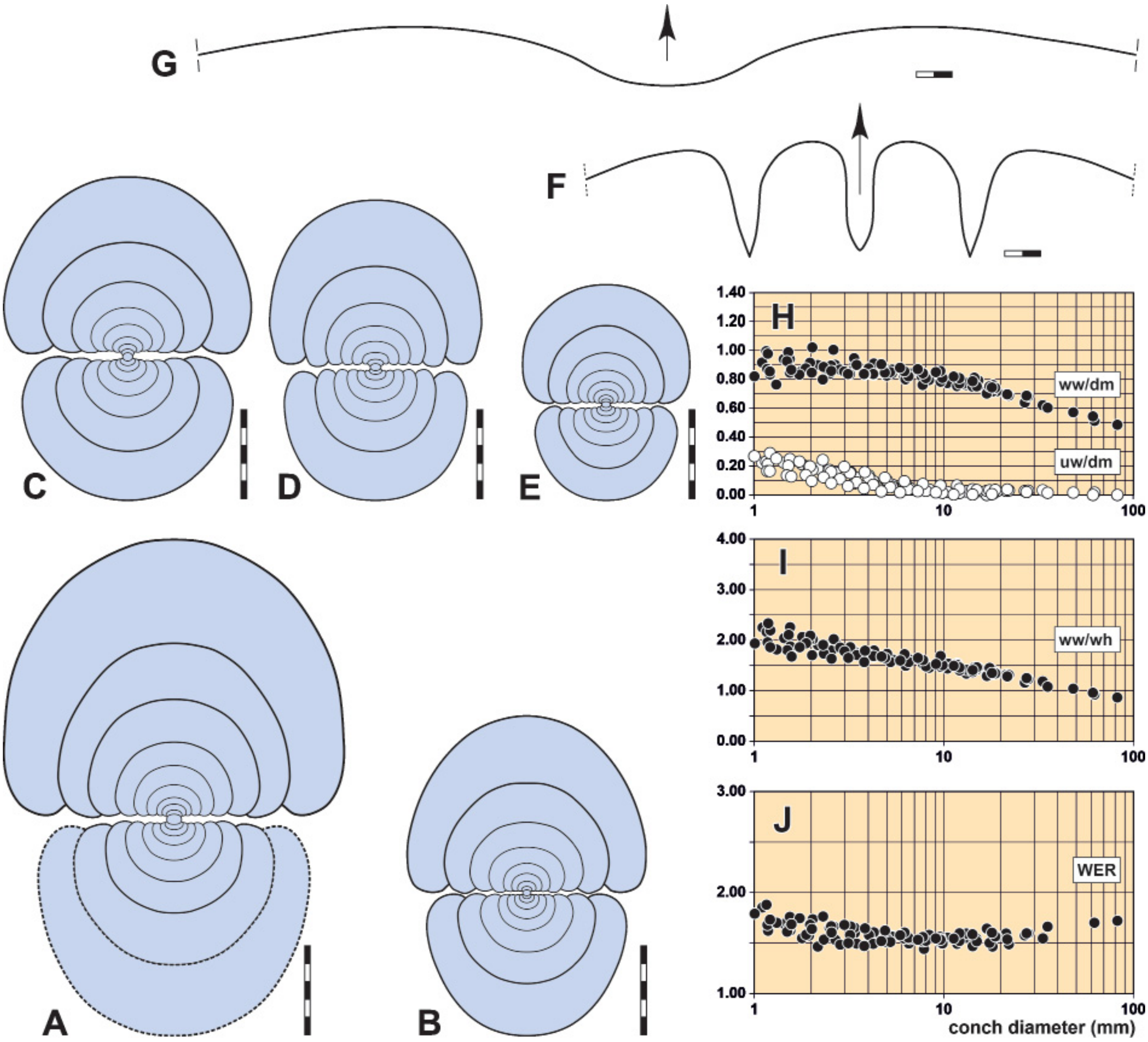

Fig. 14. *Mimimitoceras perditum* sp. nov. from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. Cross section of paratype MB.C.31054.1 from an unknown bed. **B**. Cross section of paratype MB.C.31052.1 from bed 2. **C**. Cross section of paratype MB.C.31052.2 from bed 2. **D**. Cross section of paratype MB.C.31054.2 from an unknown bed. **E**. Cross section of paratype MB.C.31052.3 from bed 2. **F**. Suture line of paratype GPIT-PV-64013 from bed 1, at dm = 25.0 mm, ww = 16.5 mm, wh = 13.0 mm. **G**. Growth line course of paratype GPIT-PV-63862 from bed 5, at ww = 26.0 mm, wh = 25.5 mm. **H**–**J**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Paratype GPIT-PV-63873 is, with 82 mm conch diameter, the largest of the present specimens (Fig. 13). Corresponding to the general ontogenetic trend towards more slender conchs, it is thickly discoidal at this growth stage (ww/dm = 0.49); the whorl profile is weakly compressed in this growth stage (ww/wh = 0.87).

Paratype GPIT-PV-63864 shows the subadult morphology at 19 mm diameter (Fig. 12B). The conch is pachyconic (ww/dm = 0.72) with broadly rounded flanks and venter and has a low coiling rate (WER = 1.56). The shell bears constrictions at 90 degree intervals; they extend with an almost straight course across the flanks and the venter. These fine constrictions are accompanied on the apertural side by a low radial bulge.

The suture line of paratype GPIT-PV-64013 is characterised by very narrow lobes (Fig. 14F). Both the lanceolate external lobe and the almost symmetrical, V-shaped adventive lobe have only about one third of the width of the broadly rounded, somewhat asymmetrical ventrolateral saddle.

Vöhringer had already produced eight cross sections, but he only used one of them for his publication. All of them are now presented here (Figs 14A–E, 15). These cross sections show very similar conch geometries and ontogenetic pathways; intraspecific variation is apparently rather low. It should be noted that the variation decreases during ontogeny for all four cardinal conch parameters.

All cross sections show very similar whorl profiles, which are already horseshoe-shaped in the juvenile stage at about 5 mm conch diameter. During ontogeny, however, the ww/wh ratio decreases continuously from an average value of 2.00 at 1 mm dm to a value of 1.35 at 20 mm dm (Fig. 14I). In the adult stage of 80 mm conch diameter, the value is only 0.90. The umbilicus is slightly open in the juvenile stage at 2 mm conch diameter with a uw/dm ratio reaching a value of 0.20, but the umbilicus is completely

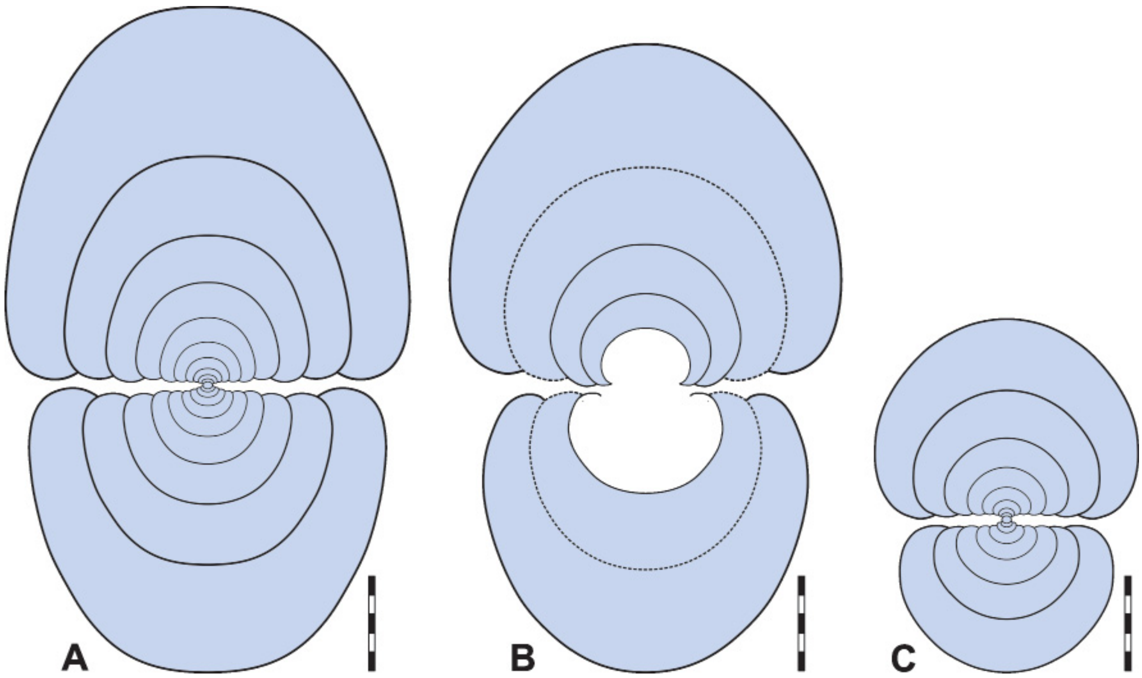

Fig. 15. *Mimimitoceras perditum* sp. nov. from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. Cross section of specimen MB.C.31051.1 from bed 2. **B**. Cross section of specimen GPIT-PV-63862 from bed 5. **C**. Cross section of specimen MB.C.31053 from bed 2. Scale bar units = 1 mm.

Table 2. Conch measurements, ratios and rates of *Mimimitoceras perditum* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63873	82.0	40.0	46.0	0.0	19.5	0.49	0.87	0.00	1.72	0.58
GPIT-PV-63861	62.1	32.0	34.5	1.0	14.5	0.52	0.93	0.02	1.70	0.58
MB.C.31051.1	35.2	21.3	19.6	0.5	7.9	0.61	1.08	0.02	1.66	0.60
GPIT-PV-63862	33.2	20.7	17.4	1.1	6.5	0.62	1.19	0.03	1.55	0.63
MB.C.31054.1	27.8	19.1	15.4	0.8	5.8	0.69	1.23	0.03	1.60	0.62
GPIT-PV-63863	19.0	13.7	10.2	0.5	3.8	0.72	1.34	0.03	1.56	0.63
MB.C.31053	18.7	13.9	10.3	0.7	3.8	0.74	1.35	0.04	1.57	0.64
MB.C.31052.2	18.1	13.9	9.9	0.2	3.7	0.77	1.40	0.01	1.57	0.63
MB.C.31052.1	17.9	13.4	9.9	0.1	3.8	0.75	1.35	0.01	1.60	0.62
MB.C.31054.2	16.8	11.9	9.2	0.5	3.7	0.70	1.30	0.03	1.64	0.60
MB.C.31052.3	12.1	9.4	6.6	0.2	2.3	0.77	1.41	0.01	1.52	0.66

Table 3. Conch ontogeny of *Mimimitoceras perditum* sp. nov.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly to thickly globular; involute to subinvolute (ww/dm = 0.85–1.00; uw/dm = 0.10–0.20)	moderately to strongly depressed; very strongly embracing (ww/wh = 1.70–2.10; IZR = 0.55–0.60)	low (WER = 1.50–1.75)
8 mm	thickly pachyconic; involute (ww/dm = 0.75– 0.85; uw/dm = 0.02–0.05)	moderately depressed; very strongly embracing (ww/wh = 1.50–1.60; IZR = 0.60–0.70)	low (WER = 1.50–1.55)
20 mm	thinly pachyconic; involute (ww/dm ~0.70; uw/dm ~0.02)	weakly depressed; very strongly embracing (ww/wh ~1.30; IZR ~0.65)	low (WER = 1.50–1.65)
40 mm	thinly pachyconic; involute (ww/dm ~0.60; uw/dm ~0.02)	weakly depressed; very strongly embracing (ww/wh = 1.20–1.30; IZR = 0.60–0.65)	low (WER ~1.70)
60 mm	thiclly discoidal; involute (ww/dm ~0.55; uw/dm ~0.02)	weakly compressed; very strongly embracing (ww/wh ~0.95; IZR ~0.60)	low (WER ~1.70)

closed already at about 8 mm conch diameter. The coiling rate remains low during ontogeny; it increases only in the adult stage, but remains below a value of 1.75 (Fig. 14J).

Remarks

The material described here as the new species *Mimimitoceras perditum* sp. nov. was previously (Vöhringer 1960; Korn 1994) attributed to the species originally described by Schindewolf (1923) as "*Postprolobites varicosus*". However, *Mimimitoceras varicosum* has a stouter conch than *M. perditum* and biconvex growth lines and constrictions. *M. varicosum* is most probably from the latest Famennian or earliest Tournaisian part of the *Gattendorfia* Limestone, because at Gattendorf only assemblages corresponding to either the "Stockum level" or the basal part of the *Gattendorfia* Limestone are known. *M. perditum*, on the other hand, occurs at Oberrödinghausen predominantly in the upper portion of the *Gattendorfia* Limestone.

Mimimitoceras perditum sp. nov. differs from *M. hoennense* in the stouter conch (ww/dm ~0.65 at 30 mm dm in *M. perditum* but only ~0.50 in *M. hoennense*). The new species differs from the Late

Devonian species *M. trizonatum* Korn, 1988, *M. liratum* (Schmidt, 1924) and *M. fuerstenbergi* Korn, 1992, which possess rather stout conchs, in the nearly straight course of the growth lines and the weaker shell constrictions.

Vöhringer (1960) already reported "*Imitoceras varicosum*" from near the base of the Hangenberg Limestone (bed 5), and, separated by a gap in the occurrence, from beds 2 and 1 at the top of the unit. Indeed, a few specimens from bed 5 are available in the Vöhringer collection. However, new collections did not produce any identifiable specimens of *Mimimitoceras* from the basal part of the *Gattendorfia* Limestone.

Mimimitoceras hoennense Korn, 1993
Figs 7A, 16–17; Tables 4–5

Mimimitoceras hoennense Korn, 1993: 585.

Imitoceras liratum – Vöhringer 1960: 125, pl. 2 fig. 2, text-fig. 5.
Mimimitoceras hoennense – Korn 1994: 18, text-figs 19b, d, 20e, 21e, 22d. — Korn & Weyer 2003: 100, pl. 2 figs 3–4.
"*Mimimitoceras*" *hoennense* – Becker & Weyer 2004: 22, text-figs 3a, 5c, 14–16.

non *Mimimitoceras hoennense* – Bockwinkel & Ebbighausen, 2006: 93, text-figs 6, 7c–d.

Diagnosis

Species of *Mimimitoceras* a conch reaching about 50 mm diameter. Conch thickly discoidal and involute (ww/dm ~0.55 at 30 mm dm); umbilicus closed at 8 mm dm. Whorl profile weakly depressed up to 30 mm dm and weakly compressed thereafter; coiling rate low (WER ~1.65). Ornament with fine and sharp, narrow-standing growth lines with convex course. Weak shell constrictions with convex course. Suture line with moderately wide, V-shaped external lobe and moderately wide, symmetric, V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by Korn (1994, text-fig. 19b), re-illustrated in Fig. 16A; GPIT-PV-63884.

Fig. 16. *Mimimitoceras hoennense* Korn, 1993 from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Holotype GPIT-PV-63884 from bed 2. **B**. Paratype GPIT-PV-63866 from bed 2. Scale bar units = 1 mm.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63867 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; GPIT-PV-63866.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; MB.C.31057 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2b; Weyer 1993–1994 Coll.; MB.C.31058 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31059.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31060 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 59; Weyer 1993–1994 Coll.; MB.C.5241.2.

Description

Holotype GPIT-PV-63884 is a moderately preserved specimen with a diameter of 36.5 mm (Fig. 16A); it is strongly affected by preparation, but shows its ornamentation in addition to the conch form. The conch is thickly discoidal (ww/dm = 0.50) and completely involute (uw/dm = 0.01). On the shell surface very fine, wide growth lines with convex course are visible. In addition, fine shell constrictions occur at irregular intervals, which are accompanied by a barely discernible radial bulge on the apertural side.

The suture line of paratype GPIT-PV-63866 shows a narrow, V-shaped external lobe, which is accompanied by a symmetrical saddle that is rather narrowly rounded at the top. The V-shaped adventive lobe is also symmetrical (Fig. 17B).

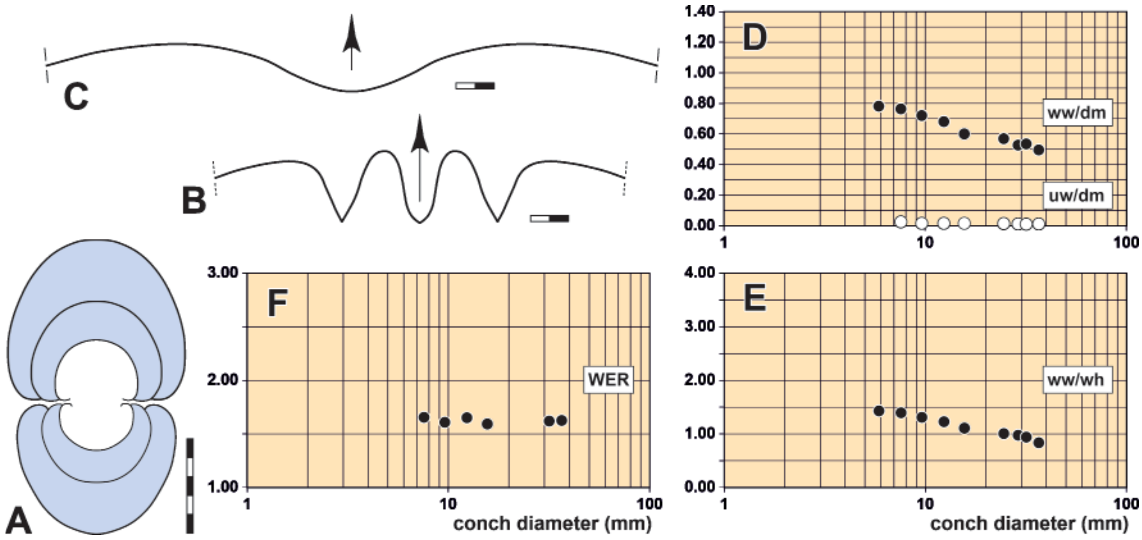

Fig. 17. *Mimimitoceras hoennense* Korn, 1994 from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. Cross section of paratype GPIT-PV-63867 from bed 3d. **B**. Suture line of paratype GPIT-PV-63866 from bed 4, at ww = 13.5 mm, wh = 12.0 mm. **C**. Growth line course of specimen GPIT-PV-63884 from bed 5, at dm = 28.5 mm, ww ~ 15.0 mm, wh = 14.6 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 4. Conch measurements, ratios and rates of *Mimimitoceras hoennense* Korn, 1993.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63884	36.5	18.1	21.7	0.5	7.9	0.50	0.83	0.01	1.63	0.64
GPIT-PV-63866	31.6	16.9	18.0	0.4	6.8	0.53	0.94	0.01	1.62	0.62
GPIT-PV-63867	15.5	9.346	8.4	0.3	3.2	0.60	1.11	0.02	1.60	0.62

Table 5. Conch ontogeny of *Mimimitoceras hoennense* Korn, 1993.

dm	conch shape	whorl cross section shape	whorl expansion
8 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.02)	weakly depressed; very strongly embracing (ww/wh ~1.40; IZR ~0.60)	low (WER ~1.60)
20 mm	thinly pachyconic; involute (ww/dm ~0.60; uw/dm ~0.02)	weakly depressed; very strongly embracing (ww/wh ~1.05; IZR ~0.62)	low (WER ~1.60)
40 mm	thickly discoidal; involute (ww/dm ~0.50; uw/dm ~0.02)	weakly compressed; very strongly embracing (ww/wh ~0.80; IZR ~0.65)	low (WER ~1.60)

The sectioned paratype GPIT-PV-63867 only allows a view into two whorls of maximum 15.5 mm conch diameter (Fig. 17A). These whorls are very similar in their horseshoe-shaped profile; only the ww/dm and ww/wh ratios decrease slightly (Fig. 17D-E).

Remarks

Mimimitoceras hoennense can be distinguished from *M. perditum* sp. nov. by the more slender conch (ww/dm at 20 mm dm ~0.60, but ~0.70 in *M. perditum*). *Mimimitoceras hoennense* differs from the Late Devonian species of the genus with a slender conch, in the strongly convex course of the growth lines, which are slightly biconvex in *M. geminum* Korn, 1992, nearly straight in *M. lentum* Korn, 1992 and weakly convex in *M. alternum* Korn, 1992.

Mimimitoceras mina sp. nov.
urn:lsid:zoobank.org:act:BF32EC27-3412-4B7A-83E0-5B5A5097B3F0
Tables 6–7

Mimimitoceras hoennense – Bockwinkel & Ebbighausen 2006: 93, text-figs 6, 7c–d.
Mimimitoceras varicosum – Bockwinkel & Ebbighausen 2006: 94, text-figs 7a–b, 8.

Diagnosis

Species of *Mimimitoceras* with thinly globular and involute conch at 5 mm dm (ww/dm ~0.85; uw/dm ~0.03); thinly pachyconic and involute conch at 15 mm dm (ww/dm ~0.70; uw/dm ~0.01). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.25); coiling rate low (WER ~1.65). Venter broadly rounded throughout ontogeny. Prominent internal shell thickenings with concavo-convex course. Suture line with very narrow, lanceolate external lobe and very narrow, symmetric, V-shaped adventive lobe.

Etymology

Acronym for *Mimimitoceras* from North Africa.

Material examined

Holotype

MOROCCO • Anti-Atlas, Mfis near Taouz, bed 9; Bockwinkel & Ebbighausen Coll.; illustrated by Bockwinkel & Ebbighausen (2006: text-fig. 7a–b); MB.C.3824.2.

Table 6. Conch measurements, ratios and rates of *Mimimitoceras mina* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.3823.4	14.57	9.97	8.16	0.17	3.18	0.68	1.22	0.01	1.64	0.61
MB.C.3824.1	14.17	10.41	7.78	0.32	3.13	0.73	1.34	0.02	1.65	0.60
MB.C.3824.2	13.9	10.2	7.2	0.6	3.0	0.73	1.41	0.04	1.62	0.59
MB.C.3823.3	11.5	8.4	6.3	0.8	–	0.73	1.35	0.07	–	–

Table 7. Conch ontogeny of *Mimimitoceras mina* sp. nov.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly globular; involute (ww/dm ~0.90; uw/dm ~0.12)	moderately depressed; very strongly embracing (ww/wh ~1.95; IZR ~0.60)	very low to low (WER ~1.50)
8 mm	thickly pachyconic; involute (ww/dm ~0.80; uw/dm ~0.02)	weakly depressed; very strongly embracing (ww/wh ~1.45; IZR = 0.60)	low (WER ~1.55)
15 mm	thinly pachyconic; involute (ww/dm ~0.70; uw/dm ~0.01)	weakly depressed; very strongly embracing (ww/wh ~1.25; IZR ~0.60)	low (WER ~1.65)

Paratypes

MOROCCO • 30 specimens; Anti-Atlas, Mfis near Taouz, bed 9; Bockwinkel & Ebbighausen Coll.; MB.C.3823.1–19, MB.C.3824.1, MB.C.3824.3–12.

Description

The species newly described here has been treated in detail by Bockwinkel & Ebbighausen (2006), so reference can be made here to that description.

Remarks

The material described here as the new species *Mimimitoceras mina* sp. nov. was placed in the two species *M. hoennense* and *M. varicosum* by Bockwinkel & Ebbighausen (2006). In fact, however, the differences within this material are so small that a species separation can hardly be justified.

Mimimitoceras mina sp. nov. resembles *M. perditum* sp. nov. in conch shape, but the whorl profile shows convergent flanks in *M. mina*, which are broadly rounded in *M. perditum*; the widest part of the conch is near the umbilicus in *M. mina* and near the middle of the flanks in *M. perditum*. Another difference lies in the course of the constrictions; these run almost linearly in *M. perditum*, but with a distinct lateral sinus and ventral sinus in *M. mina*.

Genus ***Globimitoceras*** Korn, 1993

Type species

Globimitoceras globiforme Vöhringer, 1960; original designation.

Diagnosis

Genus of the subfamily Prionoceratinae with globular conch in the juvenile and adult stage. Umbilicus almost closed throughout ontogeny. Growth lines fine and straight, without shell constrictions but with internal shell thickenings. Suture line with very narrow external and adventive lobes.

Genus composition

Central Europe (Vöhringer 1960): *Imitoceras globiforme* Vöhringer, 1960.

South Europe (Korn & Feist 2007): *Globimitoceras albaillei* Korn & Feist, 2007.

North Africa (Ebbighausen & Bockwinkel 2007): *Globimitoceras rharrhizense* Ebbighausen & Bockwinkel, 2007.

South China (Sun & Shen 1965): *Imitoceras sphericum* Sun & Shen, 1965.

Remarks

Globimitoceras contains prionoceratid ammonoids that possess a spherical, subinvolute or involute conch throughout ontogeny but, unlike *Mimimitoceras*, do not possess shell constrictions. The aperture is very low at all stages; the whorl expansion rate rarely exceeds a value of 1.50.

Kullmann (2009) did not accept *Globimitoceras* as a valid genus and placed it in the synonymy of *Paragattendorfia*. He justified this by stating that *Globimitoceras* was introduced for species that only differ in the narrow umbilicus throughout almost the entire ontogeny. However, the genus is not only separated from *Paragattendorfia* by the width of the umbilicus alone but also by differences in the suture line. While *Globimitoceras* has very narrow external and adventive lobes, these are broader and V-shaped in *Paragattendorfia*; furthermore, the ventrolateral saddle is broadly rounded in *Globimitoceras* but narrow in *Paragattendorfia*.

Globimitoceras globiforme (Vöhringer, 1960)
Figs 7B, 18–19; Tables 8–9

Imitoceras globiforme Vöhringer, 1960: 145, pl. 1 fig. 2, text-fig. 22.

Globimitoceras globiforme – Korn 1993: 585; 1994: 36, text-figs 31a–b, 32a–c, 63b; 2006: text-fig. 3f. — Korn & Weyer 2003: 96, pl. 1 figs 11–12. — Sprey 2002, pl. 3 fig.5. — Becker & Weyer 2004: 18, text-fig. 3i–j. — Korn & Feist 2007: 103, text-fig. 4g–h.
non *Imitoceras* (*Imitoceras*) *globiforme* – Ruan 1981: 76, pl. 17 figs 1–16.

Diagnosis

Species of *Globimitoceras* with a conch reaching 60 mm diameter. Conch at 25 mm dm thinly globular (ww/dm ~0.95). Whorl profile at 25 mm dm moderately depressed (ww/wh ~1.80); coiling rate very low (WER ~1.45). Venter broadly rounded. Growth lines very fine with nearly linear course. Without constrictions on the shell surface; with internal shell thickenings. Suture line with very narrow, V-shaped external lobe and very narrow, V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 1 fig. 2a–b), Korn (1994: text-fig. 31b), Sprey (2002: pl. 3 fig. 5) and Korn (2006: text-fig. 3f); re-illustrated here in Fig. 18C; GPIT-PV-63925.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63923 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63921 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-63934, GPIT-PV-63998.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31061 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31062 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31063.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31064 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31065 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Weyer 1993–1994 Coll.; MB.C.5240.7.

Description

Holotype GPIT-PV-63925 is a fairly well-preserved specimen (Fig. 18C). It has a spherical shape at 23 mm conch diameter (ww/dm ~0.95) and is almost completely involute with a very low coiling rate (WER ~1.50). Flanks and venter form an almost perfect semicircular arch. The suture line has a very narrow, lanceolate external lobe, separated from the very similar, weakly asymmetrical adventive lobe by a broadly rounded, inverted U-shaped ventrolateral saddle (Fig. 19C). Shell remains are not preserved.

Specimen MB.C.31061 is a well-preserved conch with a diameter of 36 mm (Fig. 18B). It is globular (ww/dm ~0.88) with a completely closed umbilicus and a very low coiling rate (WER ~1.42). The flanks and the venter form a semi-circular arch. The shell appears to be rather smooth, but it bears broad, weakly convex internal thickenings (Fig. 19D).

The two cross sections of the paratypes GPIT-PV-63923 (Fig. 19A) and GPIT-PV-63934 (Fig. 19B) allow the study of conch ontogeny from the initial stage to a diameter of 24 mm. The conch grows almost isometrically; all stages are very similar in their shape (Fig. 19E-G). The whorl profile is C-shaped and

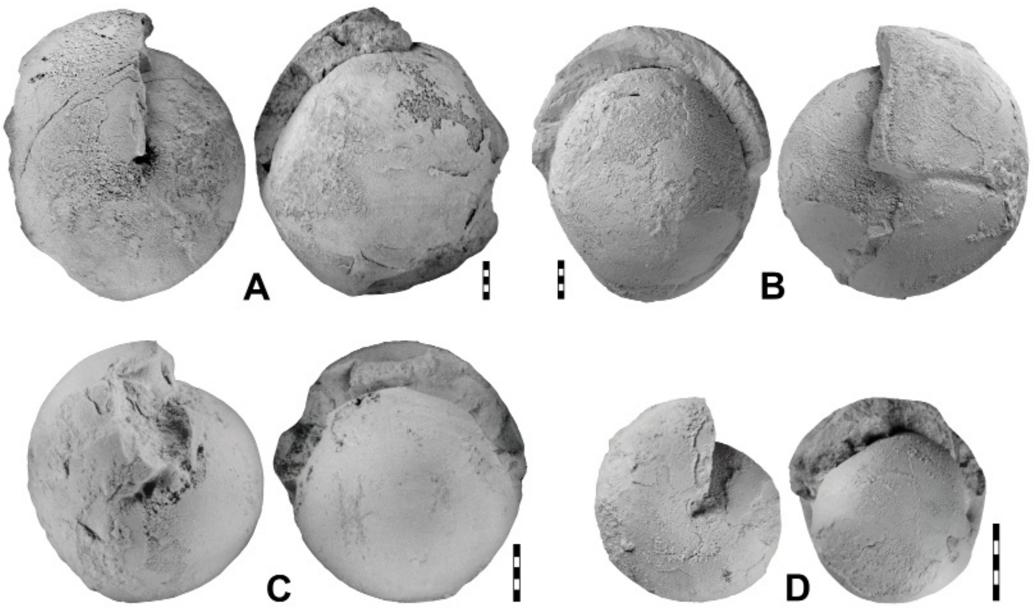

Fig. 18. *Globimitoceras globiforme* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Paratype GPIT-PV-63921 (Vöhringer Coll.) from bed 3b. **B**. Specimen MB.C.31061 (Korn 1977 Coll.) from float material. **C**. Holotype GPIT-PV-63925 (Vöhringer Coll.) from bed 2. **D**. Specimen MB.C.31065 (Weyer 1993–1994 Coll.) from bed 3e. Scale bar units = 1 mm.

Table 8. Conch measurements, ratios and rates of *Globimitoceras globiforme* (Vöhringer, 1960).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63921	38.3	35.0	19.8	1.2	6.1	0.91	1.77	0.03	1.41	0.69
MB.C.31061	36.4	31.9	20.0	0.8	5.8	0.88	1.60	0.02	1.42	0.71
GPIT-PV-63923	23.97	21.66	12.47	1.50	4.14	0.90	1.74	0.06	1.46	0.67
GPIT-PV-63925	23.4	22.2	12.2	0.9	4.2	0.95	1.82	0.04	1.49	0.66
GPIT-PV-63934	12.92	11.85	6.44	0.76	2.26	0.92	1.84	0.06	1.47	0.65
MB.C.5240.7	11.99	11.18	6.44	0.19	2.08	0.93	1.74	0.08	1.46	0.68

narrows only slowly during ontogeny; the ww/wh ratio decreases from a value of ~2.15 at 1.5 mm diameter to ~1.75 at 24 mm diameter.

Remarks

Globimitoceras globiforme can be easily distinguished from all other globular ammonoids of the Hangenberg Limestone of Oberrödinghausen and other localities in the Rhenish Mountains by the conch with very low aperture throughout ontogeny. The species of *Paragattendorfia* show some similarities,

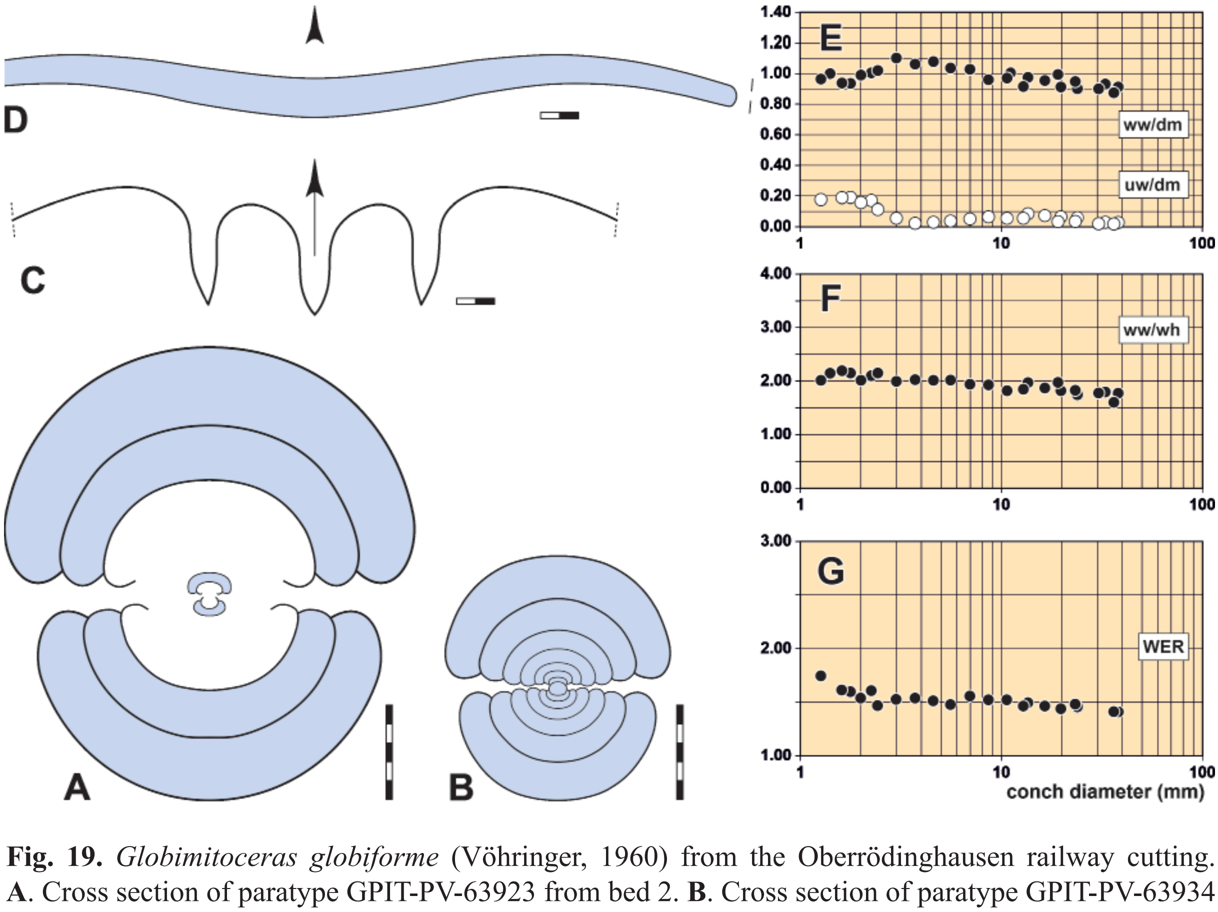

Fig. 19. *Globimitoceras globiforme* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63923 from bed 2. **B**. Cross section of paratype GPIT-PV-63934 from bed 3e. **C**. Suture line of holotype GPIT-PV-63925 from bed 2, at ww = 20.5 mm, wh = 9.4 mm. **D**. Constriction course of specimen MB.C.31061, at dm = 32.5 mm, ww = 30.0 mm, wh = 18.5 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 9. Conch ontogeny of *Globimitoceras globiforme* (Vöhringer, 1960).

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly globular; subinvolute (ww/dm ~1.00; uw/dm ~0.20)	strongly depressed; very strongly embracing (ww/wh ~2.05; IZR ~0.60)	low (WER ~1.55)
8 mm	thickly globular; involute (ww/dm ~1.00; uw/dm ~0.05)	moderately depressed; very strongly embracing (ww/wh ~1.95; IZR ~0.65)	low (WER ~1.55)
20 mm	thinly globular; involute (ww/dm ~0.95; uw/dm ~0.05)	moderately depressed; very strongly embracing (ww/wh ~1.90; IZR ~0.65)	low (WER ~1.50)
40 mm	thinly globular; involute (ww/dm ~0.90; uw/dm ~0.02)	moderately depressed; very strongly embracing (ww/wh ~1.80; IZR ~0.65)	very low (WER ~1.45)

but have a conch with a stepwise opening of the umbilicus and a suture line with a V-shaped external lobe and a V-shaped adventive lobe. Species of the genus *Kornia* are similar in the adult stage but produce a spindle-shaped juvenile conch. The growth lines, which are almost straight with shallow ventral sinus in *G. globiforme*, describe a very deep ventral sinus in the species of *Kornia*. *Globimitoceras sphericum* has a similar conch, but it is decorated with lamellar growth lines. In addition, *G. sphericum* has broader external and adventive lobes than *G. globiforme*.

Genus ***Paragattendorfia*** Schindewolf, 1924

Type species

Paragattendorfia humilis Schindewolf, 1924; original designation.

Diagnosis

Genus of the subfamily Prionoceratinae with a pachyconic to globular conch in the juvenile and adult stage. The umbilicus opens stepwise during ontogeny, the umbilical width ratio remains nearly constant throughout ontogeny. Shell with fine to lamellar, convex or straight growth lines. External lobe and adventive lobe V-shaped.

Genus composition

Central Europe (Schindewolf 1924; Vöhringer 1960; Weyer 1972): *Paragattendorfia humilis* Schindewolf, 1924; *Imitoceras patens* Vöhringer, 1960; *Paragattendorfia sphaeroides* Weyer, 1972.

North Africa (Bockwinkel & Ebbighausen 2006): *Paragattendorfia aboussalamae* Bockwinkel & Ebbighausen, 2006.

Central Asia (Librovitch 1940): *Gattendorfia applanata* Librovitch, 1940; *Gattendorfia kazakhstanica* Librovitch, 1940; *Gattendorfia occlusa* Librovitch, 1940; *Gattendorfia reticulata* Librovitch, 1940.

South China (Ruan 1981): *Imitoceras* (*Imitoceras*) *subpatens* Ruan, 1981; *Imitoceras* (*Imitoceras*) *globoidale* Ruan, 1981.

Remarks

A number of species were placed in the genus *Paragattendorfia* since its revision by Weyer (1972). However, *Paragattendorfia* was a somewhat problematic genus. It was inadequately defined by Schindewolf (1924) and insufficiently characterised by the statement that, "with a general similarity of shape to *Gattendorfia*, it only differs from the latter in that the lateral lobe lies on the seam and not next to it as in *Gattendorfia*". Furthermore, the inner lobe elements should be very narrow and deep; the growth lines should be linear without ventral sinus and constrictions were not seen.

With the redescription and diagnosis of the type species *P. humilis*, *Paragattendorfia* can be stabilised as a genus belonging to the subfamily Prionoceratinae because of the globular conch geometry, the low aperture throughout ontogeny and the rather simple ontogenetic pathways (Korn & Weyer 2023).

Paragattendorfia is unique among the prionoceratids of the Early Tournaisian in its stepwise opening of the umbilicus, meaning than the uw/dm trajectory is nearly isometric. In this respect, it can be easily separated from *Mimimitoceras*, which may have a similar morphology in distinct growth stages, but differ in possessing an involute adult conch.

Stratigraphic range

In the Rhenish Mountains, the two species *P. patens* and *P. sphaeroides* only occur in the higher part of the Hangenberg Limestone (*Pseudarietites westfalicus* Zone and *Eocanites delicatus* Zone). At Gattendorf, however, no ammonoids are known from beds higher than the regional *Acutimitoceras acutum* Zone, hence the genus has a duration throughout the "*Gattendorfia* Stufe". The species described from Kazakhstan (Librovitch 1940) have possibly a middle Tournaisian age.

Paragattendorfia patens (Vöhringer, 1960)
Figs 20–21; Tables 10–11

Imitoceras patens Vöhringer, 1960: 147, pl. 1 fig. 1, text-fig. 24.

Paragattendorfia patens – Korn 1994: 36, text-figs 31c–d, 32d, 63c; 2006: text-fig. 3g. — Sprey 2002: 52, text-fig. 17d. — Kullmann 2009: text-fig. 2.4.

Diagnosis

Species of *Paragattendorfia* with a conch reaching 40 mm diameter. Conch at 20 mm dm thickly pachyconic, subinvolute to subevolute (ww/dm ~0.75; uw/dm ~0.30). Whorl profile at 20 mm dm strongly depressed (ww/wh ~2.00); coiling rate very low (WER ~1.45). Venter broadly rounded, umbilical margin rounded. Growth lines fine, narrow-standing, with nearly linear course. Without constrictions on the shell surface; with linear internal shell thickenings. Suture line with narrowly V-shaped external lobe and narrowly V-shaped adventive lobe.

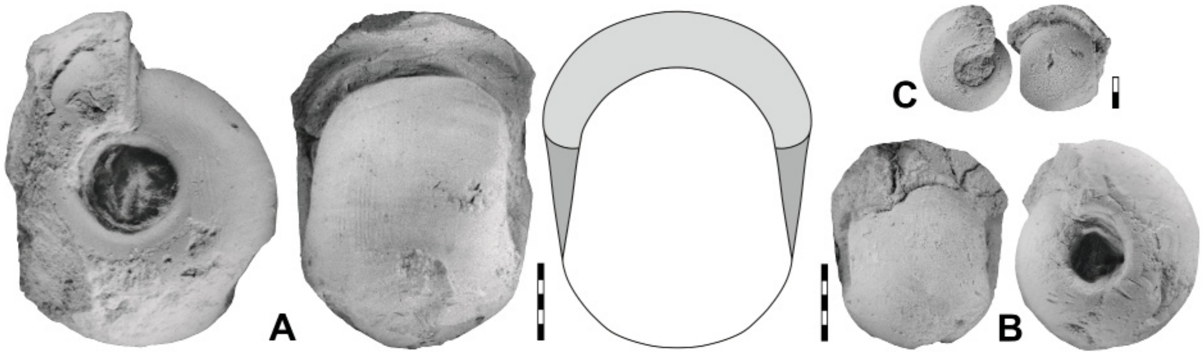

Fig. 20. *Paragattendorfia patens* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63912 (Vöhringer Coll.) from bed 2. **B**. Paratype GPIT-PV-63914 (Vöhringer Coll.) from bed 2. **C**. Specimen MB.C.31067 (Weyer 1993–1994 Coll.) from bed 3d2. Scale bar units = 1 mm.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 1 fig. 1), Korn (1994: text-fig. 31c) and Korn (2006: text-fig. 3g); re-illustrated here in Fig. 20A; GPIT-PV-63912.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63914, GPIT-PV-63916.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Korn 1991 Coll.; MB.C.31066 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31067.

Description

Holotype GPIT-PV-63912 is a moderately preserved, partly mechanically ground specimen with 22 mm conch diameter (Fig. 20A). It is thickly pachyconic and subinvolute (ww/dm = 0.73; uw/dm = 0.29) with a very low coiling rate (WER = 1.45). The whorl profile is crescent-shaped with a narrowly rounded umbilical margin. The suture line has a V-shaped external lobe and a symmetrical adventive lobe of almost the same shape, but it is slightly deeper. Both lobes are separated by a symmetrical, narrowly rounded ventrolateral saddle (Fig. 21B).

Remarks

Paragattendorfia patens is separated from *P. sphaeroides* by the more slender conch (ww/dm = 0.85 in *P. patens* but above 1.00 in *P. sphaeroides* at 10 mm dm) and in the wider umbilicus (uw/dm = 0.30 in *P. patens* but 0.20 in *P. sphaeroides* at 10 mm dm).

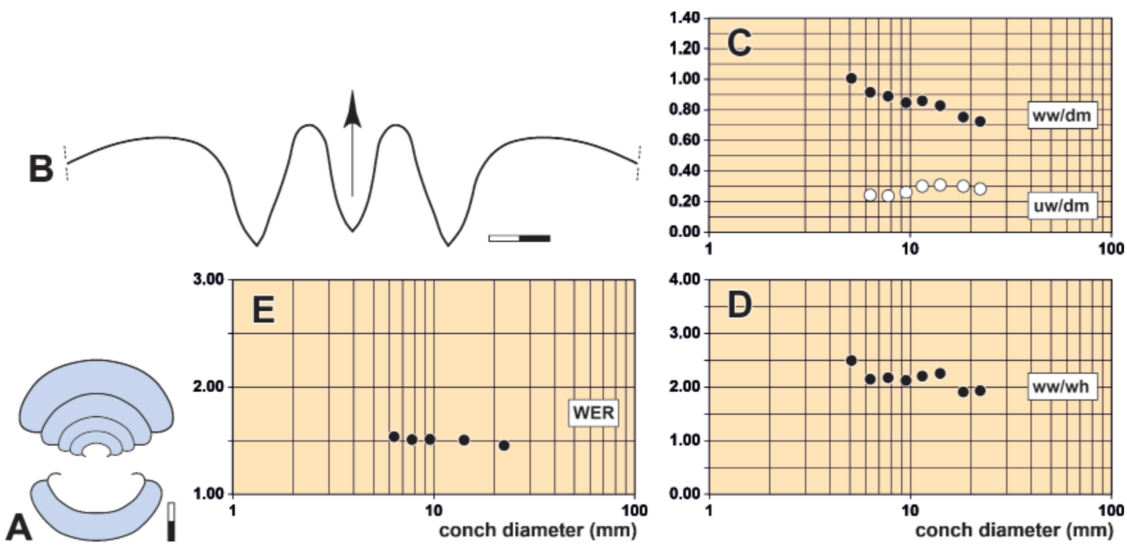

Fig. 21. *Paragattendorfia patens* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63916 from bed 2. **B**. Suture line of holotype GPIT-PV-63912 from bed 2, at ww = 12.4 mm, wh = 6.5 mm. **D–F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 10. Conch measurements, ratios and rates of *Paragattendorfia patens* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63912	22.3	16.2	8.4	6.4	3.8	0.73	1.93	0.29	1.45	0.55
GPIT-PV-63914	14.1	11.7	5.2	4.4	2.6	0.83	2.25	0.31	1.50	0.50
GPIT-PV-63916	9.54	8.10	3.82	2.54	1.78	0.85	2.12	0.27	1.51	0.53
MB.C.31067	7.07	6.71	2.66	2.69	1.39	0.95	2.52	0.38	1.55	0.48

Table 11. Conch ontogeny of *Paragattendorfia patens* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
8 mm	thinly globular; subinvolute (ww/dm ~0.90; uw/dm ~0.25)	strongly depressed; very strongly embracing (ww/wh ~2.15; IZR ~0.50)	low (WER ~1.50)
20 mm	thickly pachyconic; subinvolute (ww/dm ~0.75; uw/dm ~0.30)	moderately depressed; very strongly embracing (ww/wh ~1.90; IZR ~0.55)	very low (WER ~1.45)

The species is rather rare in the Hangenberg Limestone. A record of "*Paragattendorfia* aff. *patens*" from the Montagne Noire by Becker & Weyer (2004) does not belong here; the specimen possesses a dorsal siphuncle and must be attributed to *Wocklumeria*. It was a Late Devonian contamination in an earliest Carboniferous assemblage (Korn 2005).

Paragattendorfia sphaeroides Weyer, 1972
Figs 22–23; Tables 12–13

Paragattendorfia sphaeroides Weyer, 1972: 340.

Imitoceras globosum – Vöhringer 1960: 146, text-fig. 23.
Paragattendorfia sphaeroides – Korn 1994: 37, text-figs 31e, 32e–f, 33.

Diagnosis

Species of *Paragattendorfia* with a conch reaching 40 mm diameter. Conch at 20 mm dm thickly pachyconic, subinvolute (ww/dm ~0.80; uw/dm ~0.20). Whorl profile at 20 mm dm moderately depressed (ww/wh ~1.70); coiling rate very low (WER ~1.50). Venter broadly rounded, umbilical margin subangular. Growth lines fine, narrow-standing, with nearly linear course. Without constrictions

Fig. 22. *Paragattendorfia sphaeroides* Weyer, 1972, from the Oberrödinghausen railway cutting, (Vöhringer Coll.), holotype GPIT-PV-63909 from bed 3c. Scale bar units = 1 mm.

on the shell surface; with linear internal shell thickenings. Suture line with narrowly V-shaped external lobe and very narrowly V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Korn (1994: text-fig. 31e); re-illustrated here in Fig. 22; GPIT-PV-63909.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63935, GPIT-PV-63937.

Description

Holotype GPIT-PV-63909 is a moderately preserved specimen with 22 mm conch diameter (Fig. 22). It is a thickly pachyconic, subinvolute conch (ww/dm = 0.78; uw/dm = 0.20) with a narrowly rounded umbilical margin, steep umbilical wall and broadly and continuously rounded flanks and venter. The ornament consists of fine, closely spaced growth lines with an almost straight course (Fig. 23D).

The two sectioned paratypes GPIT-PV-63937 and GPIT-PV-63935 show almost identical cross-sectional patterns (Fig. 23A-B). The whorl profiles are rather similar in their crescent outline at all size stages larger than 6 mm conch diameter. However, particularly paratype GPIT-PV-63935 has a spindle-shaped juvenile stage at 3–5 mm conch diameter, in which the umbilical margin is slightly raised and the flanks are strongly divergent. The illustration of the ontogenetic trajectories shows a distinct allometry in the ww/dm ratio, and thus the ww/wh ratio (Fig. 23E-G).

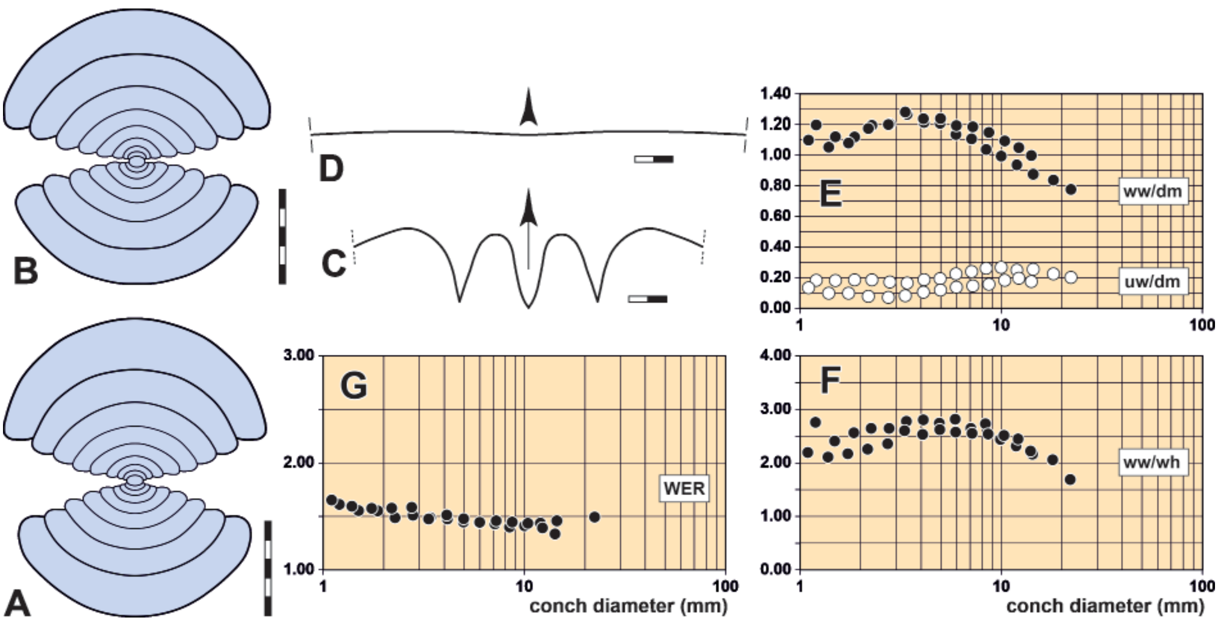

Fig. 23. *Paragattendorfia sphaeroides* Weyer, 1972 from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63937 from bed 2. **B**. Cross section of paratype GPIT-PV-63935 from bed 2. **C**. Suture line of paratype GPIT-PV-63935 from bed 2, at ww = 13.2 mm, wh = 6.0 mm. **D**. Growth line course of holotype GPIT-PV-63909 from bed 3c, at dm = 22.0 mm, ww = 17.5 mm, wh = 11.5 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 12. Conch measurements, ratios and rates of *Paragattendorfia sphaeroides* Weyer, 1972.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63909	22.1	17.2	10.2	4.5	4.0	0.78	1.69	0.20	1.49	0.61
GPIT-PV-63937	14.34	12.58	5.83	3.68	2.46	0.88	2.16	0.26	1.46	0.58
GPIT-PV-63935	14.04	14.04	6.33	2.48	1.89	1.00	2.22	0.18	1.33	0.70

Table 13. Conch ontogeny of *Paragattendorfia sphaeroides* Weyer, 1972.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	spindle-shaped; subinvolute (ww/dm ~1.15; uw/dm ~0.15)	very strongly depressed; very strongly embracing (ww/wh ~2.50; IZR ~0.55)	low (WER ~1.55)
8 mm	thickly globular; subinvolute (ww/dm ~1.05; uw/dm ~0.20)	very strongly depressed; very strongly embracing (ww/wh ~2.60; IZR ~0.65)	very low (WER ~1.40)
20 mm	thickly pachyconic; subinvolute (ww/dm ~0.80; uw/dm ~0.20)	moderately depressed; very strongly embracing (ww/wh ~1.70; IZR ~0.60)	very low (WER ~1.45)

The suture line of paratype GPIT-PV-63935 has a narrow V-shaped external lobe, a symmetrical ventrolateral saddle and a symmetrical V-shaped adventive lobe with slightly inwardly curved flanks (Fig. 23C).

Remarks

Paragattendorfia sphaeroides is separated from *P. patens* by the stouter conch (the ww/dm ratio is above 1.00 in *P. sphaeroides* but only ~0.85 in *P. patens* at 10 mm dm) and in the narrower umbilicus (uw/dm ~0.20 in *P. sphaeroides* but ~0.30 in *P. patens* at 10 mm dm).

Paragattendorfia sphaeroides differs from *P. humilis* from Upper Franconia in the course of the growth lines, which is nearly linear in *P. patens* but strongly convex in *P. humilis*.

Genus ***Kornia*** Ebbighausen & Bockwinkel, 2007

Type species

Kornia citrus Ebbighausen & Bockwinkel, 2007: 143; original designation.

Diagnosis

Genus of the subfamily Prionoceratinae with a spindle-shaped conch in the juvenile stage and globular conch in the adult stage. Umbilicus almost closed in stages larger than 7 mm diameter, in the juvenile stage with raised umbilical edge. Growth lines strongly curved back from the umbilical margin, forming broad and deep ventral sinus.

Genus composition

Central Europe (Vöhringer 1960): *Imitoceras sphaeroidale* Vöhringer, 1960; *Kornia fibula* sp. nov.; *Kornia acia* sp. nov.

North Africa (Ebbighausen & Bockwinkel 2007): *Kornia citrus* Ebbighausen & Bockwinkel, 2007.

Remarks

The genus *Kornia* was introduced by Ebbighausen & Bockwinkel (2007) for very small specimens which are characterised by their spindle-shaped conch and conspicuous umbilical shape, thus differing strongly from all other known early Tournaisian ammonoids. Juvenile ammonoids with such a shape, however, occur repeatedly in the fossil record, as shown for the Late Viséan genera *Goniatites* de Haan, 1825 (Klug *et al.* 2016; Korn 2017) and *Hibernicoceras* Moore & Hodson, 1958 (Schmidt 1925; Korn 1988a).

Kornia differs from *Globimitoceras*, apart from the juvenile conch morphology, in the course of the growth lines, which are almost straight in *Globimitoceras* are, but in *Kornia* they have a very broad and deep ventral sinus.

Kornia sphaeroidalis (Vöhringer, 1960) comb. nov.
Fig. 24; Table 14

Imitoceras sphaeroidale Vöhringer, 1960: 143, pl. 2 fig. 7.

Acutimitoceras sphaeroidale – Korn 1994: 49, text-figs 49e, 55c.
Acutimitoceras (*Stockumites*) *sphaeroidale* – Becker 1996: 36.

non *Acutimitoceras sphaeroidale* – Vöhringer 1960: 143, text-fig. 21. — Korn 1992b: 17, pl. 2 figs 30–31; 1994: text-figs 50f, 51b, 55d. — Schönlaub *et al*. 1992: pl. 5 figs 30–31.

Diagnosis

Species of *Kornia* with a thickly pachyconic, involute conch (ww/dm ~0.80; uw/dm ~0.05) at 24 mm conch diameter. Ornament with widely spaced growth lines with convex course and a shallow ventral sinus.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 2 fig. 7) and Korn (1994: text-fig. 49e); re-illustrated here in Fig. 24; GPIT-PV-63865.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a1; Weyer 1993–1994 Coll.; MB.C.31068.

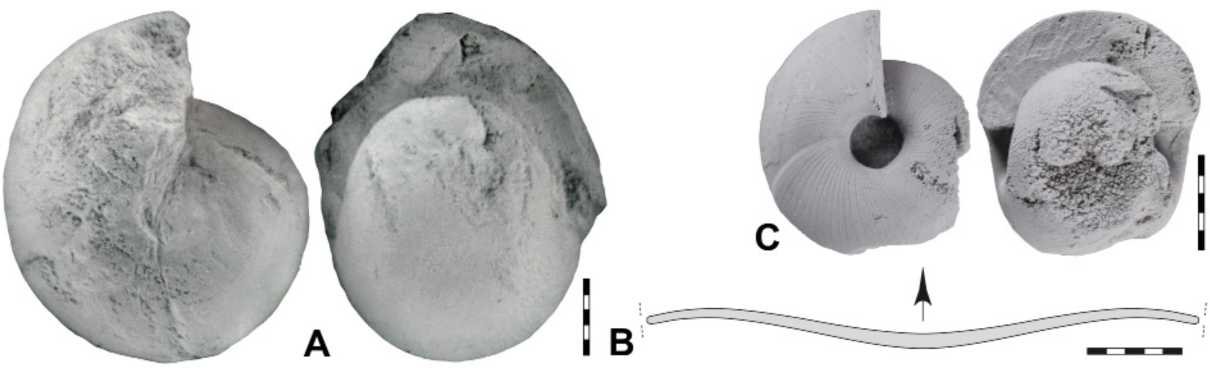

Fig. 24. *Kornia sphaeroidalis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63865 (Vöhringer Coll.) from bed 5. **B**. Constriction course of holotype GPIT-PV-63865 from bed 5, at dm = 22.0 mm, ww = 19.4 mm, wh = 12.0 mm. **C**. Paratype MB.C.31068 (Weyer 1993–1994 Coll.) from bed 5a1. Scale bar units = 1 mm.

Table 14. Conch measurements, ratios and rates of *Kornia sphaeroidale* (Vöhringer, 1960).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63865	24.2	19.8	12.7	1.5	5.5	0.82	1.56	0.06	1.67	0.57
MB.C.31068	13.0	11.8	6.0	2.4	2.6	0.91	1.97	0.19	1.56	0.57

Description

Holotype GPIT-PV-63865 (Fig. 24A) is a thickly pachyconic specimen with 24 mm dm (ww/dm = 0.82). It has a slightly opened umbilicus (uw/dm = 0.06) and a low coiling rate (WER = 1.67). The specimen bears small shell remnants that possess widely spaced, lamellar growth lines; these extend in a low and wide arc across the flanks and form a broad and shallow ventral sinus. Parallel to this extend faint inner shell thickenings (Fig. 24B).

Specimen MB.C.31068 is a rather well-preserved specimen with 13 mm conch diameter (Fig. 24C). It is globular and subinvolute (ww/dm = 0.91; uw/dm = 0.19) with a low coiling rate (WER = 1.56). The whorl profile is C-shaped with rounded umbilical margin and steep, flattened umbilical wall. The shell bears lamellar growth lines directed slightly backwardly from the umbilical margin and forming a shallow, very broad sinus on the venter. There is one shell constriction that extends parallel to the growth lines.

Remarks

Vöhringer (1960) united two species under the name "*Imitoceras sphaeroidale*". Holotype GPIT-PV-63865 is a nearly globular specimen with 24 mm dm (ww/dm = 0.82), but the illustrated cross section GPIT-PV-63927 (ww/dm = 0.69 at 15 mm dm) and the smaller specimen GPIT-PV-63932 belong to a much more slender form. This is newly described here as *Hasselbachia erronea* sp. nov. Unfortunately, the morphology of the inner whorls is not known.

Kornia fibula sp. nov.

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Figs 25–26; Tables 15–16

Paragattendorfia n. sp. I Korn & Weyer, 2003: 95, pl. 2 figs 20–21.
Paragattendorfia cf. *sphaeroides* Becker *et al*., 2021: text fig. 3n–o.

Gattendorfia cf. *crassa* – Becker 1997: 34, pl. 1 fig. 10.

Diagnosis

Species of *Kornia* with globular, moderately involute conch (ww/dm ~0.95; uw/dm ~0.15) at 12 mm conch diameter. Growth lines with very deep and wide external sinus.

Etymology

From the Latin '*fibula*' = 'clasp', a connotation of the name of the type locality at Oese.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 28; Weyer & Korn 2000 Coll.; illustrated by Korn & Weyer (2003: pl. 2 figs 20–21); re-illustrated here in Fig. 25B; MB.C.5260.3.

Paratypes
GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2a; Weyer 1993–1994 Coll.; MB.C.31069.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31070 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31071.1–2 • 3 specimens; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 22; Weyer & Korn 2000 Coll.; MB.C.5262.2, MB.C.5262.4, MB.C.5262.5 • 1 specimen; Rhenish Mountains, Letmathe, between Schälk and Grürmannsheide; Hangenberg Limestone; Denckmann 1901 Coll.; MB.C.1215.

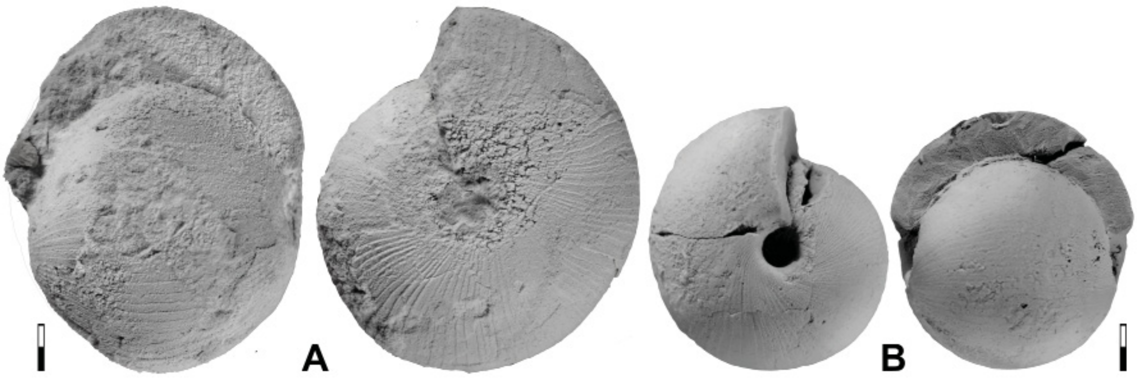

Fig. 25. *Kornia fibula* sp. nov. **A**. Paratype MB.C.31069.2 (Weyer 1993–1994 Coll.) from Oberrödinghausen, bed 2a. **B**. Holotype MB.C.5260.3 (Weyer 1993–1994 Coll.) from Oese, bed 28. Scale bar units = 1 mm.

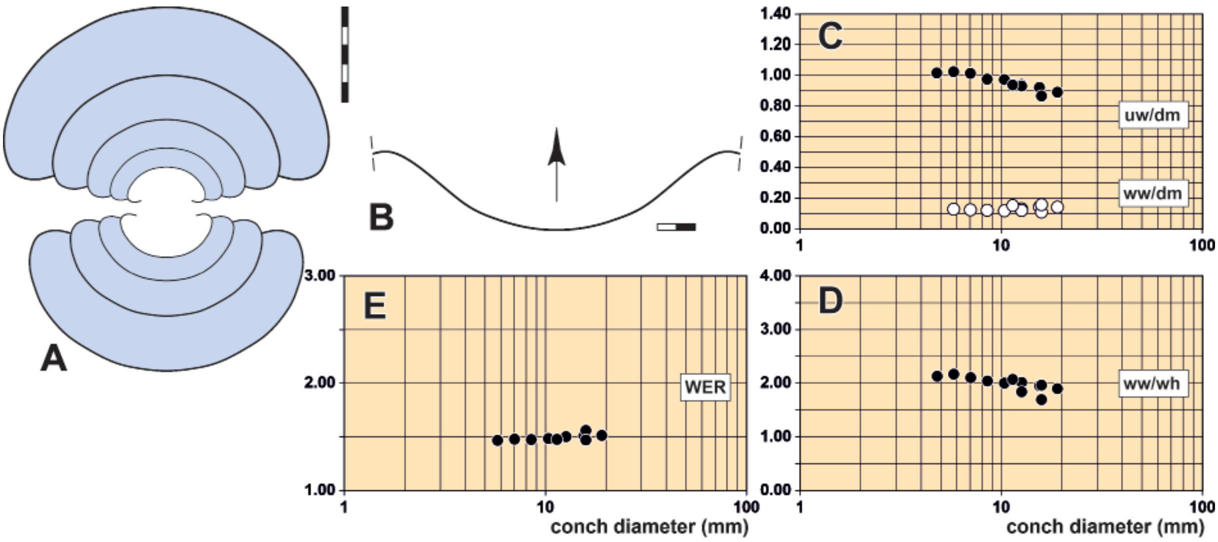

Fig. 26. *Kornia fibula* sp. nov. **A**. Cross section of paratype MB.C.31069.1 (Weyer 1993–1994 Coll.) from Oberrödinghausen, bed 2a. **B**. Growth line course of holotype MB.C.5260.3 (Weyer 1993–1994 Coll.) from Oese, bed 28, at dm = 9.8 mm, ww = 9.9 mm, wh = 4.8 mm. **C**–**E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 15. Conch measurements, ratios and rates of *Kornia fibula* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31069.1	19.21	17.16	9.09	2.70	3.59	0.89	1.89	0.14	1.51	0.61
MB.C.31072	18.97	17.06	9.36	2.47	3.60	0.90	1.82	0.13	1.52	0.61
MB.C.31069.2	15.98	13.88	8.24	1.73	3.18	0.87	1.68	0.11	1.56	0.61
MB.C.5260.3	11.44	10.77	5.22	1.73	2.02	0.94	2.06	0.15	1.47	0.61

Table 16. Conch ontogeny of *Kornia fibula* sp. nov.

dm	conch shape	whorl cross section shape	whorl expansion
8 mm	thickly globular; involute (ww/dm ~1.00; uw/dm ~0.12)	strongly depressed; very strongly embracing (ww/wh ~2.05; IZR ~0.65)	very low (WER ~1.45)
20 mm	thickly globular; involute (ww/dm ~0.90; uw/dm ~0.12)	moderately depressed; very strongly embracing (ww/wh ~1.90; IZR ~0.60)	low (WER ~1.50)

Description

Holotype MB.C.5260.3 (Fig. 25B), measuring 11.4 mm diameter, has an almost ball-shaped conch with a small umbilicus and a low aperture (ww/dm = 0.94; uw/dm = 0.15; WER = 1.46) and a C-shaped whorl profile. The ornament possesses lamellar growth lines that are strongly rursiradiate in their direction. They form a low dorsolateral projection and already on the inner flank turn back to extend with a deep and wide sinus across the outer flanks and the venter (Fig. 26B).

The larger paratype MB.C.31069.2 (Fig. 25A) with 16 mm conch diameter displays a similar growth line course, but with less strong backward turn. It has a globular, involute conch (ww/dm = 0.87; uw/dm = 0.11).

The sectioned paratype MB.C.31069.1 allows the study of conch geometry between 4.7 and 19.2 mm diameter (Fig. 26A). During this growth interval, the whorl profile maintains a similar shape. The venter is broad and merges continuously into the convex flanks; the umbilical margin is rounded. The growth trajectories show an almost isometric ontogeny in this growth interval (Fig. 26C–D).

Remarks

Kornia fibula sp. nov. differs from *K. acia* sp. nov. in the ball-shaped juvenile conch (spindle-shaped in *K. acia*) and wider umbilicus at 10 mm conch diameter (uw/dm = 0.15 in *K. fibula* but only 0.10 in *K. acia*). The superficially similar *Globimitoceras globiforme* differs in the narrower umbilicus (uw/dm ~0.15 in *Kornia fibula* but only 0.08 in *G. globiforme* at 10–15 mm dm).

Kornia acia sp. nov.

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Figs 27–28; Tables 17–18

Diagnosis

Species of *Kornia* with globular to spindle-shaped, involute conch (ww/dm ~1.05; uw/dm ~0.10) at 12 mm conch diameter. Growth lines lamellar with moderately deep, wide ventral sinus.

Etymology

From the Latin '*acia*' = 'yarn', as the conch has the shape of a yarn reel.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; illustrated in Fig. 27; MB.C.31073.1.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, *P. dorsoplanus* Zone; Korn 1977 Coll.; MB.C.31072 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; MB.C.31073.2.

Description

Holotype MB.C.31073.1 is a well-preserved specimen that is fully covered by shell material (Fig. 27). It has a conch diameter of 12.3 mm and changes from spindle-shaped to globular in the last half whorl (ww/dm = 1.13 at 10 mm dm; ww/dm = 1.05 at 12.3 mm dm); the umbilicus is very narrow (uw/dm = 0.10 at 12.3 mm dm). The peculiar apertural shape shows a pronounced umbilical margin, from where the flanks, which are nearly arranged in right angles, rapidly converge towards the broadly rounded venter. The aperture is very low (WER = 1.47). The shell surface shows lamellar growth lines; they form a pronounced dorsolateral projection and turn back to proceed in a very wide and moderately deep sinus across flanks and venter (Fig. 28B). At a major non-lethal shell damage, the growth lines deviate from this course during the interval of repair.

Paratype MB.C.31072 was sectioned and allows the study of conch ontogeny up to a diameter of 19 mm (Fig. 28A). All whorls have a similar profile, but the ww/wh ratio decreases from about 3.00 at 1.5 mm conch diameter to about 1.80 at 19 mm diameter (Fig. 28D). At the same time, the shape of the profile changes from broad kidney-shaped to C-shaped. At all size stages, the flanks are strongly convergent and the venter is comparatively narrow. The umbilical margin is particularly pronounced between 4 and 10 mm conch diameter.

Remarks

Kornia acia sp. nov. cannot be confused with any other ammonoid from the Hangenberg Limestone because of its peculiar spindle-shaped juvenile conch with raised umbilical margin and the strongly backward directed growth lines. *K. fibula* sp. nov. has a ball shaped conch with more broadly rounded venter and a wider umbilicus than *K. acia* (uw/dm ~0.10 in *K. acia* but ~0.15 in *K. fibula* at 11–12 mm dm).

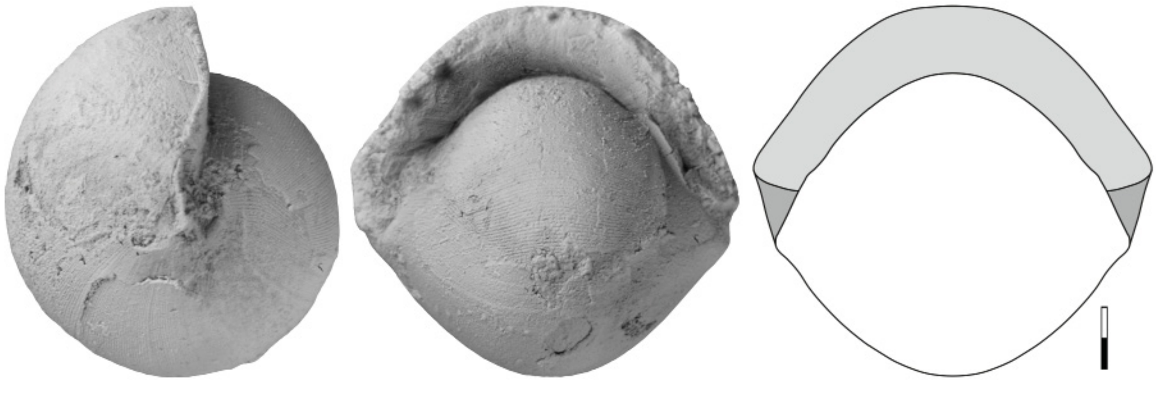

Fig. 27. *Kornia acia* sp. nov. from the Oberrödinghausen railway cutting; holotype MB.C.31073.1 (Weyer 1993–1994 Coll.) from bed 5a2. Scale bar units = 1 mm.

Kornia citrus from the Anti-Atlas has a very similar conch geometry, but differs from *C. acia* sp. nov. in the shape of the umbilical margin, which in *K. citrus* is more strikingly raised but more rouded in *K. acia*.

Table 17. Conch measurements, ratios and rates of *Kornia acia* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31072	18.97	17.06	9.36	2.47	3.30	0.90	1.82	0.13	1.47	0.65
MB.C.31073.1	12.31	12.89	6.17	1.24	2.16	1.05	2.09	0.10	1.47	0.65
MB.C.31073.1	10.11	11.01	4.84	0.99	–	1.13	2.36	0.10	–	–

Table 18. Conch ontogeny of *Kornia acia* sp. nov.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	spindle-shaped; subevolute (ww/dm ~1.05; uw/dm ~0.35)	very strongly depressed; strongly embracing (ww/wh ~2.80; IZR ~0.40)	low (WER ~1.55)
8 mm	thickly globular; involute (ww/dm ~1.00; uw/dm ~0.10)	strongly depressed; very strongly embracing (ww/wh ~2.15; IZR ~0.65)	very low (WER ~1.45)
20 mm	thinly globular; involute (ww/dm ~0.90; uw/dm ~0.10)	moderately depressed; very strongly embracing (ww/wh ~1.80; IZR ~0.65)	very low (WER ~1.45)

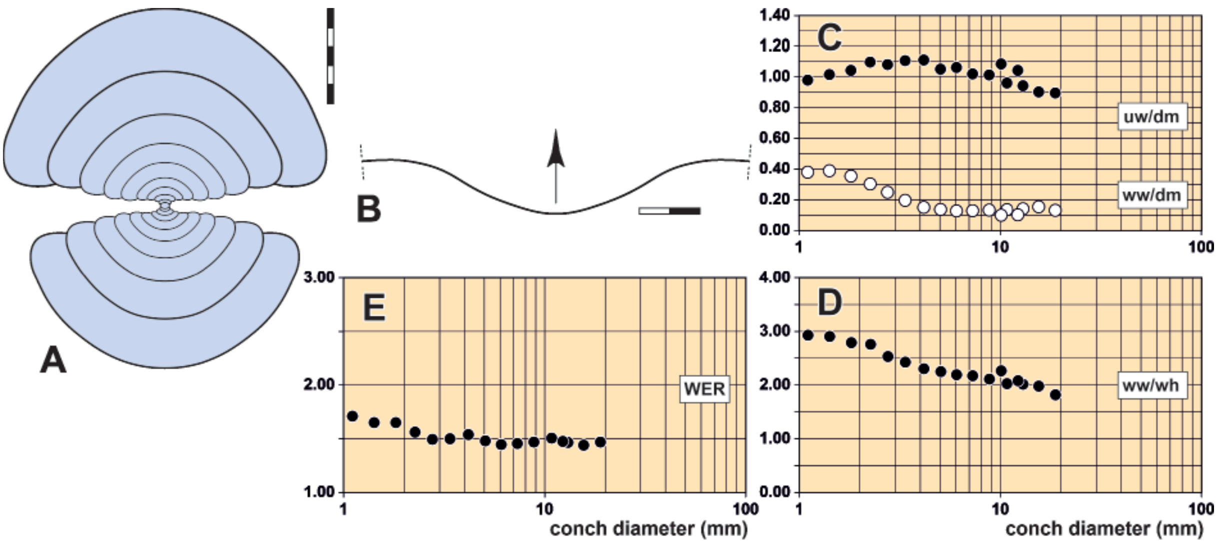

Fig. 28. *Kornia acia* sp. nov. from Oberrödinghausen railway cutting; both Weyer 1993–1994 Coll. **A**. Cross section of paratype MB.C.31072 from an unknown bed. **B**. Growth line course of holotype MB.C.31073.1 (Weyer 1993–1994 Coll.) from bed 5a2, at dm = 11.1 mm, ww = 11.6 mm, wh = 5.3 mm. **C–E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Subfamily **Acutimitoceratinae** Korn, 1994

Diagnosis

Subfamily of the family Prionoceratidae with the sutural formula E A L U I; adventive lobe V-shaped or lanceolate, pointed. Conch in the juvenile stage subevolute or evolute; adult stage involute or subinvolute. Coiling rate usually moderately high or high (WER = 1.75–2.25) and rarely very high (up to 2.35). Shell ornament with fine to coarse growth lines, usually without ribs.

Subfamily composition

The subfamily comprises six genera: *Acutimitoceras* Librovitch, 1957 (4 species); *Costimitoceras* Vöhringer, 1960 (3 species); *Sulcimitoceras* Kusina, 1985 (1 species); *Nicimitoceras* Korn, 1993 (7 species) and *Stockumites* Becker, 1996 (36 species).

Morphology

In the adult stage, the species of the subfamily Acutimitoceratinae are distinguished from the representatives of the Prionoceratinae by the mostly higher whorl expansion rate, which is almost always above a value of 1.75, but the Prionoceratinae are below this value. In the Acutimitoceratinae, the adult conch is almost always completely involute and ranges from thinly discoidal to globular; in contrast to the mostly stout conchs of the Prionoceratinae; however, discoidal conchs are more common than pachyconic or globular conchs in the Acutimitoceratinae. Oxyconic conchs occur independently in several evolutionary lineages.

Juvenile conchs of the Acutimitoceratinae show a very wide variation in their morphology, ranging from subinvolute to very evolute. Likewise, the length of the more widely umbilicate juvenile stage varies markedly between species.

The shell ornament consists of simple growth lines in almost all species of the subfamily Acutimitocratinae. These growth lines usually are with a convex curve across the flank and form a sinus on the venter. Only in some species, the growth lines have a biconvex course. Spiral lines occur in *Costimitoceras* and, together with the growth lines, form a reticulate ornament. Some species possess shell constrictions, in others only radial internal shell thickenings are present. Some species have neither shell constrictions nor internal shell thickenings.

The suture line is simple and consists of the elements E A L U I. The external lobe is usually lanceolate with parallel flanks; in some cases, however, the external lobe may be narrow V-shaped or very weakly pouched. The adventive lobe is often V-shaped and varies in shape from symmetrical to moderately asymmetrical.

Ontogeny

The ontogeny of the representatives of the Acutimitoceratinae shows spectacular changes; this is the cardinal difference to the species of the Prionoceratinae. All species of the Acutimitoceratinae show an early ontogenetic stage of variable length. The juvenile whorls only slightly embrace the preceding one, which results in a rather widely umbilicate or even serpenticonic juvenile conch shape. In the middle growth stage, the closure of the umbilicus begins by more or less wide overlap upon the preceding whorl. In most of the species, the umbilicus is already closed at 10 mm conch diameter.

The ontogenetic changes in the conch morphology can be illustrated in diagrams of ontogenetic trajectories (Korn 2012). They show that particularly the ontogenetic trajectory of the ww/dm ratio describes a strikingly triphasic course. The amplitude of the changes depends on the length of the widely umbilicate juvenile stage and the width of the conch in the middle growth stage. Species with a stout conch tend to show a more pronounced triphasic ontogeny than discoidal forms.

Phylogeny

The Acutimitoceratinae are the dominant earliest Carboniferous ammonoid group immediately after the Hangenberg Event. The origin of the subfamily is most probably in the genus *Mimimitoceras* or related forms, some of which developed rather evolute inner whorls already in the late Famennian (Korn *et al.* 2015). Although specimens of the subfamily Acutimitoceratinae are very abundant in all of the earliest Carboniferous ammonoid occurrences, there is no undoubted record older than the Hangenberg Event. This means that the phylogenetic origin of the entire group, which most probably gave rise to all post-Hangenberg ammonoids (except for a few failed survivors such as some clymeniids and species of *Mimimitoceras*), is still unknown.

The Acutimitoceratinae gave rise to at least two ammonoid clades, the subfamily Imitoceratinae and the family Gattendorfiidae. The first is characterised by a pouched external lobe and the second by an incompletely closed or open umbilicus in the adult stage. A possible third evolutionary lineage are the prolecanitids and with these all Mesozoic ammonoids.

Stratigraphic occurrence

Species of the subfamily Acutimitoceratinae are already present in the lowermost beds deposited directly after the Hangenberg Event with morphologically advanced species, i.e., species with a widely involute juvenile conch (e.g., Korn 1984; Price & House 1984; Kusina 1985; House 1996; Korn *et al.* 2004). Investigations in the Oberrödinghausen section show that most of the species have a very short stratigraphic range. A wide distribution across several ammonoid zones, as considered possible by Vöhringer (1960), could not be confirmed by the new study and revision.

In contrast to the good stratigraphic knowledge of the early Tournaisian species, not much is known about the middle Tournaisian distribution of the subfamily Acutimitoceratinae. The occurrences of possible members of the subfamily in Karaganda (Librovitch 1940) and the American Midcontinent (Miller & Collinson 1951) require confirmation.

Geographic occurrence

The subfamily Acutimitoceratinae has a very wide geographic range. In practically all assemblages of early Tournaisian ammonoids, the species of this subfamily are the dominant elements. The following list provides an overview on the occurrences (and selected references) of the Acutimitoceratinae: Rhenish Mountains (Schmidt 1924, 1925; Vöhringer 1960; Korn 1981, 1984; Becker 1988, 1996; Korn 1992c, 1994; Korn *et al.* 1994; Korn & Weyer 2003), Thuringia (Schindewolf 1952; Weyer 1976, 1977; Bartzsch & Weyer 1982, 1986), Upper Franconia (Schindewolf 1923; Korn 1994), Silesia (Tietze 1869, 1870; Weyer 1965; Dzik 1997), Carnic Alps (Korn 1992b), Montagne Noire (Becker & Weyer 2004; Korn & Feist 2007), Anti-Atlas (Korn 1999; Korn *et al.* 2004; Bockwinkel & Ebbighausen 2006; Ebbighausen & Korn 2007; Becker *et al.* 2013), Gourara in Algeria (Ebbighausen *et al.* 2004), South Urals (Balashova 1953; Barskov *et al.* 1984; Kusina 1985; Nikolaeva 2020), Karaganda (Librovitch 1940), Guizhou (Sun & Shen 1965; Ruan 1981; Sheng 1989), questionably also Missouri (Furnish & Manger 1973) and Illinois (Smith 1903; Miller & Collinson 1951).

Remarks

In the revision of the Treatise, Kullmann (2009) applied a very conservative concept with respect to the subdivision of the Early Carboniferous prionoceratid ammonoids; he did not accept the subfamilies Acutimitoceratinae, Imitoceratinae and Balviinae as valid. Instead, he merged the subfamily

Acutimitoceratinae with the family Gattendorfiidae without accepting subfamilies. This means that two rather well-separable ammonoid groups were lumped: on one side the conservative clade with forms that close the umbilicus in the adult stage (e.g., *Acutimitoceras*, *Stockumites*, *Nicimitoceras*) and on the other side those forms in which the umbilicus stays open in the adult stage (e.g., *Gattendorfia*, *Weyerella*). The concept of Kullmann (2009) is also remarkable because he put the genera *Imitoceras* and *Irinoceras* in the Prionoceratidae, despite of their close morphological similarity, in conch shape, ontogenetic development and suture line, with *Nicimitoceras*, which rather speaks for close phylogenetic relationships with that genus. As Bockwinkel & Ebbighausen (2006) have shown in their study of Early Tournaisian assemblages from Morocco, early representatives of *Imitoceras* can easily be related to genera of the Acutimitoceratinae (e.g., *Nicimitoceras*). The family Prionoceratidae as outlined by Kullmann (2009) is thus most probably a polyphyletic taxon.

Genus ***Stockumites*** Becker, 1996

Type species

Imitoceras intermedium Schindewolf, 1923: 333; original designation.

Genus diagnosis

Genus of the subfamily Acutimitoceratinae with a discoidal to globular conch with low to high coiling rate (WER = 1.70–2.10 and rarely up to 2.35); inner whorls subinvolute to very evolute to variable degree. Venter broadly or narrowly rounded. Ornament usually with convex or rarely with biconvex growth lines, shell surface with or without constrictions. Suture line with deep, lanceolate external lobe (as deep as the adventive lobe).

Genus composition

Central Europe (Münster 1839; Schindewolf 1923; Schmidt 1925; Vöhringer 1960; Korn 1984): *Goniatites subbilobatus* Münster, 1839; *Imitoceras intermedium* Schindewolf, 1923; ?*Gattendorfia involuta* Schindewolf, 1924; *Aganides prorsus* Schmidt, 1925; *Imitoceras prorsum antecedens* Vöhringer, 1960; *Imitoceras prorsum convexum* Vöhringer, 1960; *Imitoceras depressum* Vöhringer, 1960; *Imitoceras liratum exile* Vöhringer, 1960; *Imitoceras liratum simile* Vöhringer, 1960; *Imitoceras undulatum* Vöhringer, 1960; *Acutimitoceras kleinerae* Korn, 1984; *Acutimitoceras procedens* Korn, 1984; *Acutimitoceras stockumense* Korn, 1984; *Stockumites parallelus* sp. nov.; *Stockumites voehringeri* sp. nov.; *Stockumites hofensis* Korn & Weyer, 2023; *Stockumites nonaginta* Korn & Weyer, 2023.

North Africa (Korn & Klug 2002; Ebbighausen *et al.* 2004; Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007): *Acutimitoceras hilarum* Korn in Korn & Klug, 2002; *Acutimitoceras algeriense* Ebbighausen, Bockwinkel, Korn & Weyer, 2004; *Acutimitoceras sinulobatum* Ebbighausen, Bockwinkel, Korn & Weyer, 2004; *Acutimitoceras hollardi* Bockwinkel & Ebbighausen, 2006; *Acutimitoceras occidentale* Bockwinkel & Ebbighausen, 2006; *Acutimitoceras posterum* Bockwinkel & Ebbighausen, 2006; *Acutimitoceras endoserpens* Ebbighausen & Bockwinkel, 2007; *Acutimitoceras pentaconstrictum* Ebbighausen & Bockwinkel, 2007; *Acutimitoceras sarahae* Ebbighausen & Bockwinkel, 2007; *Stockumites marocensis* sp. nov.

South Urals (Barskov *et al.* 1984; Kusina 1985; Nikolaeva 2020): *Acutimitoceras mugodzharense* Kusina in Barskov *et al*., 1984; *Acutimitoceras pulchrum* Kusina, 1985; *Acutimitoceras alabasense* Nikolaeva, 2020; *Acutimitoceras dzhanganense* Nikolaeva, 2020.

Central Asia (Librovitch 1940): *Imitoceras rotiforme* Librovitch, 1940.

South China (Sun & Shen 1965; Ruan 1981): *Imitoceras inequalis* Sun & Shen, 1965; *Imitoceras sinense* Sun & Shen, 1965; *Imitoceras* (*Imitoceras*) *crassum* Ruan, 1981.

North America (questionable species) (Rowley 1895; Moore 1928): *Goniatites louisianensis* Rowley, 1895; *Aganides compressus* Moore, 1928.

Remarks

Stockumites was introduced by Becker (1996) as a subgenus of *Acutimitoceras* to separate the species with rounded venter from the acute species (such as *A. acutum* and *A. wangyuense*). This difference alone would probably not justify two genera. However, a closer examination of the material from various regions (Rhenish Mountains, Upper Franconia, Thuringia, Guizhou) shows that the acute venter is not the only character that distinguishes *Acutimitoceras* from *Stockumites*. A good additional distinguishing character is the attached keel, which gives the venter a galeate profile in cross-section in *Acutimitoceras*. Therefore, *Acutimitoceras* is defined here to accommodate the forms that possess these two characters, and the genus *Stockumites* is accepted for the forms with rounded venter and without an attached keel.

The Central European species of *Stockumites* can be classified into different categories based on their morphology:

(1) Conch size: some of the species (*S. kleinerae*, *S. intermedius*, *S. voehringeri* sp. nov., *S. subbilobatus*) attain a diameter of 70 mm; most of the others remain smaller (up to about 40–50 mm).

(2) Adult conch shape: within the genus *Stockumites*, the general conch shape varies from thickly discoidal (most of the species) to thickly pachyconic (*S. kleinerae*, *S. depressus*).

(3) Juvenile conch shape: in the juvenile stage, the conch shape varies between subinvolute (*S. depressus*) and evolute (*S. convexus*, *S. antecedens*). Within the genus, a temporal morphological trend from evolute to subinvolute can be observed; the umbilicus is particularly wide in the inner whorls of the stratigraphically older species.

(4) Growth line strength: some species have lamellar growth lines (*S. intermedius*, *S. undulatus*) and others very fine or barely visible growth lines.

(5) Growth line course: most species have convex growth lines, but these are weakly biconvex in *S. parallelus* sp. nov. and distinctly biconvex *in S. undulatus*.

(6) Constrictions: some species (*S. similis*, *S. exilis*, *S. parallelus* sp. nov.) have shell constrictions, others (*S. kleinerae*, *S. voehringeri* sp. nov., *S. subbilobatus*, *S. convexus*) have inner shell thickenings and still others (*S. intermedius*, *S. depressus*, *S. undulatus*, *S. antecedens*) have neither.

Stockumites kleinerae (Korn, 1984) comb. nov.
Figs 29–30; Tables 19–22

Acutimitoceras kleinerae Korn, 1984: 74, pl. 1 figs 1–5, pl. 3 fig. 23, text-figs 4c–d, 5a.

Acutimitoceras kleinerae – Korn 1992b: 16, pl. 2 figs 4–5; 1994: 47, text-figs 36e, 38a–e, 40b, 44g–h, 45e, 48c–d, 56a–b, 57d–e. — Schönlaub *et al*. 1992: pl. 5 figs 4–5. — Kullmann 2000: text-fig. 4h. — Korn & Klug 2002: 197, text-fig. 173a.
Rectimitoceras substriatum – Sprey 2002: 52, text-fig. 17b.
Stockumites kleinerae – Korn & Weyer 2023. — Korn & Weyer 2023: 16, figs 6–7.
Imitoceras Denckmanni – Schindewolf 1923: 336, pl. 15 figs 5–6, text-fig. 4h.
Imitoceras substriatum – Vöhringer 1960: 128, pl. 3 fig. 1, text-fig. 9.

non *Acutimitoceras kleinerae* – Sheng 1989: 110, pl. 33 figs 3–5.

Diagnosis

Species of *Stockumites* with a conch reaching 70 mm diameter. Conch at 5 mm dm pachyconic to globular, subinvolute to subevolute (ww/dm = 0.60–0.90; uw/dm = 0.20–0.40); at 15 mm dm pachyconic to globular, involute (ww/dm = 0.80–0.90; uw/dm = 0.05–0.15); at 30 mm dm thickly pachyconic, involute (ww/dm ~0.75; uw/dm = 0.00–0.05). Whorl profile at 30 mm dm weakly depressed (ww/wh ~1.35); coiling rate moderately high (WER ~1.80). Venter very broadly rounded, umbilical margin broadly rounded. Growth lines fine and rarely coarse, wide-standing, with convex course. Without constrictions on the shell surface; with weak internal shell thickenings. Suture line with narrow external lobe and narrowly V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, forestry road cutting 900 m east of Stockum; Stockum Limestone; Korn 1982 Coll.; illustrated by Korn (1984: pl. 1 fig. 3) and Korn (1994: text-fig. 38b); SMF 43001.

Paratypes

GERMANY • 15 specimens; Rhenish Mountains, forestry road cutting, 900 m east of Stockum; Stockum Limestone; Korn 1982 Coll.; SMF 43002–SMF 43016 • 13 specimens; Rhenish Mountains, trench II, 950 m east of Stockum; Stockum Limestone; Korn 1982 Coll.; SMF 43017–SMF 43029 • 10 specimens; Rhenish Mountains, Müssenberg; Hangenberg Limestone, bed 3c; Korn 1980 Coll.; SMF 43030–SMF 43039.

Additional material

GERMANY • 4 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63879, GPIT-PV-63880, GPIT-PV-64014, GPIT-PV-64016 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; GPIT-PV-64004 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; MB.C.31074 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; MB.C.31075.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; MB.C.31076 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 6; Korn 1977 Coll.; MB.C.31077 • 1 specimen; Rhenish Mountains,

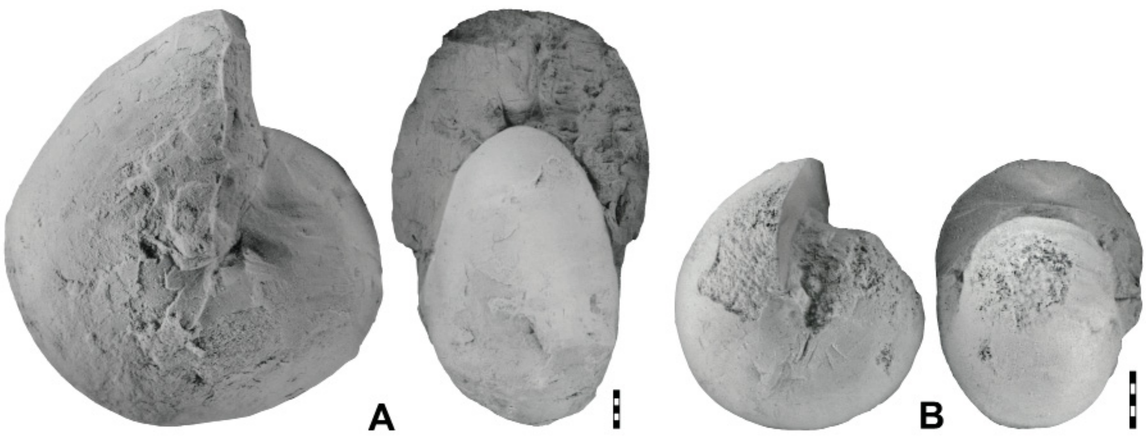

Fig. 29. *Stockumites kleinerae* (Korn, 1984) from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Specimen GPIT-PV-63880 from bed 5. **B**. Specimen GPIT-PV-64004 from bed 6. Scale bar units = 1 mm.

Hasselbachtal; Hangenberg Limestone, bed 83; Weyer 1993–1994 Coll.; MB.C.5251.4 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval III; Paproth Coll.; MB.C.5272.

Description

GPIT-PV-63880 is the largest available specimen with a conch diameter of 55 mm (Fig. 29A). Even at this diameter, the conch is still thinly pachyconic (ww/dm = 0.64). The umbilicus is completely closed, the umbilical margin is rounded and the convex flanks merge continuously into the broadly rounded venter. The coiling rate is moderate (WER = 1.91).

The smaller specimen GPIT-PV-64004 (Fig. 29B) with 24 mm conch diameter is thickly pachyconic (ww/dm = 0.78) and shows a low coiling rate (WER = 1.67). It bears a delicate ornament with fine growth lines that are directed slightly backwardly on the flank. They have a weakly biconvex course with a shallow ventral sinus (Fig. 30D). Shell constrictions are not visible.

The suture line of specimen GPIT-PV-64016 shows a very narrow, lanceolate external lobe separated from the adventive lobe by a three times wider, broadly rounded ventrolateral saddle. The symmetric adventive lobe is V-shaped and wider than the external lobe (Fig. 30C).

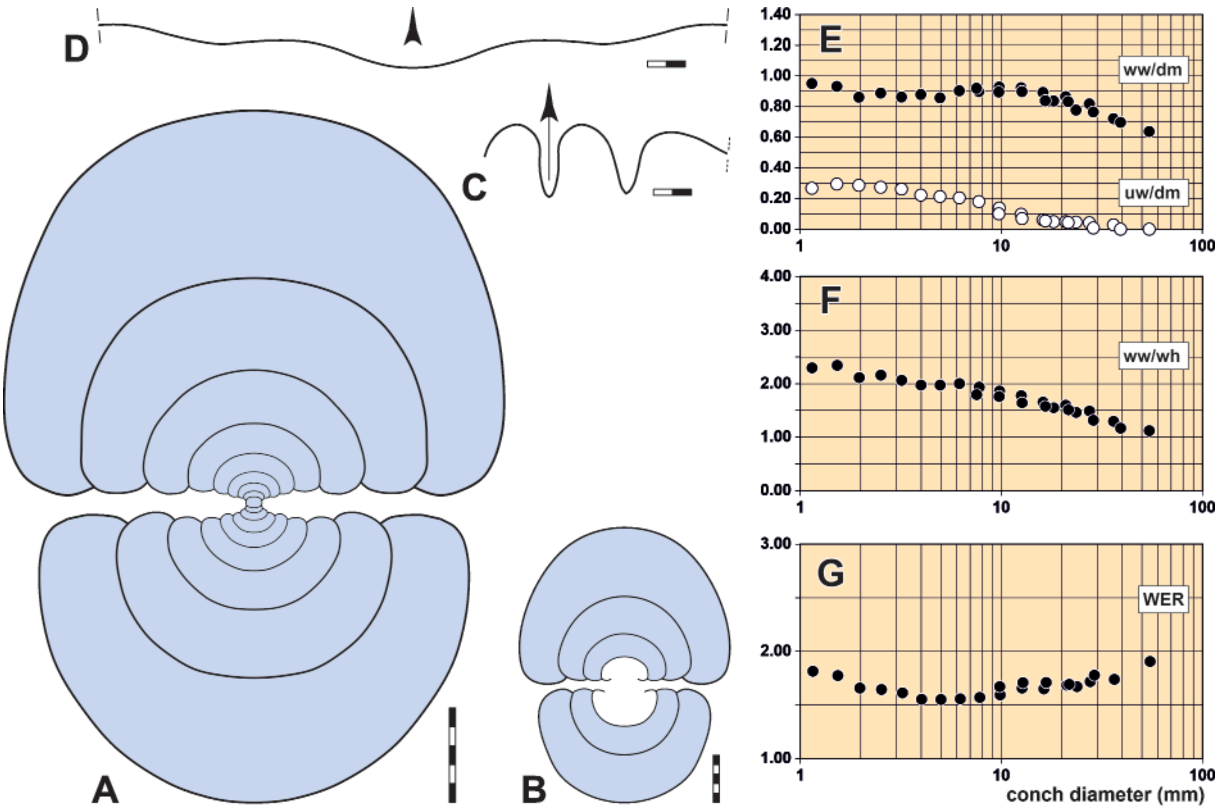

Fig. 30. *Stockumites kleinerae* (Korn, 1984) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen GPIT-PV-63879 from bed 5. **B**. Cross section of specimen MB.C.31075.1 from bed 5. **C**. Suture line of specimen GPIT-PV-64016 from bed 5, at ww = 10.5 mm. **D**. Growth line course of specimen GPIT-PV-64004 from bed 6, at dm = 23.0 mm, ww = 19.4 mm, wh = 12.8 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 19. Conch measurements, ratios and rates of *Stockumites kleinerae* (Korn, 1984) from Stockum.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
SMF 43004	53.4	36.8	32.2	0.0	13.8	0.69	1.14	0.00	1.82	0.57
SMF 43001	35.2	24.4	19.6	0.4	8.5	0.69	1.24	0.01	1.74	0.57
SMF 43005	34.0	24.7	19.2	0.6	7.8	0.73	1.29	0.02	1.68	0.59
SMF 43003	28.7	22.2	15.1	1.8	6.4	0.77	1.47	0.06	1.66	0.58
SMF 43006	23.3	19.1	12.3	1.2	5.7	0.82	1.55	0.05	1.75	0.54

Table 20. Conch measurements, ratios and rates of *Stockumites kleinerae* (Korn, 1984) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63880	55.1	35.1	31.2	0.0	15.2	0.64	1.13	0.00	1.91	0.51
GPIT-PV-63879	36.6	26.4	20.3	1.1	8.9	0.72	1.30	0.03	1.74	0.56
MB.C.31075.1	29.0	22.2	16.9	0.2	7.3	0.77	1.32	0.01	1.78	0.57
GPIT-PV-64004	23.8	18.5	12.6	1.1	5.4	0.78	1.47	0.05	1.67	0.57

Table 21. Conch ontogeny of *Stockumites kleinerae* (Korn, 1984) from Stockum.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal to pachyconic; subevolute (ww/dm = 0.55–0.75; uw/dm = 0.30–0.45)	moderately depressed; strongly embracing (ww/wh = 1.75–2.00; IZR = 0.30–0.40)	low (WER = 1.65–1.75)
5 mm	pachyconic; subinvolute to subevolute (ww/dm = 0.60–0.80; uw/dm = 0.25–0.40)	moderately depressed; strongly embracing (ww/wh = 1.70–2.00; IZR = 0.35–0.45)	low (WER = 1.60–1.75)
15 mm	thickly pachyconic; involute (ww/dm ~0.80; uw/dm = 0.05–0.15)	weakly to moderately depressed; very strongly embracing (ww/wh = 1.35–1.65; IZR = 0.50–0.55)	low (WER = 1.65–1.75)
30 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.35; IZR = 0.50–0.55)	low (WER ~1.70)
50 mm	thinly pachyconic; involute (ww/dm ~0.70; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.15; IZR = 0.50–0.55)	moderate (WER ~1.80)

Table 22. Conch ontogeny of *Stockumites kleinerae* (Korn, 1984) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	globular; subinvolute (ww/dm ~0.90; uw/dm ~0.28)	strongly depressed; strongly embracing (ww/wh ~2.10; IZR ~0.45)	low (WER ~1.70)
5 mm	globular; subinvolute (ww/dm ~0.90; uw/dm ~0.20)	moderately depressed; very strongly embracing (ww/wh ~1.90; IZR ~0.55)	low (WER ~1.60)
15 mm	globular; involute (ww/dm ~0.90; uw/dm ~0.05)	moderately depressed; very strongly embracing (ww/wh ~1.60; IZR ~0.55)	low (WER ~1.65)
30 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.35; IZR ~0.55)	moderate (WER ~1.80)
50 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.15; IZR ~0.50)	moderate (WER ~1.90)

Remarks

Stockumites kleinerae belongs to the species of the genus with the stoutest conch. The ww/dm ratio, even in the adult stage of 55 mm conch diameter, is greater than 0.60, surpassing almost all other species. The whorl profile is always depressed in *S. kleinerae* (ww/wh larger than 1.00)

The material of *S. kleinerae* shows some variation of the umbilical width of the inner whorls. Even the type material from Stockum shows this variation; specimen SMF 43002 (Korn 1984: text-fig. 5a) is evolute (uw/dm = 0.45 at 2 mm dm), while the other specimens from Stockum only reach a uw/dm ratio of about 0.30. The inner whorls of the sectioned specimens from Oberrödinghausen are even less widely umbilicate; they reach a uw/dm ratio of only 0.30 (Fig. 30E).

Stockumites kleinerae differs from the stratigraphically younger species *S. depressus* in the lack of the internal shell thickenings, which cause conspicuous constrictions of the internal mould in the latter species.

Stockumites intermedius (Schindewolf, 1923)
Figs 7D, 31–34; Tables 23–26

Imitoceras intermedium Schindewolf, 1923: 333, pl. 16 fig. 2, text-fig. 4f.

Imitoceras intermedium – Librovitch 1940: pl. 2 fig. 5a–b. — Vöhringer 1960: 131, pl. 3 figs 2, 7–8, text-fig. 11. — Furnish & Manger 1973: 20, text-fig. 2b, d. — Weyer 1977: 177, text-fig. 2.1. — House 1985: pl. 6.7.29, text-fig. 6.7.14b.
Acutimitoceras intermedium – Korn 1984: 75, pl. 3 figs 20–23, text-figs 4e, 5h–I; 1992b: 15, pl. 1 figs 22–27, 30, pl. 2 figs 2–3, 7–9, 15–16, 21–22, 26–27; 1992c: 178, pl. 1 figs 7–11; 1994: 47, text-figs 37a–c, 40c, 41a–e, 44a–c, 45a–c, 47b, 48a–b, 56d–f, 57b–c. — Schönlaub *et al*. 1992: pl. 4 figs 22–27, 30, pl. 5 figs 2–3, 7–9, 15–16, 21–22, 26–27. — Korn *et al*. 1994: text-fig. 20b. — Kullmann,2000: text-fig. 4g. — Korn & Klug 2002: 197, text-fig. 173b. — Korn & Weyer 2003: pl. 2 figs 12–13.
Acutimitoceras (*Stockumites*) *intermedium* – Sprey 2002: 52, text-fig. 17e.
Stockumites intermedius – Korn & Weyer 2023: 20, figs 8–9.
Aganides infracarbonicus – Schmidt 1924: 149, pl. 8 figs 1–2; 1929: 61, pl. 15 fig. 8.

non *Imitoceras intermedium* – Librovitch 1940: 138, pl. 35 figs 2–3. — Schindewolf 1952: 291, text-figs 4–6. — Balashova 1953: 198, pl. 12 figs 11–20. — Furnish & Manger 1973: 20, pl. 1 figs 11–15.
non *Imitoceras* (*Imitoceras*) *intermedium* – Ruan 1981: 64, pl. 12 figs 1–6, 9–13, 17–28.
non *Acutimitoceras intermedium* – Belka *et al*. 1999: pl. 5 figs 7–8. — Korn 1999: 166, pl. 2 fig. 8. — Bockwinkel & Ebbighausen 2006: 97, text-figs 13–14. — Ebbighausen & Bockwinkel 2007: 131, text-figs 8f–g, 10, 12a–b. — Korn & Feist 2007: 106, text-fig. 6b–c, h.
non *Stockumites intermedius* – Becker *et al*. 2002: pl. 2 figs 13–14.

Diagnosis

Species of *Stockumites* with a conch reaching 120 mm diameter. Conch at 5 mm dm thinly pachyconic, subinvolute to subevolute (ww/dm ~0.70; uw/dm = 0.20–0.40); at 15 mm dm thinly pachyconic, involute (ww/dm ~0.65; uw/dm ~0.00); at 30 mm dm thinly pachyconic, involute (ww/dm ~0.65; uw/dm ~0.00). Whorl profile at 30 mm dm weakly depressed (ww/wh = 1.10–1.20); coiling rate moderately high (WER = 1.85–1.95). Venter broadly rounded, umbilical margin very broadly rounded. Growth lines lamellar, wide-standing, with convex or weakly biconvex course. Without constrictions on the shell surface; without internal shell thickenings. Suture line with narrowly lanceolate external lobe and narrowly V-shaped adventive lobe.

Material examined

Lectotype

GERMANY • Upper Franconia, 400 m north-west of Kirchgattendorf; bed 21 ("*Gattendorfia* Limestone"); Schindewolf 1916 Coll.; illustrated by Schindewolf (1923: pl. 16 fig. 2), (Librovitch 1940: pl. 2 fig. 5), Korn (1994: text-fig. 56f) and (Korn & Weyer 2023: fig. 8a); SMF Mbg.3111.

Paralectotypes

GERMANY • 9 specimens; Upper Franconia, 400 m north-west of Kirchgattendorf; bed 21 ("*Gattendorfia* Limestone"); Schindewolf 1916 Coll.; SMF Mbg.7563–SMF Mbg.7571.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-64002 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63860, GPIT-PV-63892, GPIT-PV-63993, GPIT-PV-64000, GPIT-PV-64015 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; GPIT-PV-63875, GPIT-PV-63891 • 9 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; MB.C.31078.1–9 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; MB.C.31079.1–3 • 9 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; MB.C.31080.1–9 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5b; Weyer 1993–1994 Coll.; MB.C.31081.1–3 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 5; Korn 1977 Coll.; MB.C.31082 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 6; Korn 1977 Coll.; MB.C.31083 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 77; Weyer 1993–1994 Coll.; MB.C.5248.1 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 80; Weyer 1993–1994 Coll.; MB.C.5249.3 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone; Korn 1977 Coll.; MB.C.31084.

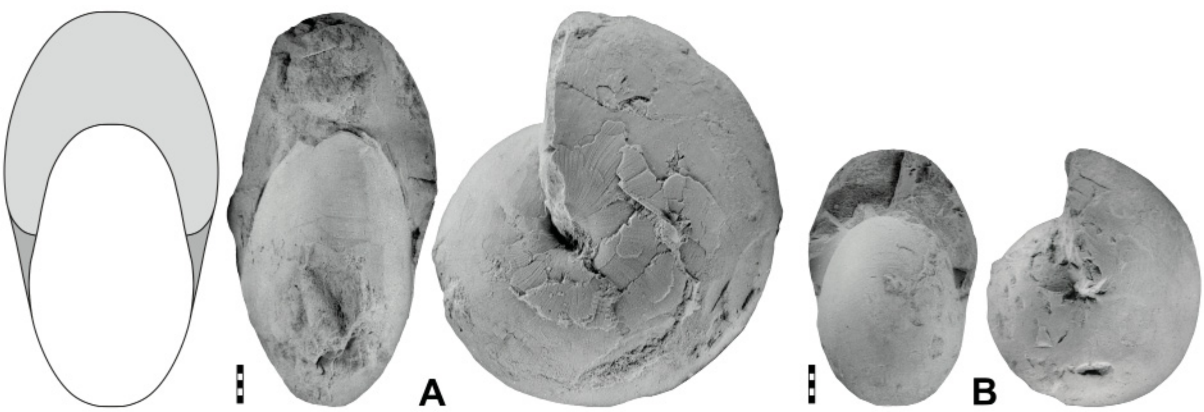

Fig. 31. *Stockumites intermedius* (Schindewolf, 1923) from the Oberrödinghausen railway cutting, bed 5. **A**. Specimen GPIT-PV-63993 (Vöhringer Coll.). **B**. Specimen GPIT-PV-64015 (Vöhringer Coll.). Scale bar units = 1 mm.

Description

The two specimens GPIT-PV-63993 (52 mm dm; Fig. 31A) and GPIT-PV-64015 (34 mm dm; Fig. 31B) represent the adult and preadult stages of the species. The former has a thickly discoidal shape (ww/dm = 0.53) with a completely closed umbilicus, strongly convex flanks and a continuously rounded venter. The coiling rate is moderately high (WER = 1.92). The shell surface bears an ornament of weakly biconvex growth lines running backwardly across the flank and form a broad ventral sinus (Fig. 33D; the growth lines appear to be widely lamellar especially on the outer flank.

The smaller specimen GPIT-PV-64015 (Fig. 31B) has similar conch proportions to the previously described specimen, but with a lower coiling rate (WER = 1.82). It shows the suture line, which has a lanceolate external lobe with weakly divergent flanks. The ventrolateral saddle is about twice as wide as the external lobe and broadly rounded. The almost symmetrical, V-shaped adventive lobe has weakly convexly curved flanks (Fig. 33C).

Ten cross sections are available for examination, of which seven show the ontogeny beginning with the initial stage. They all show the characteristic, very broadly rounded umbilical margin and the continuously rounded venter. The main differences between the specimens are in the shape of the inner whorls. These are always subevolute or evolute with a crescent-shaped profile, but this evolute stage varies in length: In the two cross sections of specimens from bed 6 (Fig. 32A–C), only two whorls are

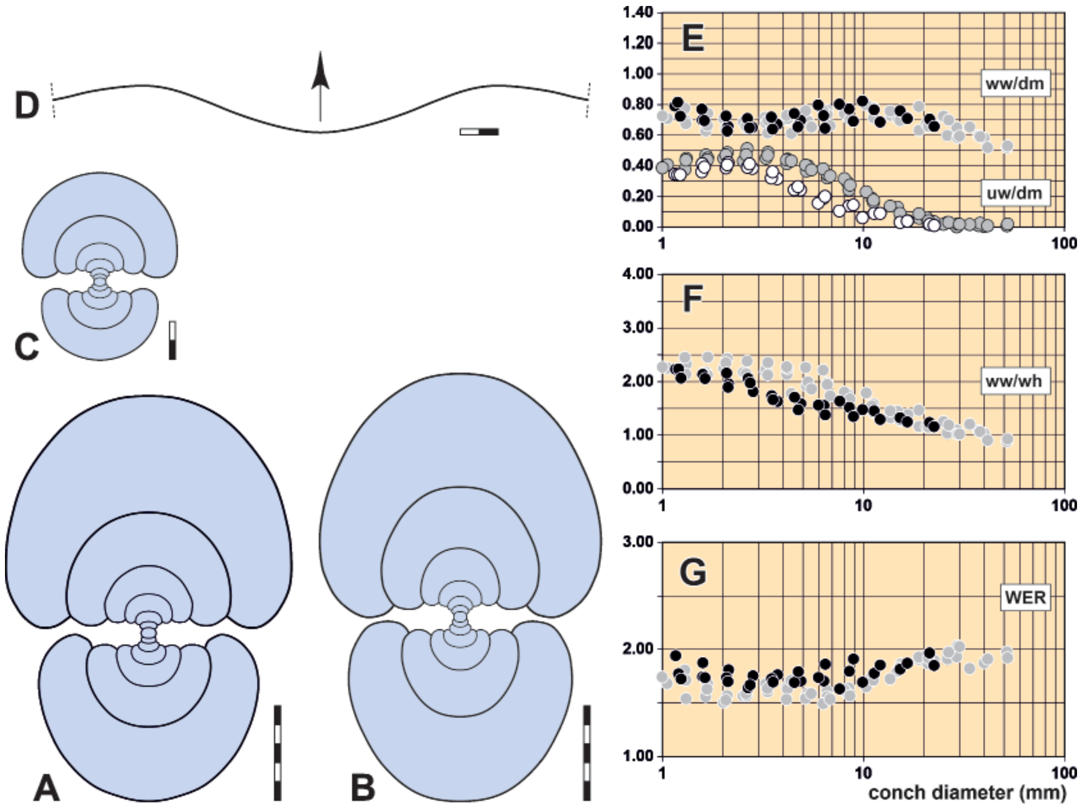

Fig. 32. *Stockumites intermedius* (Schindewolf, 1923) from bed 6 of the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Cross section of specimen GPIT-PV-63875. **B**. Cross section of specimen MB.C.31079.1. **C**. Cross section of specimen MB.C.31079.2. **D**. Growth line course of specimen GPIT-PV-63875, at dm = 22.5 mm, ww = 16.6 mm, wh = 12.8 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Grey dots = representatives from bed 5. Scale bar units = 1 mm.

widely umbilicate, while in the five specimens from bed 5 (Figs 33–34), three or even four whorls are evolute. This means that the maximum uw/dm value reaches ~0.40 in the specimens from bed 6, but ~0.50 in the specimens from bed 5 (Figs 32E, 33E). The early ontogenetic, subevolute to evolute stage is followed by a middle stage in which the whorl profile is C-shaped. At about 8 mm conch diameter, the umbilicus begins to close. This process is already completed at a conch diameter of 15–20 mm. At this stage, the whorl profile is already horseshoe-shaped with increasing whorl height.

Remarks

In his monograph on the ammonoids from the Hangenberg Limestone, Vöhringer (1960) grouped specimens of two species under the name "*Imitoceras intermedium*": (1) specimens from beds 6 and 5, which actually correspond in morphology to the type material of this species from Gattendorf and (2) non-illustrated specimens from beds 3 and 2, which belong to the here newly described species *Stockumites voehringeri* sp. nov. The latter differs from *S. intermedius* by the slightly more slender conch and particularly by the presence of internal shell thickenings in the area of the outer flank and venter.

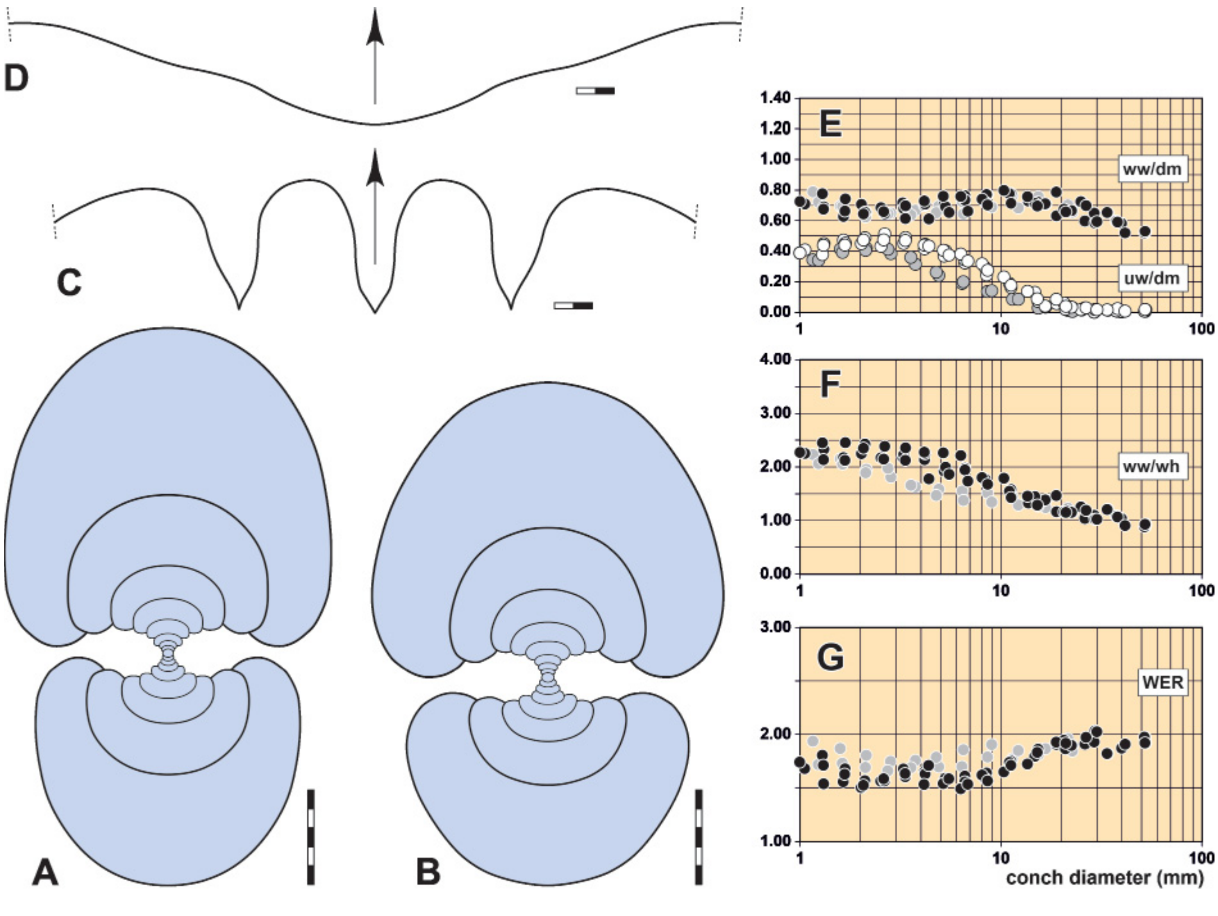

Fig. 33. *Stockumites intermedius* (Schindewolf, 1923) from bed 5 of the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Cross section of specimen MB.C.31078.1. **B**. Cross section of specimen MB.C.31078.2. **C**. Suture line of specimen GPIT-PV-64015, at dm = 28.2 mm, ww = 21.0 mm, wh = 14.8 mm. **D**. Growth line course of specimen GPIT-PV-63993, at ww = 22.0 mm, wh = 20.0 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Grey dots = representatives from bed 6. Scale bar units = 1 mm.

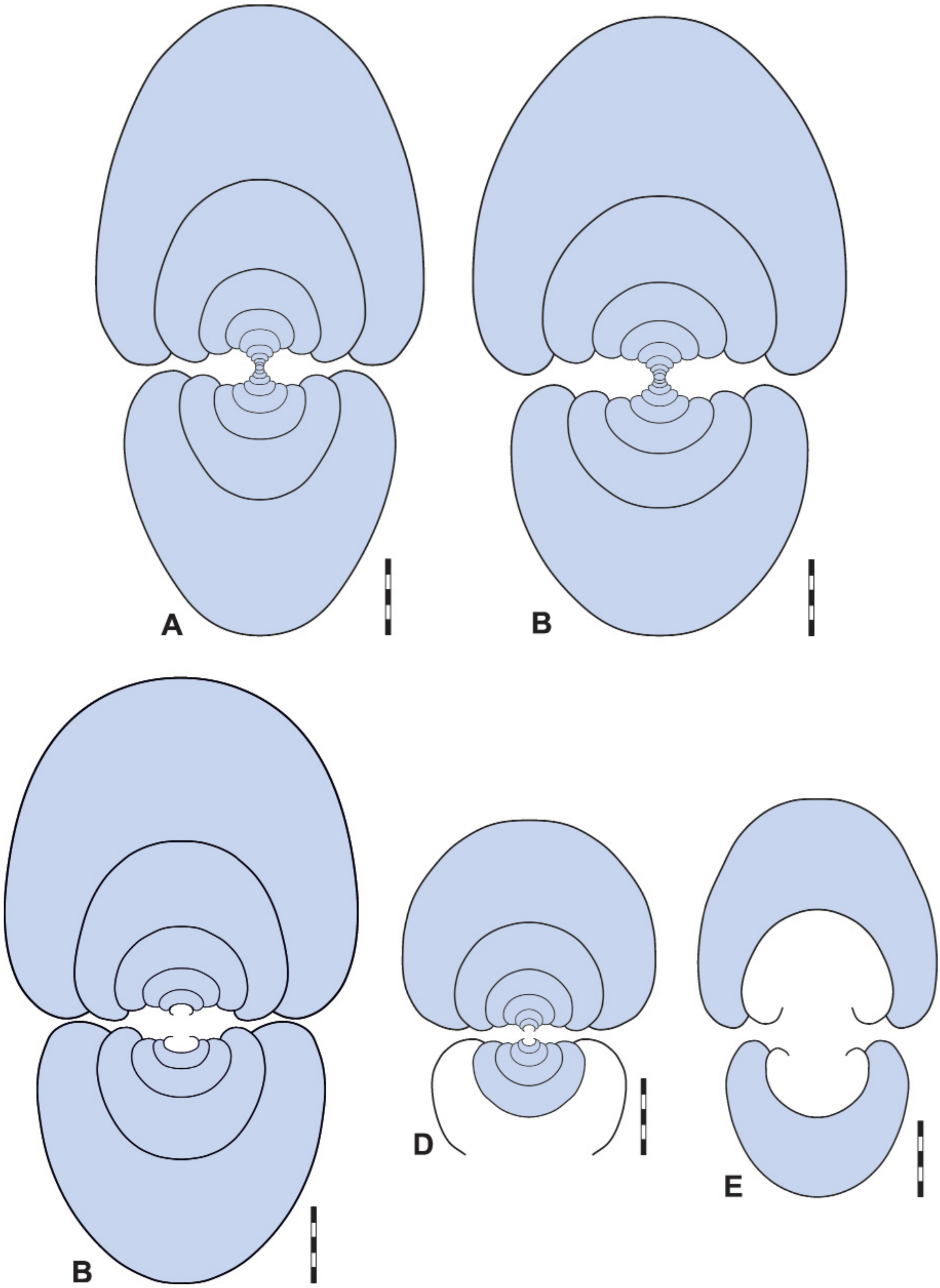

Fig. 34. *Stockumites intermedius* (Schindewolf, 1923) from bed 5 of the Oberrödinghausen railway cutting. **A**. Cross section of specimen MB.C.31078.3 (Vöhringer Coll.). **B**. Cross section of specimen MB.C.31080.1 (Weyer 1993–1994 Coll.) from bed 5a2. **C**. Cross section of specimen GPIT-PV-64000 (Vöhringer Coll.). **D**. Cross section of specimen MB.C.31078.4 (Vöhringer Coll.) from bed 5. **E**. Cross section of specimen GPIT-PV-63860 (Vöhringer Coll.). Scale bar units = 1 mm.

Table 23. Conch measurements, ratios and rates of *Stockumites intermedius* (Schindewolf, 1923) from Oberrödinghausen, bed 6.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31079.1	22.6	14.9	12.9	0.2	6.0	0.66	1.15	0.01	1.85	0.54
GPIT-PV-63875	21.4	15.1	12.3	0.4	6.1	0.70	1.23	0.02	1.97	0.50

Table 24. Conch measurements, ratios and rates of *Stockumites intermedius* (Schindewolf, 1923) from Oberrödinghausen, bed 5.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63993	52.3	27.8	29.8	1.1	14.6	0.53	0.93	0.02	1.92	0.51
GPIT-PV-63892	51.9	27.0	30.5	0.5	15.0	0.52	0.89	0.01	1.98	0.51
MB.C.31078.3	41.6	21.6	23.8	0.4	11.5	0.52	0.91	0.01	1.91	0.51
MB.C.31080.1	40.8	24.6	23.6	0.7	11.8	0.60	1.04	0.02	1.98	0.50
GPIT-PV-64000	40.0	23.3	22.5	0.2	10.8	0.58	1.04	0.01	1.88	0.52
GPIT-PV-64015	33.9	22.2	18.4	0.6	8.8	0.65	1.21	0.02	1.82	0.52
MB.C.31078.1	29.5	17.3	16.8	0.6	8.8	0.59	1.03	0.02	2.04	0.48
MB.C.31078.2	26.6	18.6	15.6	0.9	7.7	0.70	1.19	0.03	1.98	0.51
GPIT-PV-63860	26.3	15.8	15.1	0.8	7.3	0.60	1.04	0.03	1.91	0.52

Table 25. Conch ontogeny of *Stockumites intermedius* (Schindewolf, 1923) from Oberrödinghausen, bed 6.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.40)	moderately depressed; moderately embracing (ww/wh ~1.90; IZR ~0.25)	moderate (WER ~1.75)
5 mm	thinly pachyconic; subinvolute (ww/dm ~0.70; uw/dm ~0.20)	moderately depressed; very strongly embracing (ww/wh ~1.55; IZR ~0.45)	moderate (WER ~1.75)
15 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.25; IZR ~0.55)	moderate (WER ~1.80)
30 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.20; IZR ~0.55)	moderate (WER ~1.85)

Table 26. Conch ontogeny of *Stockumites intermedius* (Schindewolf, 1923) from Oberrödinghausen, bed 5.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; evolute (ww/dm ~0.70; uw/dm ~0.45)	strongly depressed; moderately embracing (ww/wh ~2.35; IZR ~0.25)	low (WER ~1.55)
5 mm	thinly pachyconic; subevolute (ww/dm ~0.70; uw/dm ~0.40)	moderately depressed; very strongly embracing (ww/wh ~1.95; IZR ~0.45)	low (WER ~1.60)
15 mm	thinly pachyconic; involute (ww/dm ~0.70; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.35; IZR ~0.50)	moderate (WER ~1.80)
30 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.10; IZR ~0.50)	moderate (WER ~1.95)
50 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.90; IZR ~0.50)	moderate (WER ~1.95)

Stockumites intermedius differs from the co-occurring species *S. kleinerae* by the more slender conch (ww/dm = 0.60–0.65 in *S. intermedius*, but 0.75–0.80 in *S. kleinerae* at 30 mm dm). In addition, *S. intermedius* has lamellar growth lines, which are finer in *S. kleinerae* and are there also visible because of rhythmic strengthening on the inner surface of the shell, causing fine undulation of the internal mould.

Other species of *Stockumites* with comparable pachyconic conch are distinguished from *S. intermedius* by the shell constrictions or internal shell thickenings. A morphologically similar species is *S. depressus*, but this has more strongly biconvex, fine and narrow-standing growth lines.

Stockumites parallelus sp. nov.
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Figs 7F, 35; Tables 27–29

Imitoceras subbilobatum – Vöhringer, 1960: 135, text-fig. 14.
Acutimitoceras subbilobatum – Korn 1984: 76, pl. 2 figs 13–15, text-fig. 5e; 1992c: 178, pl. 1 figs 2–3, pl. 2 figs 7–8; 1994: 51, text-figs 37d, 39, 42a–c, 50a. — Kullmann 2000: text-fig. 4f. — Korn & Klug 2002: 197, text-fig. 173c, f. — Korn *et al*. 2003b: 1125, text-fig. 3c. — Korn & Weyer 2003: pl. 2 figs 6–7, text-fig. 14d.

? *Aganides ornatissimus* – Schmidt 1924: 149, pl. 8 figs 3–4.

Diagnosis

Species of *Stockumites* with a conch reaching 70 mm diameter. Conch at 5 mm dm thinly pachyconic, subinvolute (ww/dm ~0.65; uw/dm ~0.20); at 15 mm dm thickly discoidal, involute (ww/dm ~0.55; uw/dm ~0.05); at 30 mm dm thickly discoidal, involute (ww/dm ~0.50; uw/dm ~0.00). Whorl profile at 30 mm dm weakly compressed (ww/wh ~0.90); coiling rate moderately high (WER ~1.90). Venter rounded, umbilical margin rounded, flanks subparallel. Growth lines fine, narrow-standing, with slightly biconvex course. Weak constrictions on the shell surface; coarse internal shell thickenings. Suture line with lanceolate external lobe and narrowly V-shaped adventive lobe.

Etymology

Named after the nearly parallel arrangement of the flanks.

Material examined

Holotype

GERMANY • Rhenish Mountains, forestry road cutting 900 m east of Stockum; Stockum Limestone (*Stockumites prorsus* Zone); Korn 1982 Coll.; illustrated by Korn (1994: text-fig. 42a); SMF 43083.

Paratypes

GERMANY • 6 specimens; Rhenish Mountains, forestry road cutting 900 m east of Stockum; Stockum Limestone; Korn 1982 Coll.; SMF 43080–43082, SMF 43084–43086 • 2 specimens; Rhenish Mountains, trench II 950 m east of Stockum; Stockum Limestone; Korn 1982 Coll.; SMF 43087–43088 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63890 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; MB.C.31085.1–5 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5c; Weyer 1993–1994 Coll.; MB.C.31086.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6b2; Weyer 1993–1994 Coll.; MB.C.31087 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 76; Weyer 1993–1994 Coll.; MB.C.5247.2 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, lower part; Paproth Coll.; MB.C.5292.

Description

Holotype SMF 43083 is an exfoliated specimen with 42 mm conch diameter; it suffered from a near-sagittal calcite vein. It is thickly discoidal (ww/dm = 0.47) with an almost closed umbilicus. The internal mould shows two constrictions standing 90 degrees apart, but the last half whorl does not possess a constriction.

Paratype MB.C.31087 (Fig. 35A) is a specimen with 28 mm conch diameter preserved on only half a side; it is obviously thinly discoidal and involute. The shell surface bears widespread growth lines, which are almost straight on the flank and bend back to a ventral sinus in the ventrolateral area. Parallel to the growth lines are shallow constrictions with distances of 90 degrees.

The two sectioned paratypes GPIT-PV-63890 (28 mm dm; Fig. 35B) from Oberrödinghausen, SMF 43081 (22 mm dm; Fig. 35C) from Stockum and MB.C.5292 (19 mm dm; Fig. 35D) from Oese show

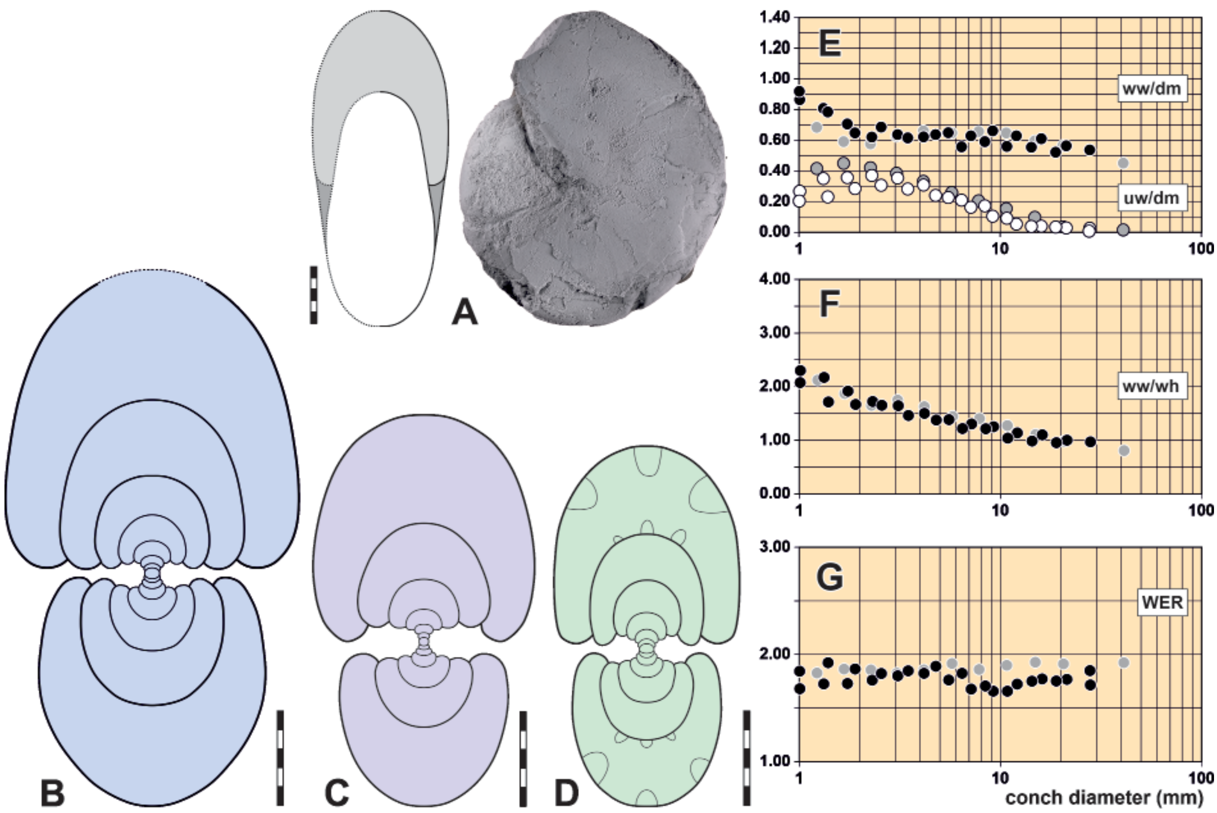

Fig. 35. *Stockumites parallelus* sp. nov. from the Oberrödinghausen railway cutting and the Oese section. **A**. Paratype MB.C.31087 (Weyer 1993–1994 Coll.) from bed 6b of Oberrödinghausen; dorsal reconstruction and lateral view. **B**. Cross section of paratype GPIT-PV-63890 from bed 5 of Oberrödinghausen. **C**. Cross section of paratype SMF 43081 (Korn 1982 Coll.) from the Stockum Limestone at Stockum (from Korn 1984). **D**. Cross section of paratype MB.C.5292 from the lower part of the Hangenberg Limestone at Oese (from Korn & Weyer 2003). **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens (grey = specimens from the type locality Stockum). Scale bar units = 1 mm.

Table 27. Conch measurements, ratios and rates of *Stockumites parallelus* sp. nov. from Stockum.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
SMF 43083	42.0	19.7	23.6	0.8	11.9	0.47	0.83	0.02	1.95	0.50
SMF 43081	21.9	12.1	12.8	0.5	6.3	0.55	0.95	0.02	1.97	0.51
SMF 43080	15.4	9.6	8.1	1.2	4.0	0.62	1.19	0.08	1.82	0.51

Table 28. Conch measurements, ratios and rates of *Stockumites parallelus* sp. nov. from Oberrödinghausen and Oese.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63890	28.3	14.9	15.7	0.5	6.9	0.53	0.95	0.02	1.74	0.56
MB.C.31087	28.0	–	15.3	0.0	7.4	–	–	0.00	1.85	0.52
MB.C.5292	19.0	9.8	10.4	0.5	4.7	0.52	0.94	0.03	1.75	0.55

Table 29. Conch ontogeny of *Stockumites parallelus* sp. nov. from Oberrödinghausen and Oese.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.70; IZR ~0.30)	moderate (WER ~1.80)
5 mm	thinly pachyconic; subinvolute (ww/dm ~0.65; uw/dm ~0.20)	weakly depressed; very strongly embracing (ww/wh ~1.40; IZR ~0.45)	moderate (WER ~1.80)
15 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.05; IZR ~0.55)	moderate (WER ~1.80)
30 mm	thickly discoidal; involute (ww/dm ~0.50; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.95; IZR ~0.55)	moderate (WER ~1.90)

sections that are largely matching. After two inner whorls with a semi-modular profile, there is a rapid transformation to a horseshoe-shaped profile with subparallel flanks.

Remarks

As can be seen from the synonymy list, specimens of the new species were often identified as *Stockumites subbilobatus*. However, the holotype of *S. subbilobatus* has no shell constrictions and is stouter than the specimens assigned here to *S. parallelus* sp. nov. At a conch diameter of 30 mm, the ww/dm ratio is about 0.45 in *S. parallelus*, but about 0.50 in *S. subbilobatus*. The problems with the poor preservation of the holotype of "*Goniatites subbilobatus*" are discussed by Korn & Weyer (2023).

Vöhringer (1960) united material of at least two species under "*Imitoceras subbilobatum*". On the one hand, there were specimens from the lowermost part of the Hangenberg Limestone (beds 6 and 5), which are indeed conspecific with the original; on the other hand, there were specimens from the middle part of the Hangenberg Limestone (beds 4 to 2), which, however, have no shell constrictions (but only internal shell thickenings) and show more strongly convergent flanks. These are separated here as the new species *S. voehringeri* sp. nov.

Only a few useful specimens are available from the Hangenberg Limestone of the Rhenish Mountains. *Stockumites parallelus* sp. nov. can easily be distinguished from the other species of the genus by the combination of the slender conch with subparallel flanks, the shell constrictions and the weakly biconvex growth lines.

Stockumites procedens (Korn, 1984) comb. nov.
Fig. 36; Tables 30–31

Acutimitoceras procedens Korn, 1984: 80, pl. 4 figs 24–25, text-fig. 5b.

Acutimitoceras procedens – Korn 1994: 47, text-figs 36b–c, 71f.
Acutimitoceras prorsum prorsum – Korn 1981: 519, text-figs 3a, 4a–d.

Diagnosis

Species of *Stockumites* with a conch reaching 40 mm diameter. Conch at 5 mm dm thinly pachyconic, subevolute (ww/dm ~0.65; uw/dm ~0.35); at 15 mm dm thinly pachyconic, involute (ww/dm ~0.65; uw/dm ~0.12); at 30 mm dm thickly discoidal, involute (ww/dm ~0.55; uw/dm ~0.00). Whorl profile at 30 mm dm weakly depressed (ww/wh ~1.05); coiling rate very high (WER ~2.35). Venter very broadly rounded, umbilical margin broadly rounded. Growth lines fine, with convex course in the middle growth stage and slightly biconvex course in the adult stage. Ornament with shallow constrictions on the shell surface; with coarse internal shell thickenings.

Material examined

Holotype

GERMANY • Müssenberg, trench 1; Hangenberg Limestone, bed 3c; Korn 1980 Coll.; illustrated by Korn (1984: pl. 4 fig. 24) and Korn (1994: text-fig. 36b); GZG.INV.131.

Paratypes

GERMANY • 1 specimen; Müssenberg, trench 1; Hangenberg Limestone, bed 3c; Korn 1980 Coll.; GZG.INV.132 • 3 specimens; same collection data as for preceding; SMF 43141–SMF 43143.

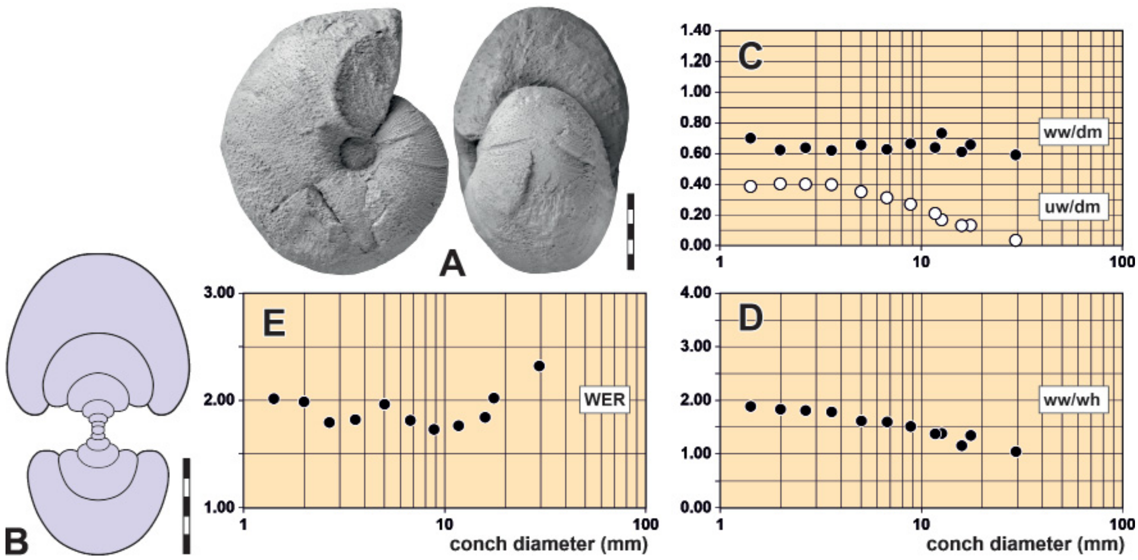

Fig. 36. *Stockumites procedens* (Korn, 1984). **A**. Specimen MB.C.31088 (Weyer 1993–1994 Coll.) from the Oberrödinghausen railway cutting, bed 6b. **B**. Cross section of paratype GZG.INV.132 (Korn 1980 Coll.) from the Hangenberg Limestone at Müssenberg (from Korn 1984). **C**–**E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of specimens from the type locality Stockum and from Oberrödinghausen. Scale bar units = 1 mm.

Table 30. Conch measurements, ratios and rates of *Stockumites procedens* (Korn, 1984) from Müssenberg and Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GZG.INV.131	29.6	17.4	17.0	0.0	10.2	0.59	1.02	0.00	2.33	0.40
MB.C.31088	17.6	11.5	8.7	2.1	5.2	0.66	1.33	0.12	2.02	0.40
GZG.INV.132	15.9	9.6	8.5	1.9	4.2	0.61	1.14	0.12	1.84	0.51

Table 31. Conch ontogeny of *Stockumites procedens* (Korn, 1984).

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.40)	moderately depressed; weakly embracing (ww/wh ~1.85; IZR ~0.15)	moderate (WER ~1.95)
5 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.35)	moderately depressed; moderately embracing (ww/wh ~1.60; IZR ~0.30)	moderate (WER ~1.95)
15 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.12)	weakly depressed; very strongly embracing (ww/wh ~1.15; IZR ~0.50)	moderate (WER ~1.85)
30 mm	thickly discoidal; involute (ww/dm ~0.58; uw/dm ~0.04)	weakly depressed; moderately embracing (ww/wh ~1.05; IZR ~0.40)	very high (WER ~2.35)

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6b; Weyer 1993–1994 Coll.; MB.C.31088.

Description

Holotype GZG.INV.131 is a very well preserved, complete specimen with 30 mm conch diameter. The conch is thickly discoidal (ww/dm = 0.58); it has a funnel-shaped umbilicus that is completely closed. The aperture is very high and leads to a coiling rate of WER = 2.34. The shell bears very fine, biconvex growth lines with only weakly developed lateral sinus. Four shell constrictions are developed at 90 degrees to each other, restricted to the venter and ventrolateral flank area.

The cross-section of the smaller paratype GZG.INV.132 has slightly wider whorls (ww/dm = 0.60) at 16 mm conch diameter. The umbilicus is still open at this stage (uw/dm = 0.12).

Specimen MB.C.31088 has a conch diameter of 17.5 mm (Fig. 36A) and shows the transition from the middle growth stage to the adult stage, which is characterised by a considerable increase in aperture height. The conch is thinly pachyconic with a slightly opened umbilicus (ww/dm = 0.66; uw/dm = 0.12) and a high coiling rate (WER = 2.02). The shell surface has initially rather coarse and lamellar but later fine growth lines, which extend with a convex arc across the flank and form a shallow subangular sinus on the venter. Weak shell constrictions extend parallel to the growth lines.

Remarks

Stockumites procedens can easily be distinguished from the other species of the genus by the very high coiling rate in the adult stage. With a value of about 2.35, it exceeds by far the rate (usually under 2.00) known from the other species. Another character to distinguish *S. procedens* from the other species of the genus is the development of shell constrictions, which extend across the venter with a subangular sinus.

Stockumites undulatus (Vöhringer, 1960) comb. nov.
Figs 37–38; Tables 32–33

Imitoceras undulatum Vöhringer, 1960: 133, pl. 3 fig. 6, text-fig. 13.

Acutimitoceras undulatum – Korn 1994: 52, text-figs 49h–i, 50l, 52c, 55e–f. — Korn *et al*. 1994: text-fig. 20a.

Diagnosis

Species of *Stockumites* with a conch reaching 40 mm diameter. Conch at 5 mm dm thinly pachyconic, subinvolute (ww/dm ~0.70; uw/dm ~0.25); at 12 mm dm thinly pachyconic, subinvolute (ww/dm ~0.65; uw/dm ~0.05); at 20 mm dm thickly discoidal, involute (ww/dm ~0.55; uw/dm ~0.02). Whorl profile at 20 mm dm weakly compressed (ww/wh ~0.95); coiling rate moderately high (WER ~1.90). Venter broadly rounded, umbilical margin broadly rounded. Growth lines lamellar, wide-standing, with biconvex course. Without constrictions on the shell surface; without internal shell thickenings. Suture line with V-shaped external lobe and V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 3 fig. 6) and Korn (1994: text-fig. 49i); re-illustrated here in Fig. 37A; GPIT-PV-63877.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-64022 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; GPIT-PV-63879, GPIT-PV-63881.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; MB.C.31089 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5c; Weyer 1993–1994 Coll.; MB.C.31090 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6a; Weyer 1993–1994 Coll.; MB.C.31091 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval III; Paproth Coll.; MB.C.5271.

Fig. 37. *Stockumites undulatus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63877 (Vöhringer Coll.) from bed 5. **B**. Paratype GPIT-PV-63879 (Vöhringer Coll.) from bed 6. Scale bar units = 1 mm.

Description

Holotype GPIT-PV-63877 is a specimen that is largely covered with shell and has 23 mm diameter (Fig. 37A). It is thickly discoidal (ww/dm = 0.52) with a closed umbilicus. The conch is widest at the rounded umbilical margin; from there the flanks converge to the continuously rounded venter. The ornament consists of lamellar growth lines with a biconvex course; the dorsolateral projection and ventrolateral projection have about the same height (Fig. 38E).

Paratype GPIT-PV-63879 with 20.5 mm diameter is very similar to the holotype in conch parameters and ornament (Fig. 37B). The suture line has a lanceolate external lobe, accompanied by an asymmetrical ventrolateral saddle. The almost symmetrical adventive lobe is broadly lanceolate with outwardly curved flanks (Fig. 38C).

Specimen MB.C.31091 shows the ornament in particularly good preservation (Fig. 38A). The lamellar growth lines with biconvex course form a dorsolateral projection on the inner third of the flank, a shallow lateral sinus on the outer third of the flank and a ventrolateral projection on the ventrolateral shoulder.

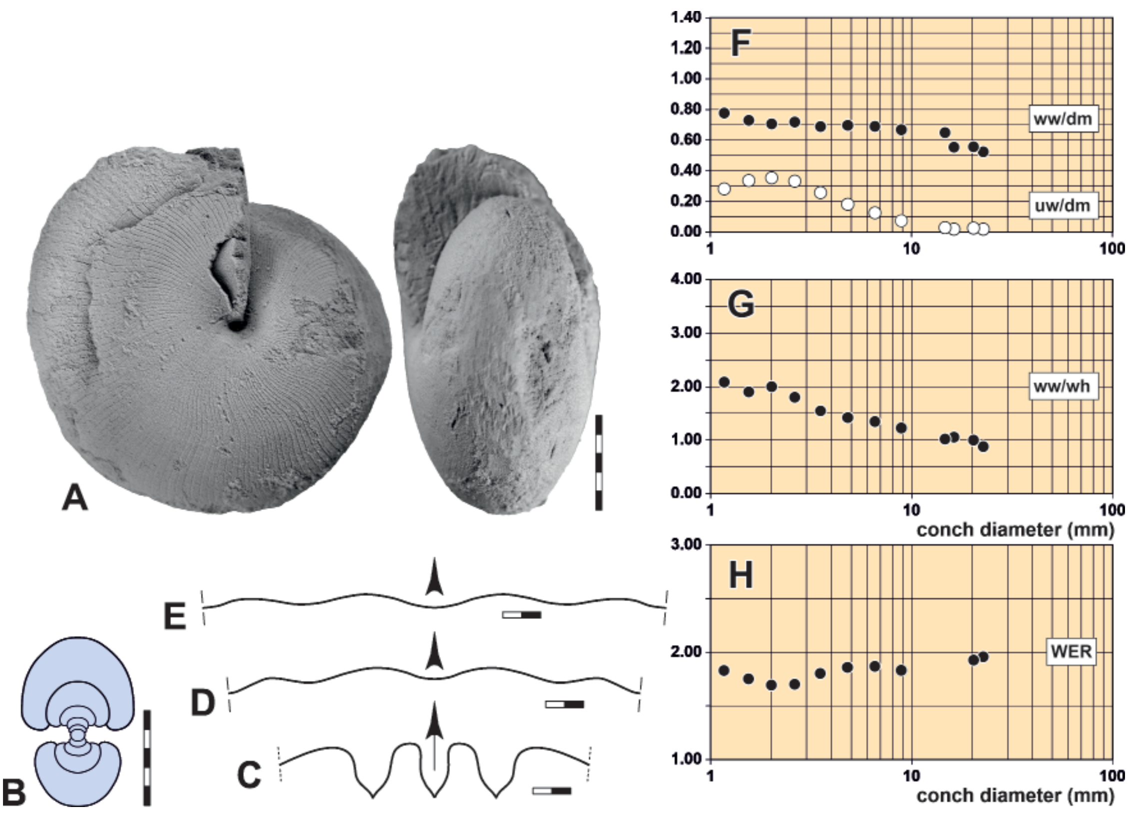

Fig. 38. *Stockumites undulatus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Specimen MB.C.31091 (Weyer 1993–1994 Coll.) from bed 6a. **B**. Cross section of paratype GPIT-PV-63881 (Vöhringer Coll.) from bed 6. **C**. Suture line of paratype GPIT-PV-63879 (Vöhringer Coll.) from bed 6, at ww = 8.5 mm, wh = 7.6 mm. **D**. Growth line course of paratype GPIT-PV-63881 (Vöhringer Coll.) from bed 5, at dm = 9.5 mm, ww = 6.0 mm, wh = 5.5 mm. **E**. Growth line course of holotype GPIT-PV-63877 (Vöhringer Coll.) from bed 5, at dm = 16.3 mm, ww = 9.2 mm, wh = 9.0 mm. **F**–**H**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 32. Conch measurements, ratios and rates of *Stockumites undulatus* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63877	22.8	11.9	13.7	0.4	6.5	0.52	0.87	0.02	1.96	0.53
MB.C.31091	21.7	11.0	11.5	0.6	5.8	0.51	0.96	0.03	1.87	0.49
GPIT-PV-63879	20.4	11.3	11.4	0.5	5.7	0.55	0.99	0.02	1.93	0.50
GPIT-PV-63881	8.9	5.9	4.9	0.6	2.3	0.67	1.21	0.07	1.83	0.52

Table 33. Conch ontogeny of *Stockumites undulatus* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.70; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.90; IZR ~0.35)	low (WER ~1.70)
4 mm	thinly pachyconic; subinvolute (ww/dm ~0.70; uw/dm ~0.25)	weakly depressed; very strongly embracing (ww/wh ~1.50; IZR ~0.45)	moderate (WER ~1.80)
12 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.10; IZR ~0.55)	moderate (WER ~1.80)
20 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.02)	weakly compressed; very strongly embracing (ww/wh ~0.95; IZR ~0.55)	moderate (WER ~1.90)

Remarks

Stockumites undulatus is an easily recognisable species because it is clearly distinguished from all other species of the genus by the characteristic, lamellar growth lines with a distinctive biconvex course.

Stockumites convexus (Vöhringer, 1960)
Figs 7E, 39–40; Tables 34–35

Imitoceras prorsum convexum Vöhringer, 1960: 139, pl. 2 fig. 5, text-fig. 17.

Imitoceras prorsum convexum – Weyer 1977: 172, pl. 2 figs 8–9.
Acutimitoceras convexum – Korn 1992b: 16, pl. 2 figs 17–18; 1994: 42, text-figs 49a–c, 50e, 52a, 54d, 56c. — Schönlaub *et al*. 1992: 16, pl. 5 figs 17–18. — Korn & Weyer 2003: 100, pl. 2 figs 1–2.
Stockumites convexus – Becker & Weyer 2004: 18, text-fig. 3g. — Korn & Weyer 2023: 30, fig. 15.

Diagnosis

Species of *Stockumites* with a conch reaching 40 mm diameter. Conch at 5 mm dm thickly discoidal to thinly pachyconic, subevolute to evolute (ww/dm = 0.55–0.65; uw/dm = 0.40–0.50); at 15 mm dm thickly discoidal, involute (ww/dm = 0.45–0.55; uw/dm = 0.05–0.10); at 25 mm dm thickly discoidal, involute (ww/dm = 0.45–0.55; uw/dm ~0.00). Whorl profile at 25 mm dm weakly compressed (ww/wh ~0.90); coiling rate moderate to high (WER = 1.90–2.10). Venter broadly rounded, umbilical margin broadly rounded. Growth lines coarse, wide-standing, with convex course. Weak constrictions on the shell surface; coarse internal shell thickenings. Suture line with lanceolate external lobe and V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen railway cutting; bed 6; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 2 fig. 6) and Korn (1994: text-fig. 49a), re-illustrated here in Fig. 39A; GPIT-PV-63903.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63904, GPIT-PV-63905 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; GPIT-PV-63906.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; MB.C.31092 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; MB.C.31093.1–2 • 7 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; MB.C.31094.1–7 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31095 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6b2; Weyer 1993–1994 Coll.; MB.C.31096 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 59; Weyer 1993–1994 Coll.; MB.C.5241.1.

Description

Holotype GPIT-PV-63903 is a rather well-preserved specimen with 22 mm diameter; it is largely covered with shell (Fig. 39A). The conch is thickly discoidal (ww/dm = 0.51) with an almost closed umbilicus (uw/dm = 0.06) and a high coiling rate (WER = 2.08). The whorl profile is weakly compressed (ww/wh = 0.93) with convex, convergent flanks and a continuously rounded venter. The shell bears rather coarse, lamellar growth lines, which run with a broad convex arc across the flank and form a broad, distinct

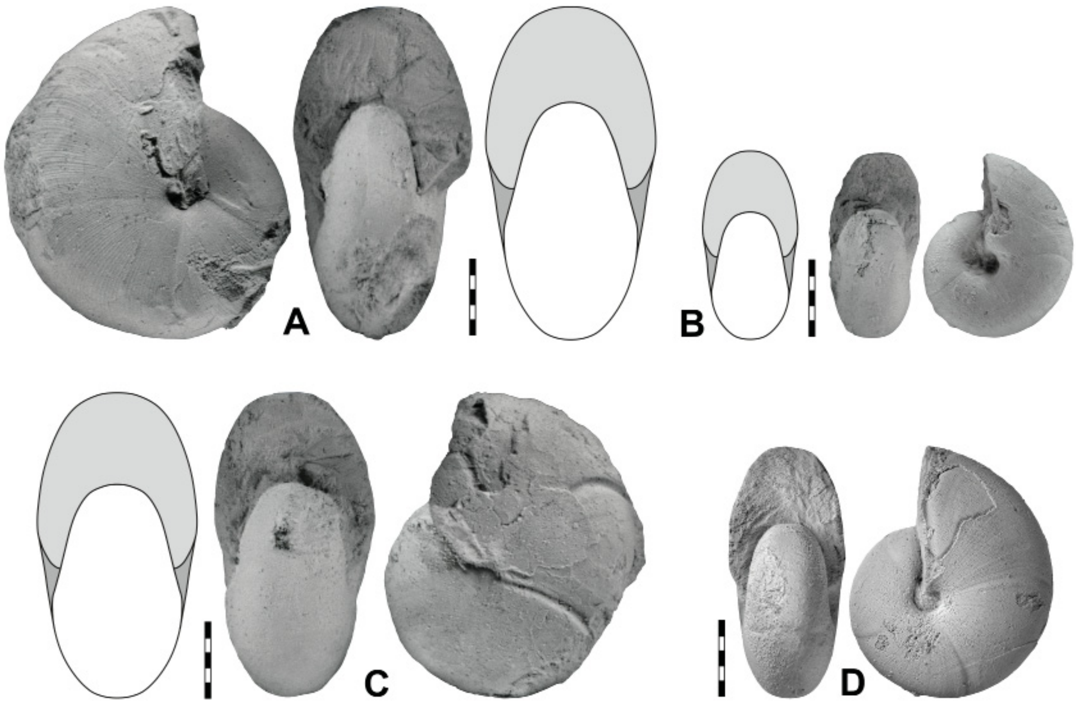

Fig. 39. *Stockumites convexus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63903 (Vöhringer Coll.) from bed 6. **B**. Paratype GPIT-PV-63905 (Vöhringer Coll.) from bed 5. **C**. Paratype GPIT-PV-63904 (Vöhringer Coll.) from bed 5. **D**. Specimen MB.C.31096 (Weyer 1993–1994 Coll.) from bed 6b2. Scale bar units = 1 mm.

sinus on the venter (Fig. 40H). On the surface of the shell, there are faint constrictions that follow the course of the growth lines.

Paratype GPIT-PV-63904 (Fig. 39C) with 20 mm diameter is very similar to the holotype in its conch proportions and also the ornament. It clearly shows that the constrictions are strengthened on the inner side of the shell and lead to very deep constrictions of the internal mould. The suture line has a lanceolate external lobe with very weakly divergent flanks, a slightly wider parabolic ventrolateral saddle and a V-shaped adventive lobe with weakly outwardly curved flanks (Fig. 40G).

Smaller specimens, such as paratype GPIT-PV-63905 (12 mm dm; Fig. 39B) and especially MB.C.31096 (18.5 mm dm; Fig. 39D) show the transition from the juvenile stage to the middle stage, which is characterised by a rather rapid closure of the umbilicus by increased overlap of the inner flank area upon the umbilicus.

Specimen MB.C.31096 is well-preserved and deserves a detailed description. It has a conch diameter of 18.5 mm (Fig. 39D). It is thickly discoidal and involute (ww/dm = 0.46; uw/dm = 0.08), but shows that

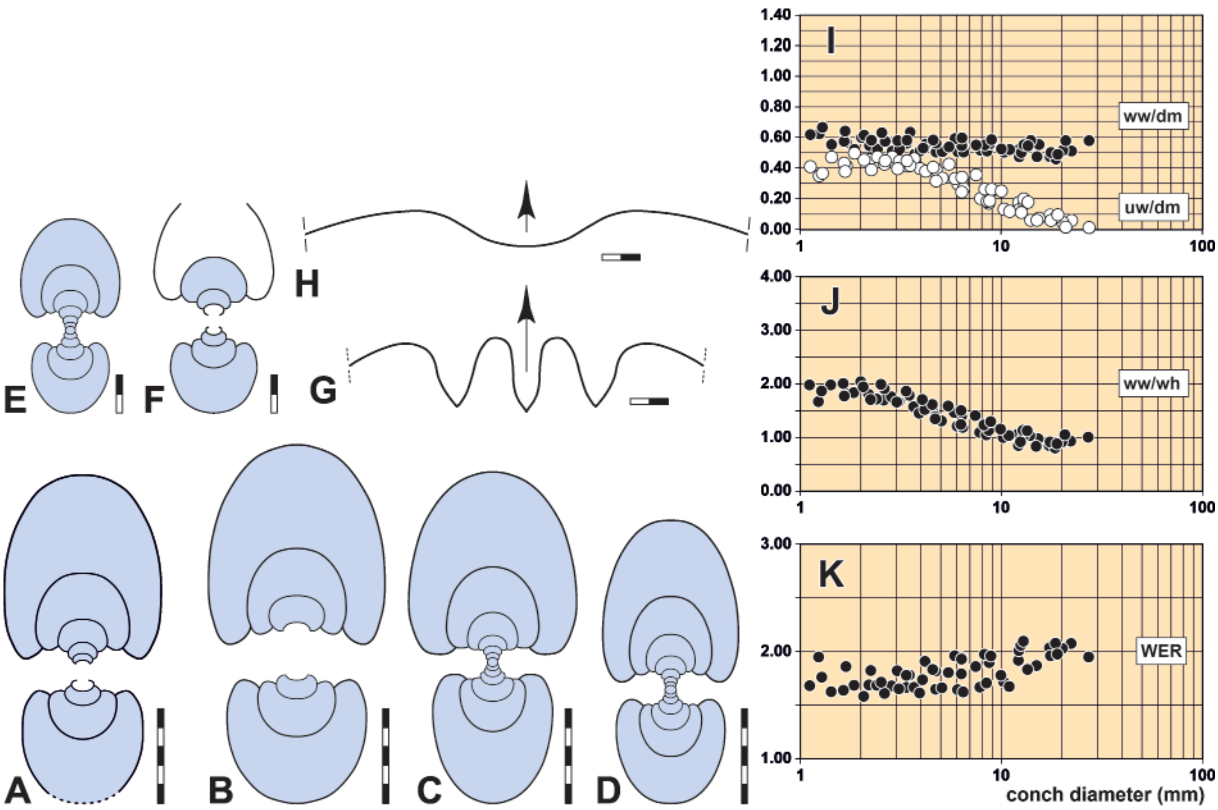

Fig. 40. *Stockumites convexus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Cross section of paratype GPIT-PV-63906 from bed 6. **B**. Cross section of specimen MB.C.31094.1 from bed 6. **C**. Cross section of specimen MB.C.31094.2 from bed 6. **D**. Cross section of specimen MB.C.31093.1 from bed 5. **E**. Cross section of specimen MB.C.31092 from bed 4. **F**. Cross section of specimen MB.C.31094.3 from bed 6. **G**. Suture line of paratype GPIT-PV-63904 from bed 5, at ww = 7.5 mm, wh = 7.0 mm. **H**. Growth line course of holotype GPIT-PV-63903 from bed 6, at dm = 16.0 mm, ww ca. 9.0 mm, wh = 8.5 mm. **I**–**K**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 34. Conch measurements, ratios and rates of *Stockumites convexus* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63903	22.2	11.4	12.2	1.4	6.8	0.51	0.93	0.06	2.08	0.44
GPIT-PV-63904	20.1	10.4	11.3	1.0	6.0	0.52	0.92	0.05	2.03	0.47
MB.C.31094.1	19.0	9.3	10.5	1.9	5.5	0.49	0.89	0.10	1.98	0.48
MB.C.31096	18.6	8.6	10.6	1.6	5.7	0.46	0.81	0.08	2.08	0.46
MB.C.31094.2	17.5	8.8	9.6	1.1	5.0	0.50	0.92	0.06	1.96	0.48
GPIT-PV-63906	17.4	8.3	9.7	1.7	5.2	0.48	0.85	0.10	2.04	0.46
MB.C.31093.1	15.0	7.1	8.5	1.0	4.0	0.48	0.84	0.06	1.87	0.53
MB.C.31092	10.3	5.2	5.2	1.4	2.4	0.51	1.00	0.14	1.72	0.53
GPIT-PV-63905	12.2	5.8	6.8	1.6	3.6	0.48	0.85	0.13	2.01	0.47
MB.C.31094.3	8.2	4.6	3.7	2.2	2.4	0.55	1.24	0.26	1.98	0.35

Table 35. Conch ontogeny of *Stockumites convexus* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal to thinly pachyconic; subevolute to evolute (ww/dm = 0.55–0.65; uw/dm = 0.40–0.50)	moderately depressed; moderately to strongly embracing (ww/wh = 1.80–2.00; IZR = 0.25–0.35)	low to moderate (WER = 1.60–1.80)
5 mm	thickly discoidal; subevolute (ww/dm = 0.50–0.60; uw/dm = 0.30–0.40)	weakly depressed; strongly embracing (ww/wh = 1.35–1.50; IZR = 0.35–0.45)	low to moderate (WER = 1.60–1.80)
15 mm	thickly discoidal; involute (ww/dm = 0.45–0.55; uw/dm = 0.05–0.10)	weakly compressed; very strongly embracing (ww/wh = 0.80–1.00; IZR = 0.45–0.55)	moderate to high (WER = 1.90–2.10)
25 mm	thickly discoidal; involute (ww/dm = 0.45–0.55; uw/dm = 0.00)	weakly compressed; very strongly embracing (ww/wh ~0.90; IZR = 0.50–0.55)	moderate to high (WER = 1.90–2.10)

the umbilicus is strikingly narrowed during the last volution by strong overlap of the dorsal flank area upon the umbilicus. Half a volution before the largest diameter, the uw/dm ratio is 0.17. The umbilical margin is rounded and the flanks converge only slowly towards the broadly rounded venter; the coiling rate is high (WER = 2.08). Almost the entire specimen is covered by shell. This shows delicate growth lines, which extend with a very low and wide projection across the flank and in the ventrolateral area turn back to form a shallow ventral sinus. The shell surface bears some weak constrictions following the course of the growth lines. These constrictions begin in the inner flank area and are deepest in the ventrolateral area.

A series of cross sections demonstrates the modification of the conch from the widely umbilicate, serpenticonic juvenile stage to the discoidal subadult stage (Fig. 40A-G). In the middle growth stage, the flanks are almost parallel; the whorl profile is widest in the middle of the convex curved flanks. The ww/dm ratio is almost constant up to a conch diameter of 30 mm (Fig. 40I). The morphological variation is particularly evident in the coiling rate. This is caused by the transformation of the serpenticonic into the disc-shaped conch at slightly different conch diameters (Fig. 40K).

Remarks

Stockumites convexus is one of the species of the genus in which the transformation of the serpenticonic juvenile stage to the involute, discoidal middle stage occurs only at a comparatively large conch diameter of about 10 mm dm. Of the species from the Rhenish Mountains, only *S. antecedens* is comparable in this respect, although with an even later onset of change (at 15 mm dm).

Stockumites convexus differs from the co-occurring species *S. subbilobatus* by the growth lines extending convexly across the flanks, which are either almost straight or slightly biconvex in *S. subbilobatus*.

Stockumites antecedens (Vöhringer, 1960) comb. nov.

Fig. 41; Tables 36–37

Imitoceras prorsum antecedens Vöhringer, 1960: 140, pl. 2 fig. 6, text-fig. 18.

Acutimitoceras prorsum antecedens – Kullmann 1983: 234, text-fig. 2b.
Acutimitoceras antecedens – Becker 1988: 205, pl. 2 figs 14–15. — Korn 1994: 42, text-figs 49d, 50c–d, 52b, 54e. — Kullmann 2000: text-fig. 4j.
Acutimitoceras (*Stockumites*) *antecedens* – Sprey 2002: 52, pl. 3 fig 6, text-fig. 17g. — Kullmann 2009: text-fig. 3.5.

Diagnosis

Species of *Stockumites* with a conch reaching 40 mm diameter. Conch at 4 mm dm thinly discoidal, evolute (ww/dm ~0.35; uw/dm ~0.60); at 12 mm dm thickly discoidal, involute (ww/dm ~0.50; uw/dm ~0.10); at 20 mm dm thickly discoidal, subinvolute (ww/dm ~0.50; uw/dm ~0.20). Whorl profile at 20 mm dm weakly compressed (ww/wh ~0.90); coiling rate moderately high (WER ~1.95). Venter rounded, umbilical margin rounded. Growth lines fine, narrow-standing, with convex course. Without constrictions on the shell surface; without internal shell thickenings. Suture line with narrowly V-shaped external lobe and narrowly V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; illustrated by Vöhringer (1960, pl. 2 fig. 6) and Korn (1994, text-fig. 49d); re-illustrated here in Fig. 41A; GPIT-PV-63907.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63908 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63910.

Description

Holotype GPIT-PV-63907 is a rather small specimen with only 15 mm conch diameter (Fig. 41A). It is thickly discoidal with an open umbilicus (ww/dm = 0.50; uw/dm = 0.20). The whorl profile is slightly depressed (ww/wh = 1.09) with broadly rounded venter and flanks as well as a broadly rounded umbilical margin.

The ornament consists of fine growth lines running with a shallow convex curve across the flanks and forming a shallow ventral sinus (Fig. 41E). In the suture line, the external lobe and the adventive lobe are about the same width. However, their shape differs; the external lobe is lanceolate, while the adventive lobe is V-shaped (Fig. 41C).

The two cross sections of paratypes GPIT-PV-63910 and GPIT-PV-63908 are very similar in the very evolute inner whorls (Fig. 41B–C), but differ markedly in the growth phase above 4 mm diameter. Paratype GPIT-PV-63910, which comes from the type horizon (bed 5) shows a rapidly increasing coiling rate up to nearly 2.00 at 10 mm diameter, while paratype GPIT-PV-63908 has a much lower coiling rate that not even reaches a value of 1.75.

The growth trajectories of the parameters ww/dm and uw/dm demonstrate their considerable ontogenetic changes (Fig. 41F–H). Due to the very evolute juvenile stage, the uw/dm ratio can reach a value of almost 0.60; the whorl profile is crescent-shaped. The stronger overlap of the volutions starting at about 7 mm conch diameter leads to a whorl profile, which gradually changes into an almost circular and finally into a horseshoe-shaped outline.

Remarks

Stockumites antecedens has, with respect to its conch morphology, a marginal position within the genus. It is the species that retains the open umbilicus of the juvenile stage the longest in ontogeny; even at about 15 mm diameter the conch is not closed (ww/dm = 0.20), while the umbilicus is already more or less completely closed in most of the other species of the genus.

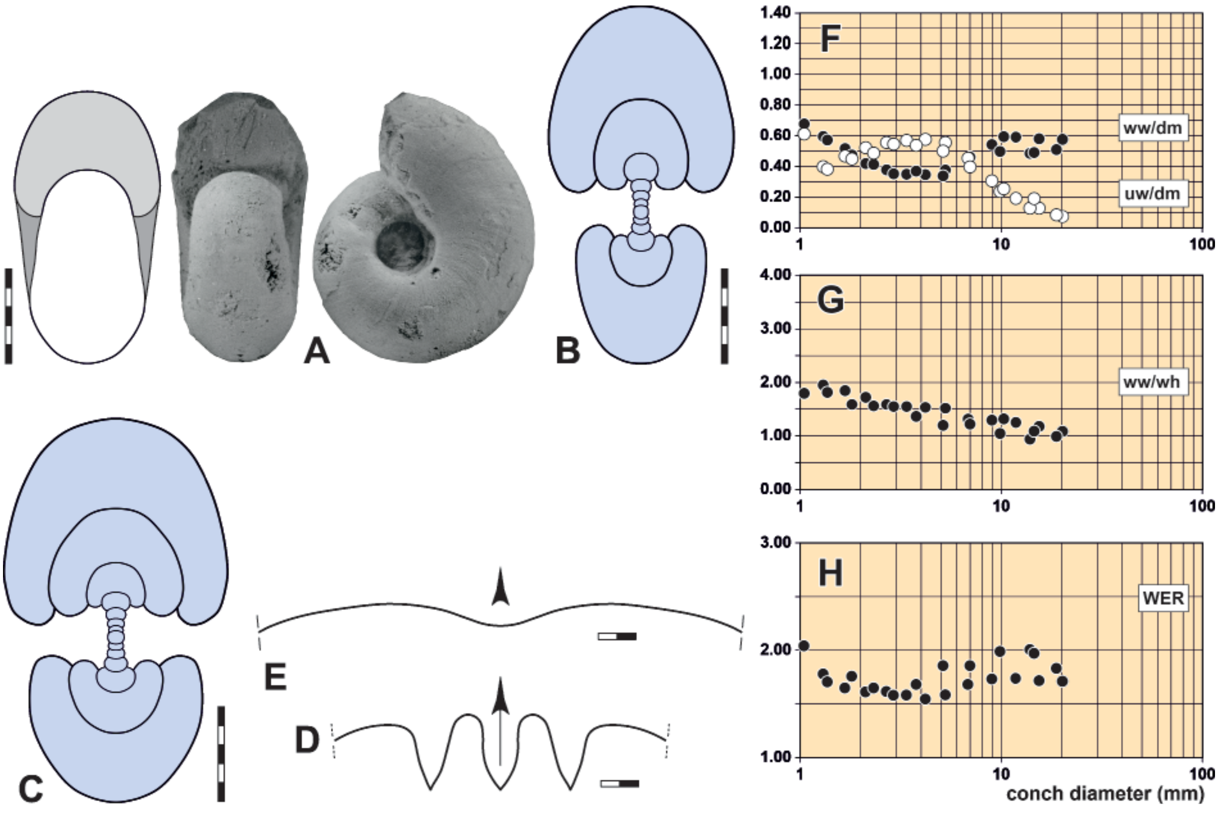

Fig. 41. *Stockumites antecedens* (Vöhringer, 1960) from the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Dorsal view reconstruction and photographs of holotype GPIT-PV-63907 from bed 5. **B**. Cross section of paratype GPIT-PV-63910 from bed 5. **C**. Cross section of paratype GPIT-PV-63908 from bed 3d. **D**. Suture line of paratype GPIT-PV-63910 from bed 5, at dm = 14.5 mm, ww = 7.7 mm, wh = 7.5 mm. **E**. Growth line course of holotype GPIT-PV-63907 from bed 5, at dm = 16.0 mm, ww = 9.0 mm, wh = 8.5 mm. **F–H**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 36. Conch measurements, ratios and rates of *Stockumites antecedens* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63908	20.2	11.8	10.9	1.7	4.8	0.58	1.09	0.08	1.71	0.56
GPIT-PV-63910	19.4	9.8	10.4	1.8	5.5	0.50	0.94	0.09	1.94	0.47
GPIT-PV-63907	14.6	7.3	6.7	2.9	4.2	0.50	1.09	0.20	1.97	0.37

Table 37. Conch ontogeny of *Stockumites antecedens* (Vöhringer, 1960) from Oberrödinghausen, bed 5.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	discoidal; evolute (ww/dm ~0.45; uw/dm ~0.50)	moderately depressed; moderately embracing (ww/wh ~1.70; IZR ~0.20)	low (WER ~1.60)
4 mm	thinly discoidal; evolute (ww/dm ~0.35; uw/dm ~0.60)	weakly depressed; moderately embracing (ww/wh ~1.40; IZR ~0.20)	low (WER ~1.70)
12 mm	thickly discoidal; subinvolute (ww/dm ~0.50; uw/dm ~0.20)	weakly compressed; strongly embracing (ww/wh ~0.95; IZR ~0.40)	moderate (WER ~1.95)
20 mm	thickly discoidal; involute (ww/dm ~0.50; uw/dm ~0.10)	weakly compressed; very strongly embracing (ww/wh ~0.90; IZR ~0.50)	moderate (WER ~1.95)

Stockumites prorsus also has an open umbilicus at comparable sizes; however, this species differs from *A. antecedens* by the coarse, biconvex growth lines. From the basal Carboniferous strata of the Anti-Atlas, the two species *S. saharae* and *S. endoserpens* are known (Ebbighausen & Bockwinkel 2007); both also have a very evolute juvenile conch, but close the umbilicus earlier in ontogeny than *S. antecedens*.

Stockumites voehringeri sp. nov.
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Figs 7C, 42–45; Tables 38–39

Imitoceras subbilobatum – Vöhringer 1960: 135, pl. 3 fig. 3.
Acutimitoceras subbilobatum – Korn 1994: 51, text-figs 44d–f, 47a, 53a–b, 58f.
Acutimitoceras (*Stockumites*) *subbilobatum* – Sprey 2002: pl. 4 fig. 2.
Acutimitoceras cf. *intermedium* – Korn & Weyer 2003: pl. 1 figs 1–2.
Rectimitoceras substriatum – Sprey 2002: pl. 3 fig. 2.

Diagnosis

Species of *Stockumites* with a conch reaching 70 mm diameter. Conch at 5 mm dm globular, subinvolute to subinvolute (ww/dm ~0.90; uw/dm ~0.20); at 15 mm dm thickly pachyconic, involute (ww/dm ~0.75; uw/dm ~0.05); at 30 mm dm thickly discoidal, involute (ww/dm = 0.50–0.60; uw/dm ~0.00). Whorl profile at 30 mm dm weakly compressed to weakly depressed (ww/wh = 0.90–1.10); coiling rate moderately high (WER = 1.80–1.95). Venter broadly rounded, umbilical margin rounded. Growth lines fine, wide-standing, with convex course. Without constrictions on the shell surface; with prominent internal shell thickenings on the outer flank and the venter. Suture line with lanceolate external lobe and V-shaped adventive lobe.

Etymology

Named after Eugen Vöhringer in appreciation of his monograph on the ammonoids of Oberrödinghausen.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 3 fig. 3a, as *Imitoceras subbilobatum*), Korn (1994: text-fig. 44e, as *Acutimitoceras subbilobatum*) and Sprey (2002: pl. 4 fig. 2, as *Acutimitoceras* (*Stockumites*) *subbilobatum*); re-illustrated here in Fig. 42A; GPIT-PV-63995.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63888, GPIT-PV-64005 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63883, GPIT-PV-63885 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63851 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-63850 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; GPIT-PV-63988 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; MB.C.31097 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; MB.C.31098.1–4 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; MB.C.31099.1–2 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; MB.C.31100.1–3 • 6 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material;

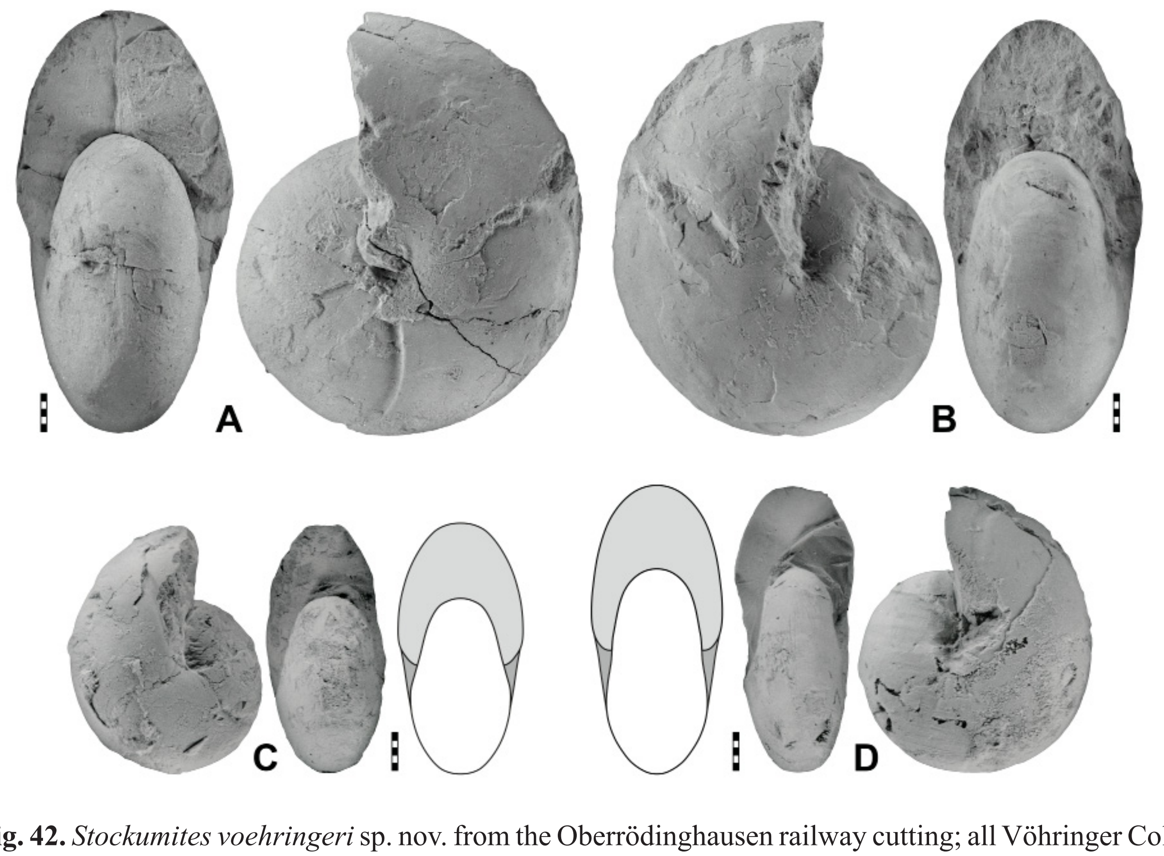

Fig. 42. *Stockumites voehringeri* sp. nov. from the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Holotype GPIT-PV-63995 from unknown bed. **B**. Paratype GPIT-PV-63885 from bed 3b. **C**. Paratype GPIT-PV-64005 from bed 2. **D**. Paratype GPIT-PV-63850 from bed 3e. Scale bar units = 1 mm.

Korn 1977 Coll.; MB.C.31101.1–6 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1982 Coll.; MB.C.31102 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1990 Coll.; MB.C.31103.1–3 • 6 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Korn 1991 Coll.; MB.C.31104.1–6 • 1 specimen; Rhenish Mountains, Oberrödinghausen, west of railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31105 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31106.1–3 • 7 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31107.1–7 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c1; Weyer 1993–1994 Coll.; MB.C.31108.1–5 • 7 specimens; Rhenish

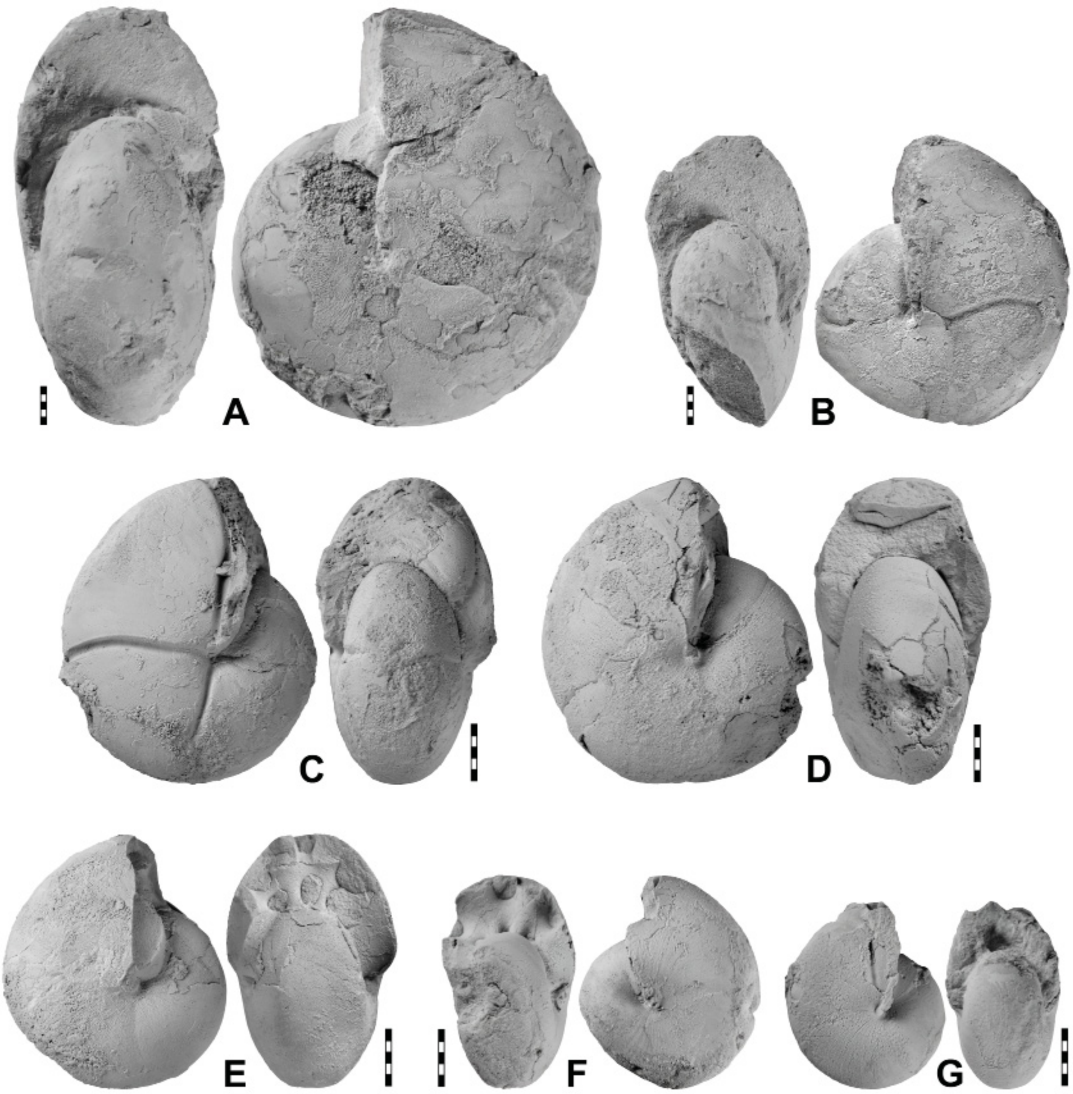

Fig. 43. *Stockumites voehringeri* sp. nov. from the Oberrödinghausen railway cutting. **A**. Paratype MB.C.31107.1 (Weyer 1993–1994 Coll.) from bed 3b. **B**. Paratype MB.C.31111.1 (Weyer 1993–1994 Coll.) from bed 3d2b. **C**. Paratype MB.C.31101.1 (Korn 1977 Coll.) from unknown bed. **D**. Paratype MB.C.31101.2 (Korn 1977 Coll.) from unknown bed. **E**. Paratype MB.C.31105 (Korn 1977 Coll.) from unknown bed. **F**. Paratype MB.C.31109.1 (Weyer 1993–1994 Coll.) from bed 3d1. **G**. Paratype MB.C.31110.1 (Weyer 1993–1994 Coll.) from bed 3d1b. Scale bar units = 1 mm.

Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.31109.1–7 • 8 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31110.1–8 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31111.1–3 • 8 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31112.1–8 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 3d; Korn & Weyer 2000 Coll.; MB.C.31113 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 45; Weyer 1993–1994 Coll.; MB.C.5234.1 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 46; Weyer 1993–1994 Coll.; MB.C.5235.1 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval V; Paproth Coll.; MB.C.5274.

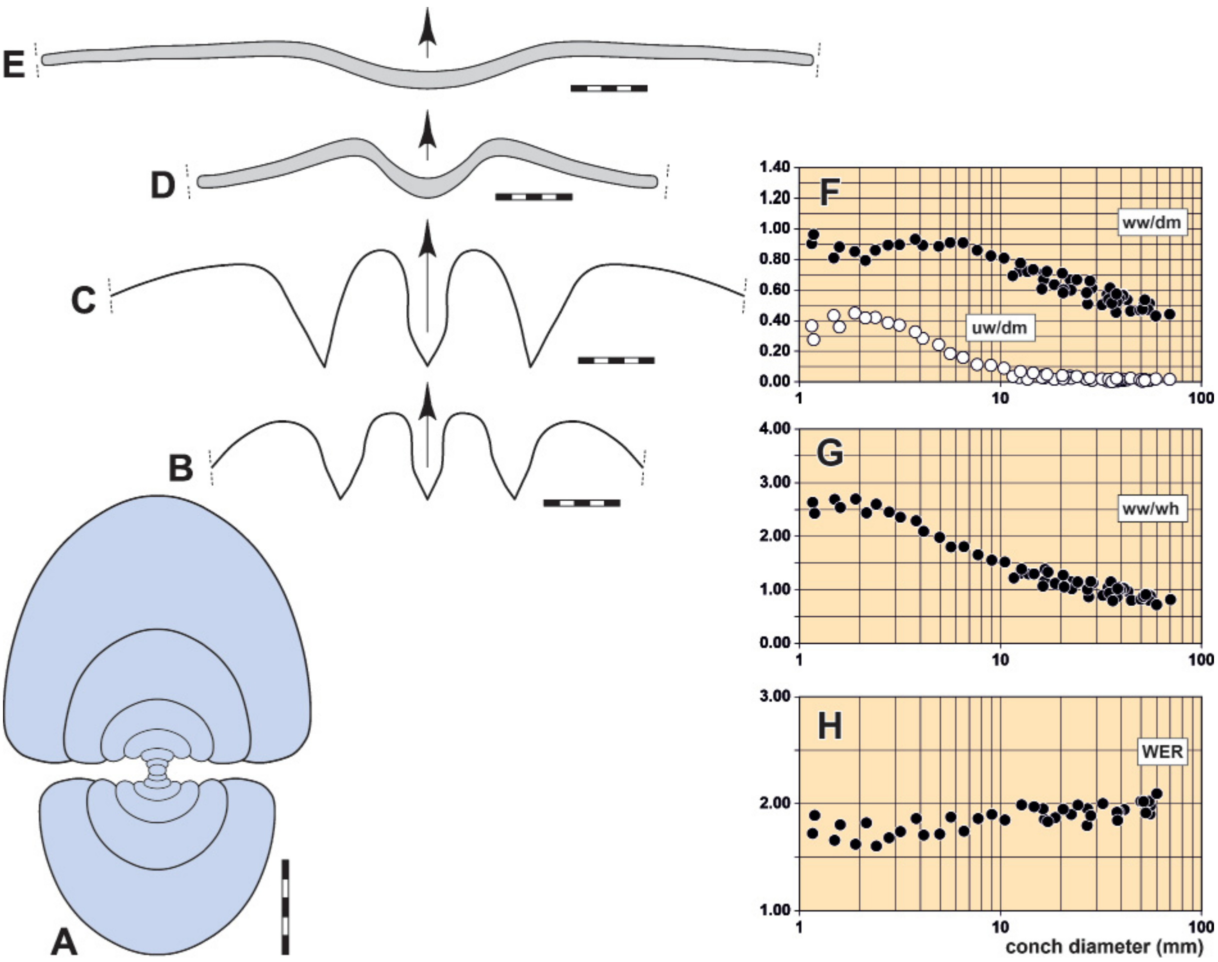

Fig. 44. *Stockumites voehringeri* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype MB.C.31111.2 (Weyer 1993–1994 Coll.) from bed 3d2. **B**. Suture line of paratype MB.C.31111.3 (Weyer 1993–1994 Coll.) from bed 3d2, at dm = 20.0 mm, ww = 13.1 mm, wh = 12.6 mm. **C**. Suture line of paratype GPIT-PV-63885 (Vöhringer Coll.) from bed 3b, at ww = 20.5 mm, wh = 17.5 mm. **D**. Course of the internal shell thickenings of paratype GPIT-PV-63850 (Vöhringer Coll.) from bed 3e, at dm = 34.0 mm, ww = 17.0 mm, wh = 21.5 mm. **E**. Course of the internal shell thickenings of holotype GPIT-PV-63995 (Vöhringer Coll.) from unknown bed of Oberrödinghausen, at dm = 40.0 mm, ww = 20.5 mm, wh = 22.0 mm. **F–H**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Description

Holotype GPIT-PV-63995 is an almost complete, rather well preserved specimen with a diameter of 56 mm (Fig. 42A). It is thickly discoidal (ww/dm = 0.51) with a completely closed umbilicus. The whorl profile is widest in the immediate vicinity of the rounded umbilical margin, from where the flanks converge strongly towards the comparatively narrowly rounded venter. The whorl expansion rate almost reaches the value of 2.00. Areas of the specimen are covered with shell remains; these show fine growth lines, which extend almost straight across the flank and form a sinus on the venter. The internal mould bears several wide and rather deep constrictions, which are produced by prominent radial internal shell thickenings. They are largely parallel to the growth lines (Fig. 44E).

The suture lines of the two paratypes MB.C.31111.3 (Fig. 44B) and GPIT-PV-63885 (Fig. 44C) closely resemble each other. Both show a lanceolate external lobe and a V-shaped adventive lobe.

Two complete cross sections are available for study; paratype MB.C.31111.2 (24 mm dm; Fig. 44A) and paratype MB.C.31099.1 (53 mm dm; Fig. 45A) show almost identical section images in juvenile and middle growth stages. Both show the transformation of the short widely umbilicate initial stage (up

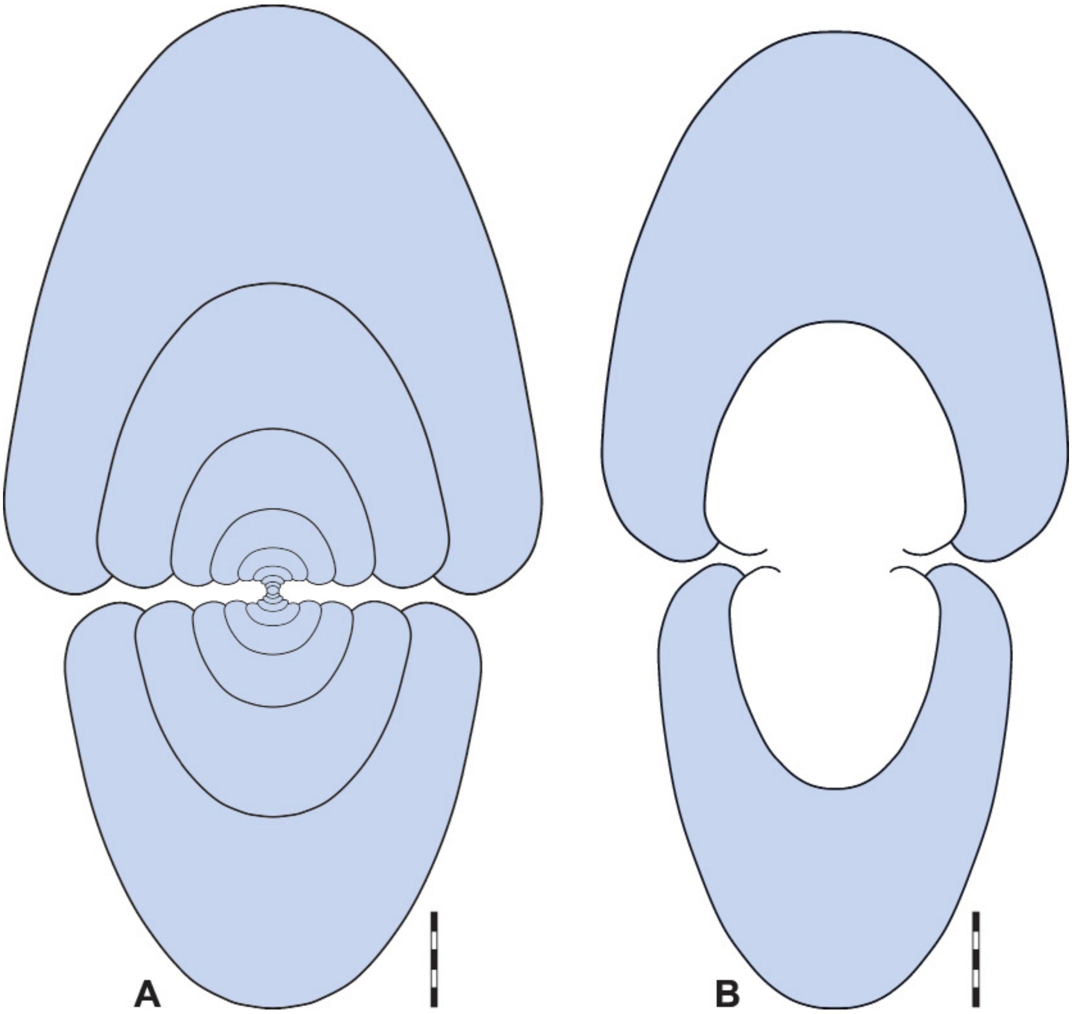

Fig. 45. *Stockumites voehringeri* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype MB.C.31099.1 (Vöhringer Coll.) from bed 4. **B**. Cross section of paratype MB.C.31112.1 (Weyer 1993–1994 Coll.) from bed 3e. Scale bar units = 1 mm.

Table 38. Conch measurements, ratios and rates of *Stockumites voehringeri* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63883	67.9	31.4	37.9	0.50	19.90	0.46	0.83	0.01	2.00	0.47
GPIT-PV-63995	55.9	28.6	32.3	0.5	16.2	0.51	0.89	0.01	1.98	0.50
MB.C.31107.1	55.7	27.8	30.5	0.5	15.3	0.50	0.91	0.01	1.90	0.50
GPIT-PV-63885	54.9	26.0	32.1	0.4	16.3	0.47	0.81	0.01	2.02	0.49
MB.C.31112.1	51.6	24.5	28.0	0.2	15.3	0.48	0.88	0.00	2.02	0.45
MB.C.31101.3	50.1	23.5	28.5	0.6	14.9	0.47	0.82	0.01	2.02	0.48
GPIT-PV-63888	43.3	20.2	23.5	0.3	11.9	0.47	0.86	0.01	1.90	0.49
MB.C.31112.3	41.4	22.4	21.6	0.3	11.7	0.54	1.04	0.01	1.94	0.46
MB.C.31111.1	38.8	22.1	21.0	0.2	10.8	0.57	1.05	0.01	1.92	0.49
GPIT-PV-63850	38.1	17.3	20.1	0.6	10.6	0.45	0.86	0.02	1.92	0.47
GPIT-PV-64005	32.4	16.3	18.2	0.6	9.5	0.50	0.90	0.02	2.00	0.48
MB.C.31101.1	27.1	15.8	15.6	0.5	7.7	0.58	1.01	0.02	1.95	0.51
MB.C.31101.2	27.0	15.5	15.3	0.5	6.9	0.58	1.02	0.02	1.80	0.55
MB.C.31105	22.5	15.0	13.0	0.8	6.2	0.67	1.15	0.04	1.90	0.52
MB.C.31109.1	18.8	11.9	10.6	0.3	5.0	0.63	1.12	0.02	1.87	0.52
MB.C.31110.1	16.6	11.1	9.5	0.4	4.4	0.67	1.16	0.02	1.85	0.54
MB.C.31109.2	16.3	9.9	9.2	0.5	4.6	0.61	1.07	0.03	1.95	0.50

Table 39. Conch ontogeny of *Stockumites voehringeri* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subevolute (ww/dm ~0.80; uw/dm ~0.42)	strongly depressed; strongly embracing (ww/wh ~2.50; IZR ~0.35)	moderate (WER ~1.80)
5 mm	thinly globular; subinvolute (ww/dm ~0.90; uw/dm ~0.25)	strongly depressed; very strongly embracing (ww/wh ~2.00; IZR ~0.45)	moderate (WER ~1.80)
15 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.30; IZR ~0.55)	moderate (WER ~1.95)
30 mm	thickly discoidal; involute (ww/dm = 0.50–0.60; uw/dm ~0.00)	weakly compressed to weakly depressed; very strongly embracing (ww/wh = 0.90–1.10; IZR ~0.50)	moderate (WER = 1.80–1.95)
50 mm	thickly discoidal; involute (ww/dm = 0.45–0.55; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh = 0.80–0.90; IZR ~0.50)	Moderate to high (WER = 1.90–2.05)

to 2.5 mm dm) to the stout late juvenile stage between 4 and 7 mm conch diameter, where the conch is almost spherical (ww/dm = 0.90). Thereafter, there is a rapid increase in whorl height; at the same time, the flanks become significantly more convergent.

The intraspecific variation is rather low (Fig. 44F–H) and seems to increase in the middle and adult stages. However, this effect in the diagrams is possibly caused by the large number of specimens from this size class, while only two very similar specimens allow the study of juvenile morphology.

Remarks

Specimens of the new species *Stockumites voehringeri* sp. nov. were included in *S. subbilobatus* by (Vöhringer 1960) and (Korn 1994). The two species differ in the shape of the conch and the ornament of the shell. *Stockumites voehringeri* has convergent flanks, but they are almost parallel or only slightly convergent in *S. subbilobatus*. In addition, *S. voehringeri* only has very weak shell constrictions in the juvenile stage, while *S. subbilobatus* has distinct shell constrictions. In this feature, *S. voehringeri* also differs from *S. intermedius*, which has no constrictions.

Stockumites exilis (Vöhringer, 1960) comb. nov.

Figs 46–47; Tables 40–41

Imitoceras liratum exile Vöhringer, 1960: 126, pl. 2 fig. 3, text-fig. 6.

Acutimitoceras exile – Korn 1994: 45, text-figs 46c–d, 50h, 52d, 54b–c.

Diagnosis

Species of *Stockumites* with a conch reaching 40 mm diameter. Conch at 4 mm dm thinly pachyconic, subinvolute (ww/dm ~0.65; uw/dm ~0.15); at 12 mm dm thickly discoidal, involute (ww/dm ~0.55; uw/dm ~0.05); at 20 mm dm thickly discoidal, involute (ww/dm ~0.55; uw/dm ~0.03). Whorl profile at 20 mm dm weakly compressed (ww/wh ~0.85); coiling rate moderately high (WER ~1.80). Venter rounded, umbilical margin rounded. Growth lines fine, wide-standing, with convex course. Moderately deep constrictions on the shell surface; weak internal shell thickenings. Suture line with lanceolate external lobe and V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; illustrated by Vöhringer (1960, pl. 2 fig. 3) and Korn (1994, text-fig. 46d); re-illustrated here in Fig. 46A; GPIT-PV-63868.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63870, GPIT-PV-64019 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-64018, GPIT-PV-64021 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63933.

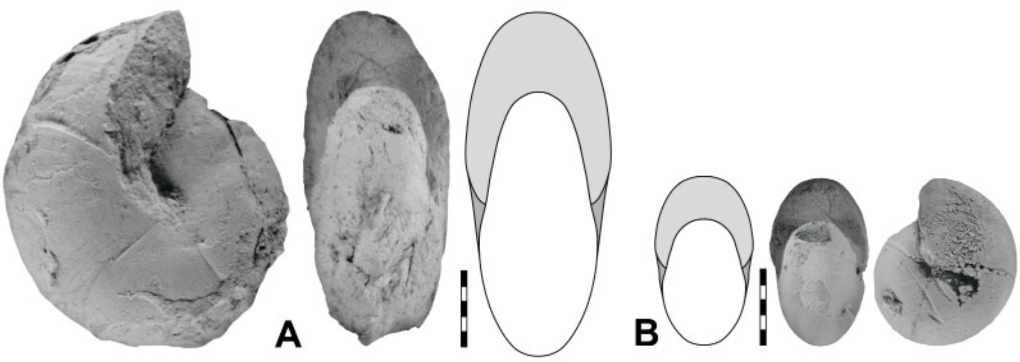

Fig. 46. *Stockumites exilis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Holotype GPIT-PV-63868 from bed 4. **B**. Paratype GPIT-PV-64021 from bed 3c. Scale bar units = 1 mm.

Table 40. Conch measurements, ratios and rates of *Stockumites exilis* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63868	22.1	9.9	11.7	0.7	5.3	0.45	0.85	0.03	1.73	0.55
GPIT-PV-63870	11.1	6.6	5.7	0.5	2.8	0.59	1.16	0.05	1.79	0.51
GPIT-PV-63933	8.5	5.5	4.6	0.0	2.3	0.65	1.20	0.00	1.87	0.50

Description

Holotype GPIT-PV-63868 is a moderately well-preserved specimen with 22 mm conch diameter (Fig. 46A). It has a discoidal shape (ww/dm = 0.45) with a closed umbilicus, a compressed whorl profile (wh/dm = 0.85) and a low coiling rate (WER = 1.73). The shell surface is preserved on the last half whorl and shows fine, widely spaced growth lines. These extend almost straight across the flank and bend backwards in the ventrolateral area to form a ventral sinus. Parallel to the growth lines, distinct shell constrictions are arranged at intervals of less than 90 degrees (Fig. 47D). These constrictions vary in depth.

The suture line of paratype GPIT-PV-64018 has a V-shaped external lobe, a rather narrow, narrowly rounded ventrolateral saddle and a V-shaped adventive lobe (Fig. 47B). The latter is slightly wider than the external lobe and has slightly convexly curved flanks.

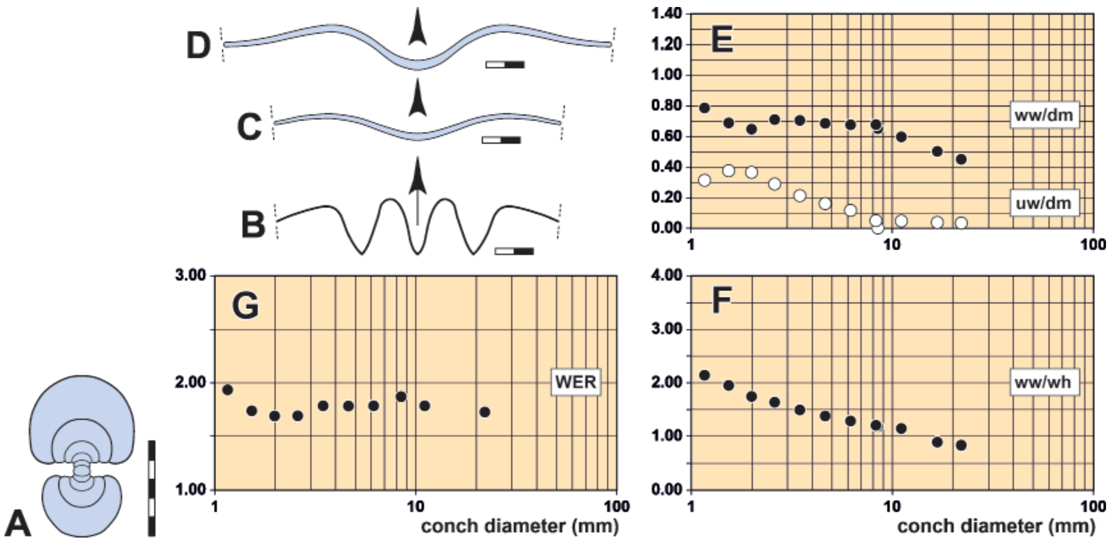

Fig. 47. *Stockumites exilis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63933 from bed 3d. **B**. Suture line of paratype GPIT-PV-64018 from bed 3c, at dm = 13.0 mm, ww = 8.1 mm, wh = 7.3 mm. **C**. Constriction course of paratype GPIT-PV-64018 from bed 3c, at dm = 9.5 mm, ww = 6.0 mm, wh = 5.5 mm. **D**. Constriction course of holotype GPIT-PV-63868 from bed 4, at dm = 15.6 mm, ww = 9.2 mm, wh = 8.3 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 41. Conch ontogeny of *Stockumites exilis* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.75; IZR ~0.35)	low (WER ~1.70)
4 mm	thinly pachyconic; subinvolute (ww/dm ~0.65; uw/dm ~0.15)	weakly depressed; very strongly embracing (ww/wh ~1.45; IZR ~0.50)	moderate (WER ~1.80)
12 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.05; IZR ~0.50)	moderate (WER ~1.80)
20 mm	discoidal; involute (ww/dm ~0.45; uw/dm ~0.03)	weakly compressed; very strongly embracing (ww/wh ~0.85; IZR ~0.50)	moderate (WER ~1.80)

Remarks

Stockumites exilis belongs to the species of the genus with a small conch. The species is distinguished from most other species by its very slender conch. The combination of these features with the distinct shell constrictions, which are absent in many of the species of *Stockumites*, is important to characterise this species.

Stockumites similis (Vöhringer, 1960) comb. nov.
Figs 48–49; Tables 42–43

Imitoceras liratum simile Vöhringer, 1960: 127, pl. 2 fig. 4, text-fig. 7.

Prionoceras (*Imitoceras*) *liratum simile* – Weyer 1965: 446, pl. 8 figs 1–2.
Acutimitoceras simile – Korn 1994: 49, text-figs 46a–b, 47d, 50g, 54a.

non *Imitoceras* (*Imitoceras*) *simile* – Ruan 1981: 75, pl. 16 figs 10–12.

Diagnosis

Species of *Stockumites* with a conch reaching 40 mm diameter. Conch at 5 mm dm thickly pachyconic, involute (ww/dm ~0.75; uw/dm ~0.10); at 15 mm dm thinly pachyconic, involute (ww/dm ~0.65; uw/dm ~0.00); at 30 mm dm thickly discoidal, involute (ww/dm ~0.55; uw/dm ~0.02). Whorl profile at 30 mm dm weakly depressed (ww/wh ~1.00); coiling rate moderately high (WER ~1.95). Venter broadly rounded, umbilical margin broadly rounded. Growth lines very fine, narrow-standing, with

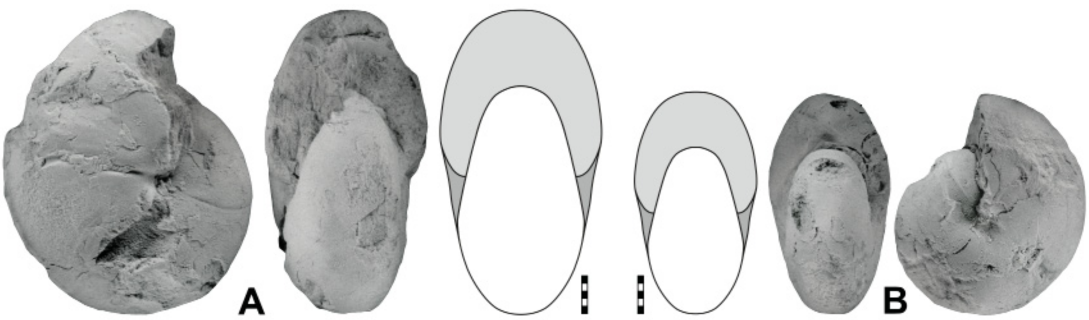

Fig. 48. *Stockumites similis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Paratype GPIT-PV-63874 from bed 1. **B**. Holotype GPIT-PV-63894 from bed 1. Scale bar units = 1 mm.

convex course. Weak constrictions on the shell surface; weak internal shell thickenings. Suture line with narrowly lanceolate external lobe and narrowly V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 2 fig. 4) and Korn (1994: text-fig. 46b); re-illustrated here in Fig. 48B; GPIT-PV-63894.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; GPIT-PV-63874, GPIT-PV-63878 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-63876.

Additional material

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31114.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2a; Weyer 1993–1994 Coll.; MB.C.31115 • 1 specimen;

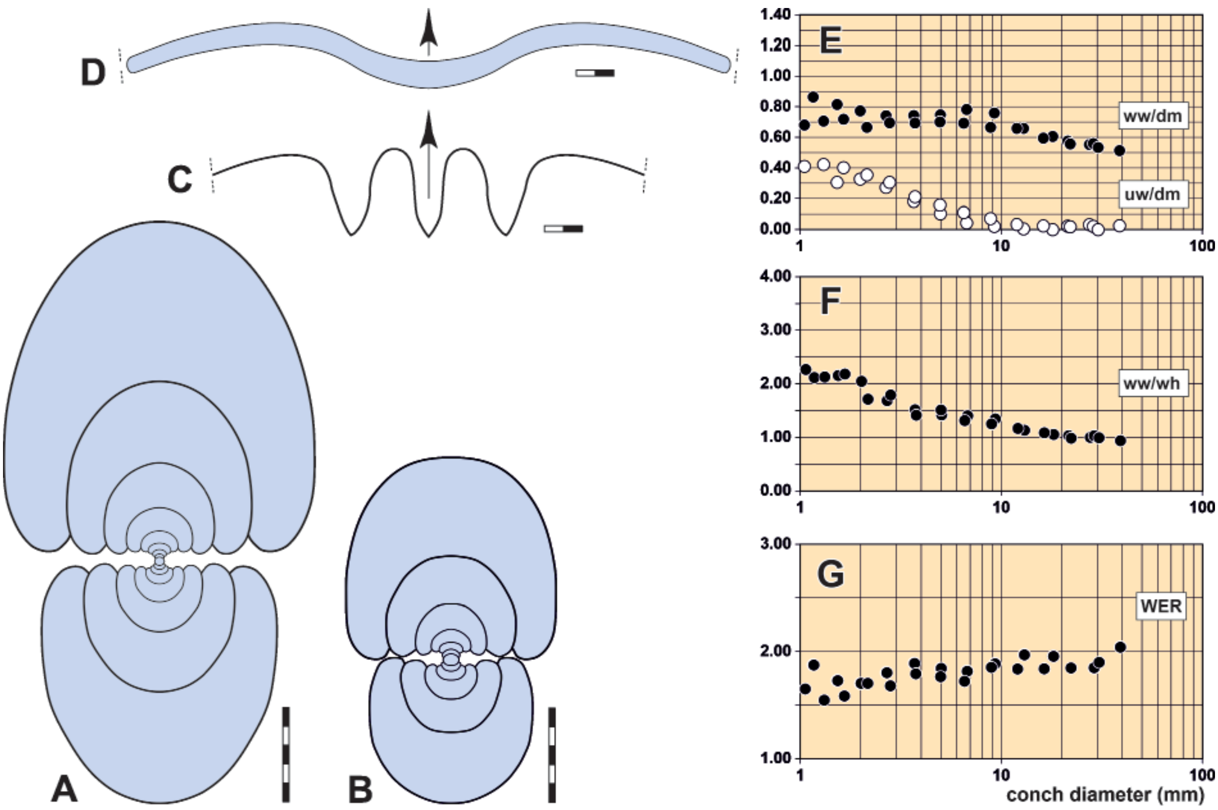

Fig. 49. *Stockumites similis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen MB.C.31115 (Weyer 1993–1994 Coll.) from bed 2a. **B**. Cross section of paratype GPIT-PV-63878 (Vöhringer Coll.) from bed 1. **C**. Suture line of paratype GPIT-PV-63876 (Vöhringer Coll.) from bed 3c, at ww = 12.2 mm, wh = 9.5 mm. **D**. Constriction course of holotype GPIT-PV-63894 (Vöhringer Coll.) from bed 1, at ww = 15.0 mm, wh = 13.0 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 42. Conch measurements, ratios and rates of *Stockumites similis* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63874	39.3	20.2	21.8	1.0	11.8	0.51	0.93	0.03	2.04	0.46
MB.C.31115	30.6	16,4	16.8	0.0	8.4	0.53	0.98	0.00	1.90	0.50
GPIT-PV-63894	29.1	16.3	16.0	0.6	7.7	0.56	1.02	0.02	1.85	0.52
GPIT-PV-63878	18.3	11.1	10.7	0.0	5.2	0.61	1.04	0.00	1.96	0.51

Table 43. Conch ontogeny of *Stockumites similis* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subevolute (ww/dm ~0.75; uw/dm ~0.35)	strongly depressed; strongly embracing (ww/wh ~2.05; IZR ~0.35)	low (WER ~1.70)
5 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.10)	weakly depressed; very strongly embracing (ww/wh ~1.40; IZR ~0.50)	moderate (WER ~1.85)
15 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.10; IZR ~0.50)	moderate (WER ~1.95)
30 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.00)	weakly depressed; very strongly embracing (ww/wh ~1.00; IZR ~0.50)	moderate (WER ~1.95)

Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2b; Weyer 1993–1994 Coll.; MB.C.31116 • 2 specimens; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 2; Korn 1977 Coll.; MB.C.31117.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 1; Korn & Weyer 2000 Coll.; MB.C.31118.

Description

Holotype GPIT-PV-63894 is a specimen with partially preserved shell, 29 mm in diameter (Fig. 48B). It is thickly discoidal (ww/dm = 0.56) with an almost completely closed umbilicus and a moderate coiling rate (WER = 1.85). The whorl profile is characterised by a broadly rounded venter that merges continuously into the broadly rounded flanks. The umbilical margin is also evenly rounded. The shell surface bears extremely fine growth lines extending with a convex arch across the flanks. Broad but shallow shell constrictions run parallel to the growth lines (Fig. 49D).

Paratype GPIT-PV-63874 with 39 mm conch diameter is more slender (ww/dm = 0.51) and has a higher coiling rate (WER = 2.04). This specimen has very fine growth lines and shell constrictions, which are additionally reinforced on the inner side of the shell and therefore cause deep constrictions of the internal mould (Fig. 48A). The suture line of paratype GPIT-PV-63876 shows a lanceolate external lobe with weakly divergent flanks. It is almost as wide as the narrowly rounded ventrolateral saddle and the V-shaped adventive lobe (Fig. 49C).

The cross sections of specimen MB.C.31115 and paratype GPIT-PV-63878 allow the study of conch ontogeny up to a diameter of 30 mm (Fig. 49A-B). The whorl profile is crescent-shaped up to about 2 mm in diameter; after that, a transformation into a C-shaped and finally horseshoe-shaped form takes place very quickly. Both cross sections show very similar trajectories; the difference in the early juvenile stage could be due to a non-central location of the section of paratype GPIT-PV-63878.

Remarks

Stockumites similis was introduced as a subspecies of the Late Devonian species "*Imitoceras liratum*" by Vöhringer (1960). However, apart from being prionoceratids, these two species share only the thickly discoidal to pachyconic conch with shell constrictions, while the inner whorls have a very dissimilar morphology. Furthermore, the adult conch has a very low aperture in *Mimimitoceras liratum*; the WER is only around 1.50 in contrast to 1.95 in *S. similis*.

Stockumites similis differs from *S. exilis* by the stouter conch; at 15 mm conch diameter, the ww/dm ratio is 0.65 for *S. similis*, but only 0.55 for *S. exilis*. In addition, the coiling rate is apparently higher in *S. similis* than in *S. exilis* (WER ~1.95 in *S. similis* but only ~1.75 in *S. exilis*).

Other species with shell constrictions are *S. convexus* and *S. parallelus* sp. nov. Both species are more slender at 15 mm conch diameter (ww/dm = 0.55). In addition, both bear distinctly coarser growth lines, which are weakly biconvex in *S. parallelus* in contrast to *S. similis*.

Stockumites depressus (Vöhringer, 1960) comb. nov.
Figs 50–51; Tables 44–45

Imitoceras depressum Vöhringer, 1960: 130, pl. 3 fig. 5, text-fig. 10.

Acutimitoceras depressum – Korn 1994: 43, text-figs 44i–j, 45d, f–g, 47c, 48e. — Ebbighausen & Bockwinkel 2007: 131, text-figs 12c–d, 13.

non *Imitoceras* (*Imitoceras*) *depressum* – Ruan 1981: 66, pl. 13 figs 10–11.

Diagnosis

Species of *Stockumites* with a conch reaching 50 mm diameter. Conch at 5 mm dm globular, subinvolute (ww/dm ~0.85–0.95; uw/dm = 0.15–0.25); at 15 mm dm pachyconic, involute (ww/dm = 0.70–0.80; uw/dm = 0.05–0.10); at 30 mm dm thinly pachyconic, involute (ww/dm ~0.70; uw/dm ~0.05). Whorl profile at 30 mm dm weakly depressed (ww/wh ~1.35); coiling rate moderately high (WER ~1.90). Venter broadly rounded, umbilical margin broadly rounded. Growth lines fine, wide-standing, with weakly biconvex course. Without constrictions on the shell surface; with weak internal shell thickenings. Suture line with narrowly lanceolate external lobe and V-shaped adventive lobe.

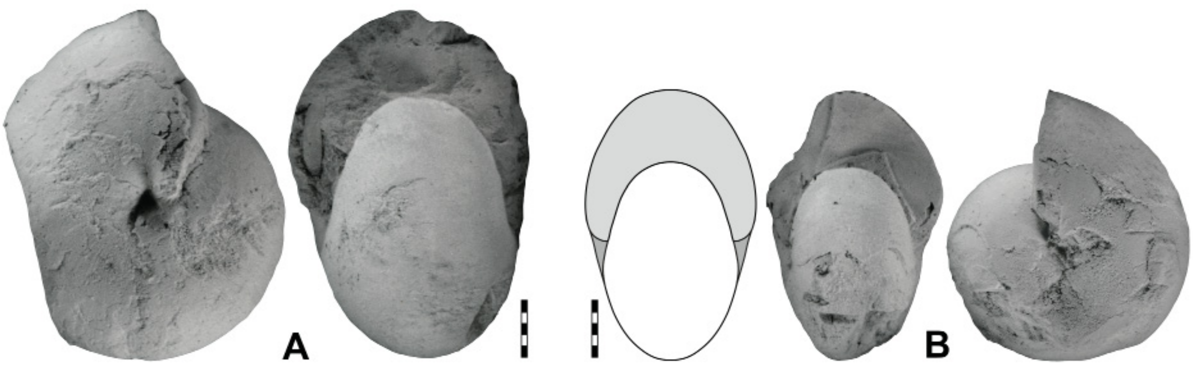

Fig. 50. *Stockumites depressus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Paratype GPIT-PV-63886 from bed 3b. **B**. Holotype GPIT-PV-63872 from bed 2. Scale bar units = 1 mm.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 3 fig. 5) and Korn (1994: text-fig. 44i); re-illustrated here in Fig. 50B; GPIT-PV-63872.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63887, GPIT-PV-63889 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63886.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31119 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; MB.C.31120.

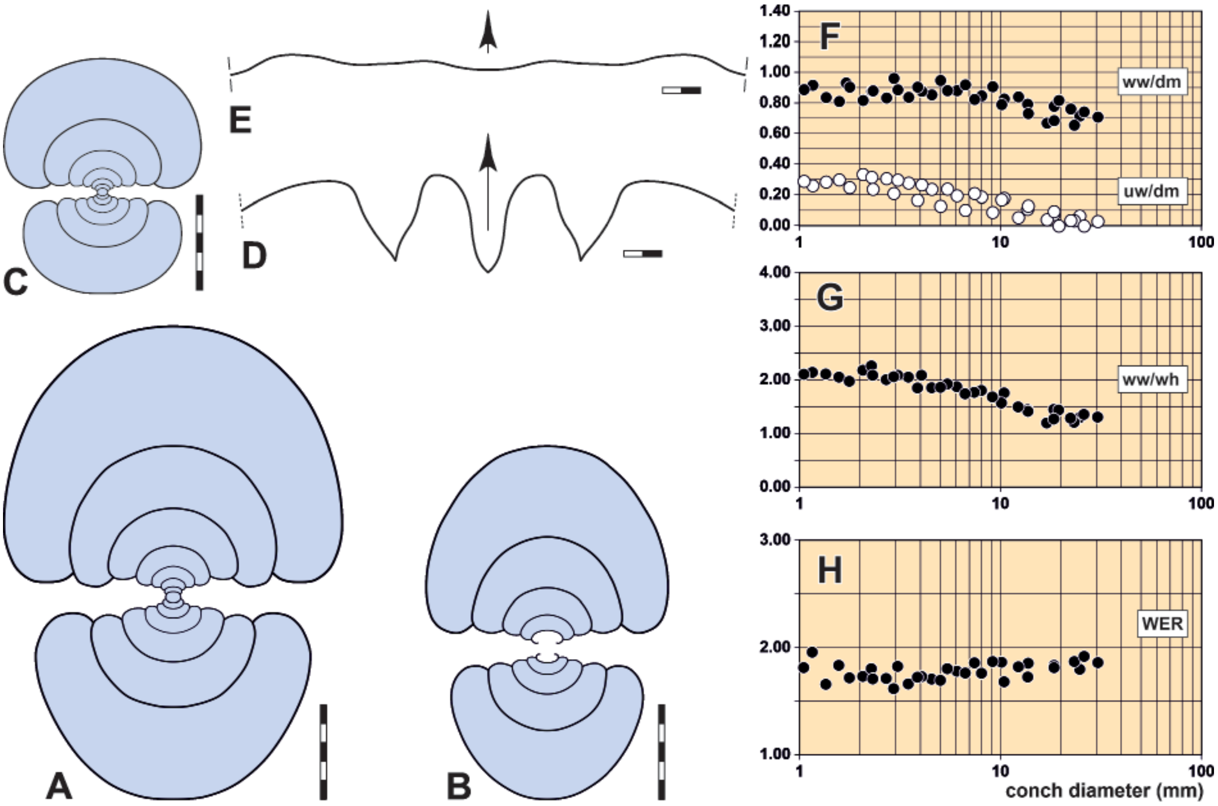

Fig. 51. *Stockumites depressus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. Cross section of paratype GPIT-PV-63889 from bed 2. **B**. Cross section of paratype GPIT-PV-63887 from bed 2. **C**. Cross section of specimen MB.C.31119 from bed 2. **D**. Suture line of holotype GPIT-PV-63872 from bed 2, at dm = 23.0 mm, ww = 11.2 mm, wh = 7.5 mm. **E**. Growth line course of holotype GPIT-PV-63872 from bed 2, at dm = 23.0 mm, ww = 11.2 mm, wh = 7.5 mm. **F–H**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 44. Conch measurements, ratios and rates of *Stockumites depressus* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63886	30.8	21.8	16.4	0.9	8.2	0.71	1.33	0.03	1.86	0.50
MB.C.31120	26.3	19.5	14.1	0.0	7.3	0.74	1.38	0.00	1.92	0.48
GPIT-PV-63889	25.0	17.9	13.5	1.6	6.3	0.71	1.32	0.07	1.79	0.53
GPIT-PV-63872	23.5	15.4	12.5	0.8	6.3	0.66	1.23	0.03	1.87	0.50
GPIT-PV-63887	18.7	12.8	9.9	1.8	4.8	0.69	1.30	0.09	1.81	0.51
MB.C.31119	12.4	10.4	6.8	0.7	3.2	0.84	1.52	0.05	1.82	0.53

Table 45. Conch ontogeny of *Stockumites depressus* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic to globular; subinvolute (ww/dm = 0.80–0.90; uw/dm = 0.25–0.30)	strongly depressed; strongly embracing (ww/wh ~2.10; IZR = 0.30–0.40)	low (WER ~1.70)
5 mm	globular; subinvolute (ww/dm = 0.85–0.95; uw/dm = 0.15–0.25)	moderately depressed; very strongly embracing (ww/wh ~1.95; IZR = 0.45–0.55)	low (WER ~1.70)
15 mm	pachyconic; involute (ww/dm = 0.70–0.80; uw/dm = 0.05–0.10)	weakly depressed; very strongly embracing (ww/wh ~1.45; IZR = 0.50–0.55)	moderate (WER ~1.80)
30 mm	thinly pachyconic; involute (ww/dm ~0.70; uw/dm ~0.05)	weakly depressed; very strongly embracing (ww/wh ~1.35; IZR = 0.50–0.55)	moderate (WER ~1.90)

Description

Holotype GPIT-PV-63872 with a diameter of 24 mm is the smaller of two rather well preserved specimens from the type series. It is thinly pachyconic (ww/dm = 0.67) with closed umbilicus and broadly arched flanks and venter (Fig. 50B). The coiling rate is moderately high (WER = 1.87). The shell surface bears fine growth lines that are weakly biconvex on the flank with a dorsolateral projection that is slightly higher than the ventrolateral projection (Fig. 51E). The ventral sinus is broad and shallow. The suture line has a narrow V-shaped external lobe, a somewhat asymmetrical, narrowly rounded ventrolateral saddle and a V-shaped adventive lobe (Fig. 51D).

The larger paratype GPIT-PV-63886 with a conch diameter of 31 mm has a somewhat stouter conch shape (ww/dm = 0.71) compared to the holotype. This specimen also has very fine, slightly biconvex growth lines and like in the holotype, shell constrictions and internal shell thickenings are absent (Fig. 50A).

The three cross sections shown (Fig. 51A–C) demonstrate the rather large variation within the species. The growth trajectories show only minor ontogenetic changes; up to a conch diameter of 10 mm, growth is even almost isometric. Only thereafter, the ww/dm ratio (and thus the ww/wh ratio) shows a decrease. However, the umbilicus begins to close at about 4 mm conch diameter.

Remarks

Stockumites depressus has a conch form most similar to that of *S. intermedius*. However, *S. depressus* has a rather narrowly rounded umbilical margin, which is clearly different from the very broadly rounded umbilical margin of *S. intermedius*. The inner whorls are less widely umbilicate in *S. depressus* when compared to *S. intermedius*. The growth lines are clearly different; they are fine and with a biconvex course in *S. depressus* but lamellar and convex in *S. intermedius*. Other species of *Stockumites* have either a stouter (*S. kleinerae*) or more slender conch (most of the other species of the genus).

Stockumites marocensis sp. nov.
urn:lsid:zoobank.org:act:A143D72A-BF03-46B2-B337-F2FD600C598F
Tables 46–47

Acutimitoceras intermedium – Belka *et al*. 1999: pl. 5 figs 7–8. — Korn 1999: 166, pl. 2 fig. 8. — Bockwinkel & Ebbighausen 2006: 97, text-figs 13–14. — Ebbighausen & Bockwinkel 2007: 131, text-figs 8f–g, 10, 12a–b. — Korn & Feist 2007: 106, text-fig. 6b–c, h.
Stockumites intermedius – Becker *et al*. 2002: pl. 2 figs 13–14.

Diagnosis

Species of *Stockumites* with a thickly pachyconic and subinvolute conch at 5 mm dm (ww/dm = 0.75–0.85; uw/dm = 0.15–0.25) and a pachyconic and involute conch at 15 mm dm (ww/dm = 0.65–0.75; uw/dm = 0.00–0.10). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.20); coiling rate moderate to high (WER = 1.90–2.15). Venter broadly rounded throughout ontogeny, umbilical margin broadly rounded. Prominent internal shell thickenings with weakly biconvex course in the preadult stage. Suture line with lanceolate external lobe and symmetric, V-shaped adventive lobe with gently curved flanks.

Etymology

Named after Morocco, where the material comes from.

Material examined

Holotype

MOROCCO • Anti-Atlas, Bou Tlidat near Fezzou, bed 2; Ebbighausen & Bockwinkel Coll.; illustrated by Ebbighausen & Bockwinkel (2007: text-fig. 8g); MB.C.10155.1.

Paratypes

MOROCCO • 263 specimens; Anti-Atlas, Bou Tlidat near Fezzou, bed 2; Ebbighausen & Bockwinkel Coll.; MB.C.10155.2–MB.C.10155.264 • 14 specimens; Anti-Atlas, Tazoult near Fezzou, bed 2; Ebbighausen & Bockwinkel Coll.; MB.C.10193.1–MB.C.10193.14 • 26 specimens; Anti-Atlas, Tazoult near Fezzou, float material; Ebbighausen & Bockwinkel Coll.; MB.C.10206.1.1–MB.C.10206-26 • 4 specimens; Anti-Atlas, Rich el Mbidia near Fezzou, bed 2; Ebbighausen & Bockwinkel Coll.; MB.C.10171.1–MB.C.10171.4 • 4 specimens; Anti-Atlas, Tizi Ibaouâne near Fezzou, bed 2; Ebbighausen & Bockwinkel Coll.; MB.C.10216.1–MB.C.10216.4 • 4 specimens; Anti-Atlas, Tizi Malilane near Fezzou, bed 2; Ebbighausen & Bockwinkel Coll.; MB.C.10239.1–MB.C.10239.4 • 16 specimens; Anti-Atlas, Mfis near Taouz, bed 1c; Bockwinkel & Ebbighausen Coll.; MB.C.3807.1–16 • 5 specimens; Anti-Atlas, Mfis near Taouz, bed 2; Bockwinkel & Ebbighausen Coll.; MB.C.3813.1–5.

Description

The species newly named here has been described in detail by Bockwinkel & Ebbighausen (2006) and Ebbighausen & Bockwinkel (2007), hence reference can be made here to those articles.

Table 46. Conch measurements, ratios and rates of *Stockumites marocensis* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.3807.3	20.32	13.69	11.81	0.36	5.96	0.67	1.16	0.02	2.00	0.50
MB.C.10206.1	19.18	13.26	11.21	0.34	5.26	0.69	1.18	0.02	1.90	0.53
MB.C.10193.1	19.14	13.25	10.31	0.67	5.58	0.69	1.29	0.04	1.99	0.46
MB.C.10155.4	15.66	10.44	8.91	0.82	4.95	0.67	1.17	0.05	2.14	0.44
MB.C.10155.1	14.80	10.51	8.33	0.85	4.23	0.71	1.26	0.06	1.96	0.49
MB.C.10216.1	13.68	9.25	7.80	0.52	3.84	0.68	1.19	0.04	1.93	0.51
MB.C.10155.2	11.05	8.38	5.63	0.89	3.08	0.76	1.49	0.08	1.92	0.45

Table 47. Conch ontogeny of *Stockumites marocensis* sp. nov.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subevolute (ww/dm = 0.75–0.85; uw/dm = 0.30–0.40)	strongly depressed; strongly embracing (ww/wh ~2.35; IZR ~0.40)	low (WER ~1.55)
5 mm	thickly pachyconic; subinvolute (ww/dm = 0.75–0.85; uw/dm = 0.15–0.25)	moderately depressed; very strongly embracing (ww/wh = 1.80–2.00; IZR ~0.50)	low (WER = 1.60–1.75)
15 mm	pachyconic; involute (ww/dm = 0.65–0.75; uw/dm = 0.00–0.10)	weakly depressed; very strongly embracing (ww/wh ~1.20; IZR ~0.50)	moderate to high (WER ~1.90–2.15)

Remarks

The material described here as the new species *Stockumites marocensis* sp. nov. was originally attributed to *Acutimitoceras intermedium* by several authors. In fact, both species have a very similar stout conch shape and even resemble each other in the shape of the umbilicus with a broadly rounded umbilical margin. However, there are considerable differences in the ontogenetic development of the conch; the ontogeny of *S. marocensis* is accelerated. This means that the umbilicus closes earlier than in *S. intermedius*. For example, the uw/dm ratio falls below the value of 0.20 already between 4 and 6 mm conch diameter, whereas in *S. intermedius* from bed 5 of Oberrödinghausen this is the case only above 10 mm diameter. Specimens of *S. intermedius* from bed 6 are similar in closure of the umbilicus to specimens of *S. marocensis*, but the latter has an accelerated increase in coiling rate.

Genus ***Acutimitoceras*** Librovitch, 1957

Type species

Imitoceras acutum Schindewolf, 1923: 333; original designation.

Genus diagnosis

Genus of the Acutimitoceratinae with a discoidal, lenticular conch with low to high coiling rate (WER = 1.70–2.20); inner whorls subevolute or evolute. Venter narrowly rounded or oxyconic with an attached ventral keel. Ornament with biconvex growth lines, shell with constrictions. Suture line with deep and broad, V-shaped external lobe (as deep as the adventive lobe).

Genus composition

Central Europe (Schindewolf 1923): *Imitoceras acutum* (Schindewolf, 1923); *Acutimitoceras ucatum* sp. nov.; *Acutimitoceras paracutum* sp. nov.

South China (Sun & Shen 1965): *Imitoceras wangyuense* Sun & Shen, 1965.

Remarks

Acutimitoceras was established by Librovitch (1957) for prionoceratids with a sharpened venter. The genus was subsequently not considered further but was revived and broadened by Korn (1981, 1984) to include those early Tournaisian prionoceratid species that differ from the genus *Mimimitoceras* by more widely umbilicate inner whorls. However, this definition also includes species that are now placed in other genera (e.g., *Stockumites*, *Nicimitoceras*, *Hasselbachia*).

Acutimitoceras was then restricted to the oxyconic forms by Becker (1996), who established the subgenus *Stockumites* for those forms with a rounded venter throughout ontogeny. This concept was either not supported (e.g., Korn & Klug 2002; Korn & Weyer 2003; Korn 2006; Korn & Feist 2007) or accepted on the condition that *Stockumites* remains only a subgenus of *Acutimitoceras* (Kullmann 2009). However, a closer examination of the material from the various regions (Rhenish Mountains, Upper Franconia, Thuringia, Guizhou) shows that the acute venter is not the only character to distinguish *Acutimitoceras* from *Stockumites* (Korn & Weyer 2023). An additional good distinguishing character is the attached keel, which gives the external side a galeate profile in cross-section even when the venter is not acute. Therefore, *Acutimitoceras* is reduced here to the forms with these two characters and the genus *Stockumites* is accepted for the forms without an attached keel.

Acutimitoceras ucatum sp. nov.
urn:lsid:zoobank.org:act:93EC6766-E4CB-4811-A919-79F87CF41BAE
Figs 52–53; Tables 48–49

Aganides acutus – Schmidt 1925: 534, pl. 19 fig. 5.
Imitoceras acutum – Vöhringer 1960: 137, pl. 1 fig. 7, text-fig. 16.
Acutimitoceras acutum – Korn 1994: 42, text-figs 49j–k, 50b, 51a, 53c–d, 56h, 57a.
Acutimitoceras acutum acutum – Bartzsch & Weyer 1996: 95, text-fig. 1.
Acutimitoceras (*Acutimitoceras*) *acutum* – Becker 1996: 36.

Diagnosis

Species of *Acutimitoceras* with thickly discoidal and subinvolute conch at 6 mm dm (ww/dm ~0.50; uw/dm ~0.25), thinly discoidal and involute conch at 12 mm dm (ww/dm ~0.40; uw/dm ~0.12) and thinly discoidal and involute conch at 24 mm dm (ww/dm ~0.35; umbilicus closed). Whorl cross section at 24 mm dm compressed (ww/wh ~0.60); coiling rate high (WER ~2.10). Venter subacute at 8 mm dm and acute at 15 mm dm. Lamellar growth lines with slightly biconvex course. Weak shell constrictions; they largely follow the course of the growth lines.

Etymology

An anagram of acutum, referring to the close resemblance of the two species.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; illustrated by Korn (1994: text-fig. 49k); re-illustrated here in Fig. 52B; GPIT-PV-63900.

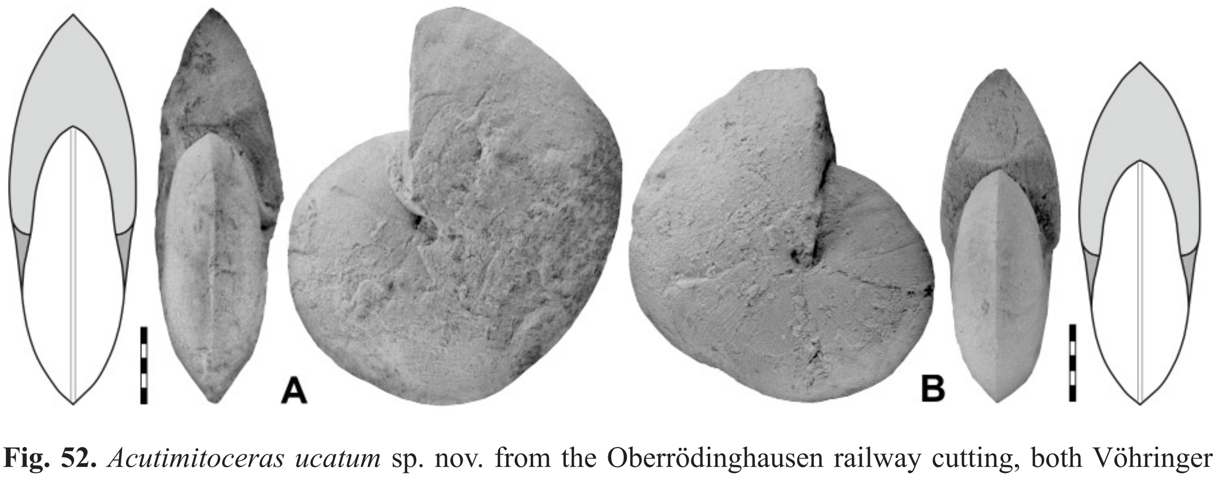

Fig. 52. *Acutimitoceras ucatum* sp. nov. from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Paratype GPIT-PV-63899 from bed 5. **B**. Holotype GPIT-PV-63900 from bed 6. Scale bar units = 1 mm.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; GPIT-PV-63901, GPIT-PV-63902 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; GPIT-PV-63899 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; MB.C.31121.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; MB.C.31122 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; MB.C.31123 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6a; Weyer 1993–1994 Coll.; MB.C.31124 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6b2; Weyer 1993–1994 Coll.; MB.C.31125 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 10; Becker 1988 Coll.; MB.C.3374.

Description

Holotype GPIT-PV-63900 is the better preserved of the two illustrated specimens collected by Vöhringer (1960). It has a conch diameter of 22 mm and is widely covered with shell remains (Fig. 52B). The conch has the shape of a discus (ww/dm = 0.35) and the umbilicus is almost completely closed. The whorl profile shows convex flanks, which are almost parallel in the dorsolateral region and, in the ventrolateral region, converge rapidly towards the acute venter. An attached keel supports the sharpening of the venter.

The shell surface of the holotype shows lamellar, regularly spaced growth lines with a weakly biconvex course (Fig. 53C). Both lateral projections are low and the ventral sinus is very shallow. Very weak shell constrictions extend parallel to the growth lines.

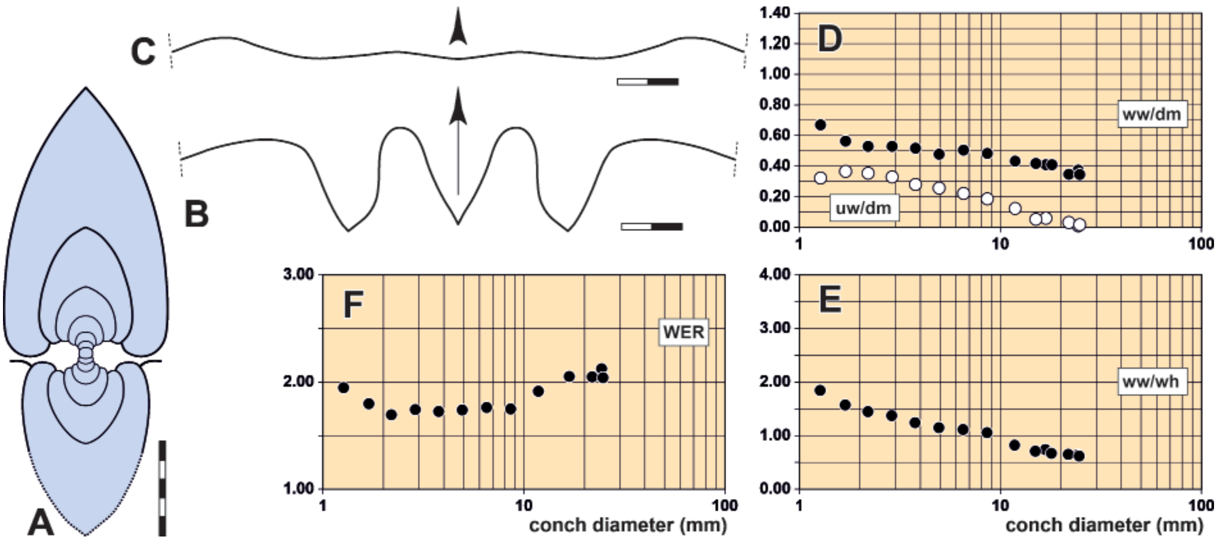

Fig. 53. *Acutimitoceras ucatum* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63902 from bed 6. **B**. Suture line of paratype GPIT-PV-63899 from bed 5, at ww = 7.2 mm, wh = 8.5 mm. **C**. Growth line course of holotype GPIT-PV-63900 from bed 6, at ww = 7.3 mm, wh = 8.8 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 48. Conch measurements, ratios and rates of *Acutimitoceras ucatum* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63899	25.1	8.7	14.3	0.5	7.5	0.34	0.60	0.02	2.03	0.48
GPIT-PV-63902	24.7	9.2	14.8	0.3	7.7	0.37	0.62	0.01	2.11	0.48
GPIT-PV-63900	22.2	7.7	12.1	0.8	6.6	0.35	0.63	0.04	2.04	0.45

Table 49. Conch ontogeny of *Acutimitoceras ucatum* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; subevolute (ww/dm ~0.55; uw/dm ~0.35)	weakly depressed; strongly embracing (ww/wh ~1.45; IZR ~0.35)	low (WER ~1.70)
5 mm	thickly discoidal; subinvolute (ww/dm ~0.50; uw/dm ~0.28)	weakly depressed; strongly embracing (ww/wh ~1.15; IZR ~0.35)	low (WER ~1.70)
15 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.05)	weakly compressed; very strongly embracing (ww/wh ~0.70; IZR ~0.50)	moderate (WER ~1.95)
25 mm	thinly discoidal; involute (ww/dm ~0.35; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.60; IZR ~0.50)	high (WER ~2.05)

Paratype GPIT-PV-63899 has a 25 mm conch diameter and is very similar to the holotype in its conch proportions and also in its shell ornament (Fig. 52A). In this specimen, too, the umbilicus is not yet completely closed. The suture line has a wide, V-shaped external lobe with nearly straight flanks, a rounded ventrolateral saddle and an asymmetric adventive lobe. This is pointed at its base and possesses a strongly convex ventral flank and a weakly convex dorsal flank (Fig. 53B).

The sectioned paratype GPIT-PV-63902 allows the study of its conch ontogeny up to a diameter of 24 mm (Fig. 53A). There are very noticeable changes in conch geometry; the whorl profile begins kidney-shaped in the early juvenile stage, followed by an almost circular profile, which changes to a galeate and finally oxyconic shape with increasing whorl height. The coiling rate shows an almost continuous increase during ontogeny. Between 2 and 3 mm conch diameter it is only about 1.70 and gradually increases to a maximum value of WER = 2.11 at 25 mm diameter.

Remarks

For the separation of *Acutimitoceras ucatum* sp. nov. and *A. acutum*, cross-sections of the conchs are best suited. Paratype GPIT-PV-63902 (with the penultimate half of the whorl reconstructed by interpolation) and a cross-section of a paratype of "*A. acutum oxynotum*" (= *A. acutum*) from Saalfeld show especially the differences in the shape of the flanks. While the flanks are convex in *A. ucatum*, they are flattened and more strongly convergent in *A. acutum*. The growth diagrams show that *A. acutum* and *A. ucatum* hardly differ in the ontogenetic courses. The two species can also be separated by the strength of the growth lines, which are rather coarse in *A. ucatum* but very delicate in *A. acutum*.

Acutimitoceras paracutum sp. nov.

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Fig. 54; Table 50

Diagnosis

Species of *Acutimitoceras* with a thinly discoidal and involute adult stage at 20 mm dm (ww/dm ~0.40; uw/dm ~0.12). Whorl cross section at 20 mm dm compressed (ww/wh ~0.75); coiling rate low (WER ~1.70). Venter narrowly rounded at 10 mm dm and subacute at 20 mm dm. Lamellar growth lines with slightly biconvex course. Weak constrictions on the shell surface; they stand in distances of about 75 degrees and largely follow the course of the growth-lines.

Etymology

Named because of the morphological similarity to *Acutimitoceras acutum*.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6a; Weyer 1993–1994 Coll.; illustrated in Fig. 54B; MB.C.31127.

Paratype

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6a; Korn 1989 Coll.; MB.C.31126.

Description

Holotype MB.C.31127 has a conch diameter of 20 mm and is a well-preserved specimen (Fig. 54B). It is discus-shaped and involute (ww/dm = 0.40; uw/dm = 0.12) and possesses a whorl profile with a rounded umbilical margin, from where the convex flanks converge towards the subacute venter. The ww/wh ratio is 0.77 and the coiling rate is low (WER = 1.72). The last whorl of the specimen is increasingly overlapping upon the umbilicus; therefore, the uw/dm ratio has a value of 0.17 at about 15.5 mm conch diameter.

The entire specimen is covered with shell, which possesses nearly equidistant lamellar growth lines, five of which are counted on one millimetre on the outer flank. They have a weakly biconvex course with a low dorsolateral projection in some distance from the umbilicus on the inner flank, a very shallow lateral sinus, a low ventrolateral projection and a shallow, broadly V-shaped but closely rounded ventral sinus. The specimen has five shell constrictions, which are almost regularly spaced. They are slightly oblique in their course so that they cross the growth lines at a very acute angle.

Paratype MB.C.31126 has 24 mm conch diameter and corresponds to the holotype with regard to conch geometry (Fig. 54A). However, the umbilicus is almost closed in this specimen. The shape of the venter is subacute with an attached keel. The shell bears widespread, lamellar growth lines running across the keel and four constrictions at 90-degree intervals.

Fig. 54. *Acutimitoceras paracutum* sp. nov. from the Oberrödinghausen railway cutting. **A**. Paratype MB.C.31126 (Korn 1989 Coll.) from bed 6a. **B**. Holotype MB.C.31127 (Weyer 1993–1994 Coll.) from bed 6a. Scale bar units = 1 mm.

Table 50. Conch measurements, ratios and rates of *Acutimitoceras paracutum* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31126	24.4	8.7	14.0	0.5	5.7	0.36	0.62	0.02	1.70	0.59
MB.C.31127	20.4	8.2	10.6	2.4	4.8	0.40	0.77	0.12	1.72	0.55

Remarks

Acutimitoceras paracutum sp. nov. differs from the other species of the genus by the low coiling rate and the rapid closure of the umbilicus at a large conch diameter. While the holotype of *A. paracutum* has a whorl expansion rate of only ~1.72 at 20 mm conch diameter, the other species of *Acutimitoceras* show a much higher value (normally above 2.00). The similar *A. acutum*, for instance, shows a much more rapid coiling (WER ~2.05) at the same growth stage. The second difference to *A. acutum* is the wider umbilicus in *A. paracutum* (uw/dm ~0.12 at 20 mm dm in *A. paracutum* but only about ~0.05 in *A. acutum*).

Genus ***Costimitoceras*** Vöhringer, 1960

Type species

Costimitoceras ornatum Vöhringer, 1960: 148; original designation.

Genus diagnosis

Genus of the Acutimitoceratinae with a discoidal conch and moderately high to high coiling rate (WER = 1.90–2.20); inner whorls evolute. Ornament with biconvex growth lines and spiral lines. Suture line with deep external lobe.

Genus composition

Central Europe (Vöhringer 1960): *Costimitoceras ornatum* Vöhringer, 1960.

North Africa (Ebbighausen & Bockwinkel 2007): *Costimitoceras aitouamar* Ebbighausen & Bockwinkel, 2007.

South China (Ruan 1981): *Imitoceras* (*Costimitoceras*) *epichare* Ruan, 1981.

Remarks

Costimitoceras can be easily distinguished from all other prionoceratids due to the very striking combination of coarse growth lines and spiral lines.

Costimitoceras ornatum Vöhringer, 1960
Figs 55–56; Tables 51–52

Costimitoceras ornatum Vöhringer, 1960: 148, pl. 1 fig. 8, text-fig. 25.

Costimitoceras ornatum – Korn 1994: 53, text-figs 61a–b, 62a–b, 63d, 71a

Diagnosis

Species of *Costimitoceras* with a conch reaching 40 mm diameter. Conch thickly discoidal, subevolute at 5 mm dm (ww/dm ~0.55; uw/dm ~0.35); thickly discoidal, involute at 15 mm dm (ww/dm ~0.50; uw/dm ~0.05); thinly discoidal, involute at 25 mm dm (ww/dm ~0.40; uw/dm = 0.00). Whorl profile at

25 mm dm weakly compressed (ww/wh ~0.70); coiling rate high (WER ~2.10). Venter broadly rounded in the early and subadult stage, narrowly rounded in the adult stage. Growth lines coarse with biconvex course, coarse spiral lines. Without constrictions on the shell surface; without internal shell thickenings. Suture line with lanceolate external lobe and symmetric, V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 1 fig. 8) and Korn (1994: text-fig. 61a); re-illustrated here in Fig. 55A; GPIT-PV-63918.

Paratype

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63920 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-63922.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31128.

Description

Holotype GPIT-PV-63918 is a rather well-preserved specimen with 28 mm conch diameter (Fig. 55A). It has the shape of a thick lens (ww/dm ~0.40) with a closed umbilicus and a narrowly rounded venter. The coiling rate is high (WER ~2.10). The very conspicuous ornament consists of a combination of coarse, biconvex growth lines with a rather high dorsolateral projection (Fig. 56D) and a deep ventral sinus and almost equally coarse spiral lines, which are coarsest especially in the ventrolateral region. The suture line shows a lanceolate external lobe and a V-shaped adventive lobe with the same depth (Fig. 56B).

The smaller paratype GPIT-PV-63920 with 13 mm conch diameter is slightly stouter (ww/dm = 0.50) than the holotype and has a slightly open umbilicus (Fig. 55B). A distinct reticulate ornamentation is also developed in this specimen, but the spiral lines are restricted to the flank. The course of the sharp growth lines is concavo-convex, i.e. without a dorsolateral projection (Fig. 56C).

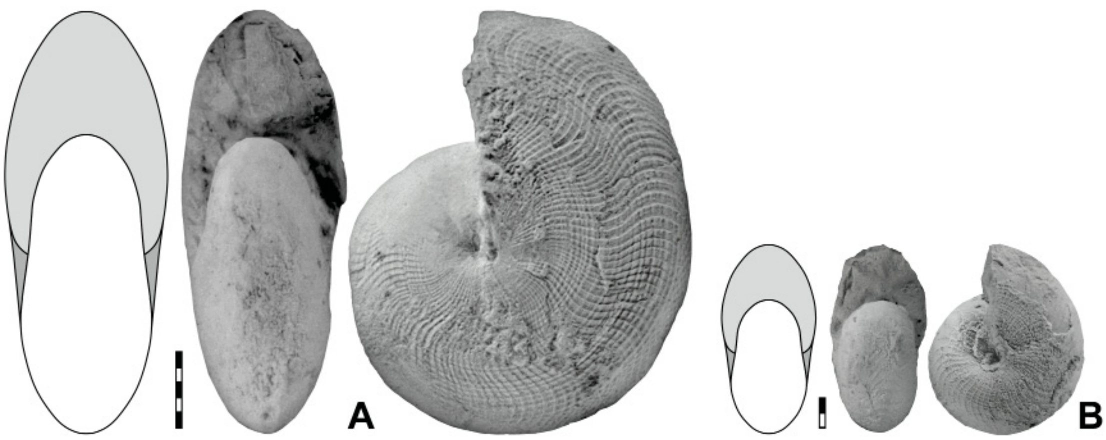

Fig. 55. *Costimitoceras ornatum* Vöhringer, 1960 from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Holotype GPIT-PV-63918 from bed 3e. **B**. Paratype GPIT-PV-63920 from bed 3d. Scale bar units = 1 mm.

Table 51. Conch measurements, ratios and rates of *Costimitoceras ornatum* Vöhringer, 1960 from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63918	27.9	10.9	15.9	0.0	8.7	0.39	0.69	0.00	2.11	0.45
GPIT-PV-63920	12.9	6.5	7.2	1.0	3.6	0.50	0.91	0.08	1.93	0.50

Table 52. Conch ontogeny of *Costimitoceras ornatum* Vöhringer, 1960 from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
5 mm	thickly discoidal; subevolute (ww/dm ~0.55; uw/dm ~0.35)	weakly depressed; strongly embracing (ww/wh ~1.40; IZR ~0.35)	moderate (WER ~1.75)
15 mm	thickly discoidal; involute (ww/dm ~0.50; uw/dm ~0.05)	weakly compressed; very strongly embracing (ww/wh ~0.90; IZR ~0.50)	moderate (WER ~1.95)
25 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.70; IZR ~0.45)	high (WER ~2.10)

Remarks

Costimitoceras ornatum apparently does not differ from *C. epichare* in the shape of the conch as well as the ornamentation. Both species are only distinguished by the suture line, which has a lanceolate external lobe in *C. ornatum*, but which is V-shaped in *C. epichare*.

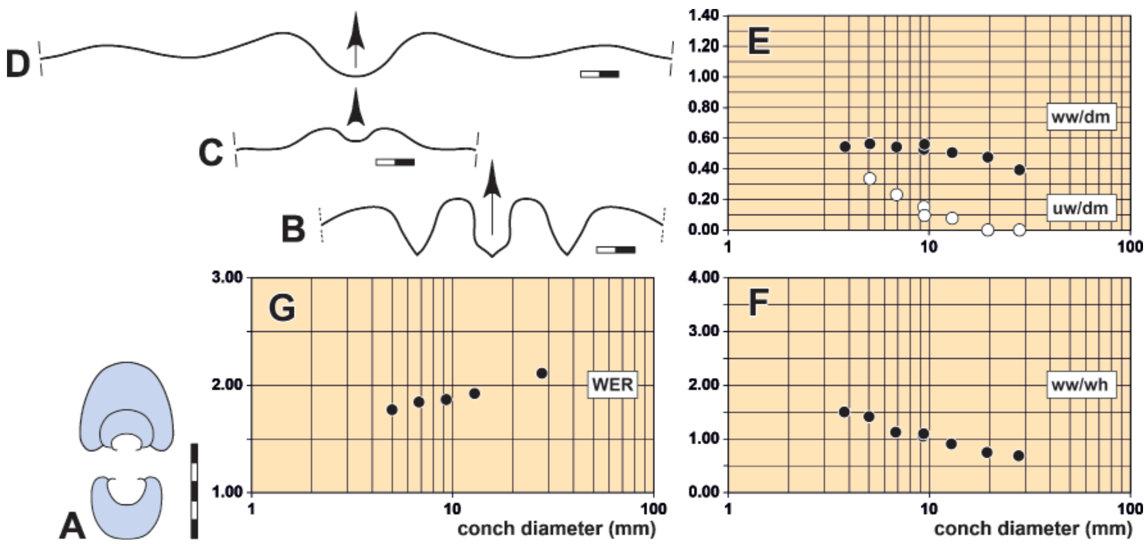

Fig. 56. *Costimitoceras ornatum* Vöhringer, 1960 from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63922 from bed 3e. **B**. Suture line of holotype GPIT-PV-63918 from bed 3e, at ww = 7.7 mm, wh = 8.5 mm. **C**. Growth line course of paratype GPIT-PV-63920 from bed 3d, at dm = 10.5 mm, ww = 5.5 mm, wh = 5.5 mm. **D**. Growth line course of holotype GPIT-PV-63918 from bed 3e, at dm = 28.0 mm, ww = 11.5 mm, wh = 15.5 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Genus ***Nicimitoceras*** Korn, 1993

Type species

Imitoceras subacre Vöhringer, 1960: 120; original designation.

Genus diagnosis

Genus of the Acutimitoceratinae with a discoidal conch with moderately high to high coiling rate (WER = 1.90–2.20); inner whorls subinvolute to evolute to variable degree. Ornament with convex or slightly biconvex growth lines. Suture line with short, V-shaped or lanceolate external lobe (0.50 to 0.75 depth of the adventive lobe).

Genus composition

Central Europe (Schmidt 1924; Vöhringer 1960; Korn 1984): *Aganides carinatus* Schmidt, 1924; *Imitoceras trochiforme* Vöhringer, 1960; *Imitoceras subacre* Vöhringer, 1960; *Imitoceras acre* Vöhringer, 1960; *Imitoceras heterolobatum* Vöhringer, 1960; *Acutimitoceras caesari* Korn, 1984.

North Africa (Bockwinkel & Ebbighausen 2006): *Acutimitoceras mfisense* Bockwinkel & Ebbighausen, 2006.

Remarks

Vöhringer (1960) placed his three new species "*Imitoceras. trochiforme*", "*I. subacre*" and "*I. acre*" in the species group of "*Imitoceras lineare*", which was putatively characterised by a conch that is involute in all growth stages and by the absence of shell constrictions. This concept can no longer be followed for several reasons:

(1) "*Imitoceras lineare*" from the Late Devonian is a species of the genus *Mimimitoceras* and possesses shell constrictions in the juvenile and middle growth stage (Korn 1994). The species has hardly any features in common with the three Early Carboniferous species and therefore cannot be considered closely related. *Mimimitoceras lineare* differs markedly in the low coiling rate (WER = 1.50) and the deep external lobe, which has the same depth when compared with the adventive lobe. Species of *Nicimitoceras* have a very characteristic, short external lobe.

(2) Vöhriger's assumption that the three species have a conch that is involute at all growth stages is apparently based on the cross section of specimen GPIT-PV-638645 (*N. trochiforme*). However, this cross section is off-centre and does not allow the study of the innermost whorls; there is no evidence for the assumption of involute whorls. In fact, other preparations show that the inner whorls are subinvolute or subevolute.

The following genera must be discussed in the context of *Nicimitoceras*:

Follimitoceras, introduced by Ruan (1995) as a subgenus of *Acutimitoceras* with the type species *Imitoceras* (*Imitoceras*) *folliforme* Ruan, 1981. – The subgenus was established for discoidal prionoceratid ammonoids with a deep, slightly pouched external lobe. The conch characters are very similar to *Nicimitoceras*, with which it shares the lenticular conch shape and the high coiling rate. However, *Follimitoceras* differs in the deeper, pouched external lobe. *Follimitoceras* should therefore be regarded as a valid, independent genus. Kullmann (2009) regarded *Follimitoceras*, with a question mark, as a synonym of *Zadelsdorfia.* Such an attribution as proposed by Kullmann is very unlikely because of the conch shape and the open umbilicus in the adult stage in *Zadelsdorfia*.

Acrimitoceras, also introduced by Ruan (1995) as a subgenus of *Acutimitoceras* with the type species *Imitoceras acre* Vöhringer, 1960. – The subgenus separates the acute end-member of an evolutionary lineage, not paying attention to the evolutionary lineage leading to it, i.e., possibly through *Nicimitoceras subacre*, the type species of *Nicimitoceras*. *Acrimitoceras* should therefore be regarded as synonym of *Nicimitoceras*.

Streeliceras, introduced by Becker (1996) as a subgenus of *Acutimitoceras* with the type species *Imitoceras heterolobatum* Vöhringer, 1960. – The subgenus was introduced for species that possess evolute inner whorls in combination with a short external lobe. Separation from *Nicimitoceras* was only justified by the higher number of evolute juvenile whorls. However, numerous studies of cross-sections of acutimitoceratin ammonoids have shown that the juvenile umbilical width changes gradually between species of the different groups. In contrast, the short external lobe is a very constant character of the acutimitoceratin ammonoids of the "*Gattendorfia* Stufe" and is always accompanied by lenticular conchs and high coiling rates. Therefore, "*Imitoceras heterolobatum*" does hardly fulfil the criteria for an own subgenus and is thus kept in *Nicimitoceras* here.

Nicimitoceras differs from *Stockumites* by the short external lobe and, in most cases, by the higher coiling rate (WER usually above 2.00, but usually below this value in *Stockumites*).

A genus with similar species is *Imitoceras*, but in the species of this genus the external lobe is pouched in contrast to *Nicimitoceras* with a lanceolate or V-shaped external lobe. In the stratigraphically earliest members of the genus this feature may still be weakly developed (Bockwinkel & Ebbighausen 2006), but the shape of the adventive lobe, the dorsal of which is curved inwards in *Imitoceras*, is another distinguishing criterion.

Nicimitoceras trochiforme (Vöhringer, 1960)
Figs 57–58; Tables 53–54

Imitoceras trochiforme Vöhringer, 1960: 119, pl. 1 fig. 4, text-fig. 1.

Imitoceras trochiforme – Bartzsch & Weyer 1982: 21.
Nicimitoceras trochiforme – Korn 1994: 59, text-figs 58a, 59a–b, 60a–b. — Sprey 2002: 52, pl. 4 fig. 8, text-fig. 17c.

non *Nicimitoceras trochiforme* – Bockwinkel & Ebbighausen 2006: 107, text-figs 23, 24a–b, e–f.

Diagnosis

Species of *Nicimitoceras* with a conch reaching 70 mm diameter. Conch thickly pachyconic, involute at 5 mm dm (ww/dm ~0.75; uw/dm ~0.10); thickly discoidal, involute at 15 mm dm (ww/dm ~0.55; uw/dm ~0.02); thinly discoidal, involute at 30 mm dm (ww/dm ~0.45; uw/dm = 0.00). Whorl profile at 30 mm dm weakly compressed (ww/wh ~0.85); coiling rate high (WER ~2.05). Venter broadly rounded in the early and subadult stage, narrowly rounded in the adult stage. Growth lines extremely fine, with convex course. Without constrictions on the shell surface; without internal shell thickenings. Suture line with lanceolate external lobe and twice as deep, asymmetric adventive lobe with steep ventral flank.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 1 fig. 4), Korn (1994: text-fig. 58a) and Sprey (2002: pl. 4 fig. 8); re-illustrated here in Fig. 57; GPIT-PV-63848.

Table 53. Conch measurements, ratios and rates of *Nicimitoceras trochiforme* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63848	56.2	20.6	33.1	0.0	15.3	0.37	0.62	0.00	1.89	0.54
MB.C.31129	25.9	12.5	15.1	0.6	8.4	0.48	0.83	0.02	2.19	0.45
GPIT-PV-63849	23.5	11.5	12.8	0.0	7.1	0.49	0.90	0.00	2.05	0.45
GPIT-PV-63851	22.9	11.8	13.3	0.4	7.1	0.51	0.89	0.02	2.10	0.47
GPIT-PV-63992	22.9	12.2	13.5	0.4	7.5	0.54	0.91	0.02	2.23	0.44
GPIT-PV-63869	19.1	9.4	11.0	0.2	5.8	0.49	0.86	0.01	2.06	0.47

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63849, GPIT-PV-63951 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63992.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31129.

Description

Holotype GPIT-PV-63848 is a rather complete but somewhat corroded specimen with 56 mm conch diameter (Fig. 57). It is a thinly discoidal conch (ww/dm = 0.37) with a closed umbilicus and a moderately high coiling rate (WER ~1.90). The whorls are widest in the area of the inner flank near the umbilicus; from there the broadly rounded flanks converge to the rather narrowly rounded venter. The body chamber is corroded and there are no shell remains preserved; the internal mould does not show constrictions. The suture line has a small, narrow, lanceolate external lobe. The adventive lobe is almost twice as deep and very asymmetrical with an almost vertical ventral and a distinctly convex dorsal flank (Fig. 58D).

The cross sections of the paratypes GPIT-PV-63851 (Fig. 58B) and GPIT-PV-63992 (Fig. 58C) allow the study of conch morphology up to a diameter of 23 mm. Particularly paratype GPIT-PV-63851 shows the transition from the early juvenile stage (up to about 4 mm dm), which has a crescent-shaped whorl

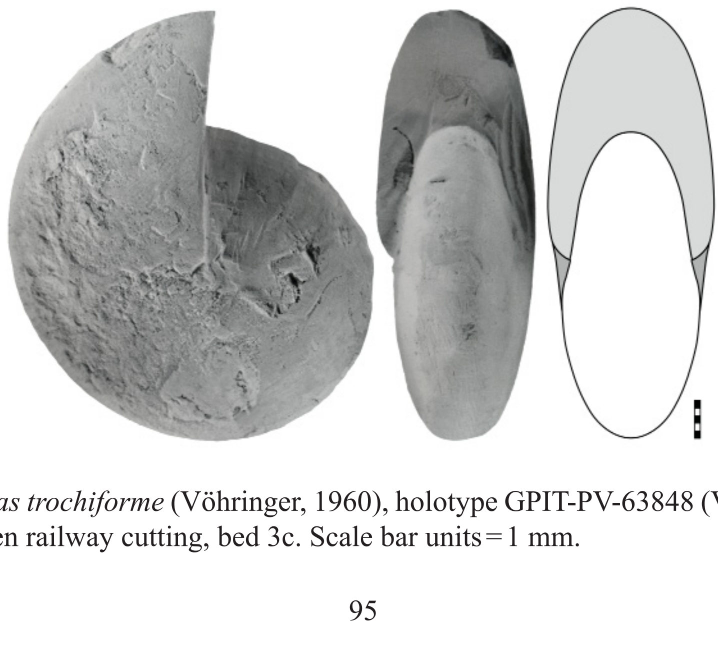

Fig. 57. *Nicimitoceras trochiforme* (Vöhringer, 1960), holotype GPIT-PV-63848 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 3c. Scale bar units = 1 mm.

Table 54. Conch ontogeny of *Nicimitoceras trochiforme* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subinvolute (ww/dm ~0.85; uw/dm ~0.25)	strongly depressed; very strongly embracing (ww/wh ~2.10; IZR ~0.45)	low (WER ~1.70)
5 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.10)	weakly depressed; very strongly embracing (ww/wh ~1.40; IZR ~0.45)	moderate (WER ~1.95)
15 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.02)	weakly compressed; very strongly embracing (ww/wh ~0.95; IZR ~0.45)	high (WER ~2.10)
30 mm	thinly discoidal; involute (ww/dm ~0.45; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.85; IZR ~0.45)	high (WER ~2.05)
50 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.65; IZR ~0.55)	moderate (WER ~1.90)

profile, to the middle stage with increasing whorl height. At a conch diameter of 4 mm dm, the umbilicus begins to close rapidly.

The growth trajectories of the sectioned specimens are rather simple in their course. The ww/dm and ww/wh ratios are monophasic with a continuous decrease; for example, the ww/dm ratio decreases from ~1.00 at 1 mm dm to a value of ~0.37 at 56 mm (Fig. 58E–G).

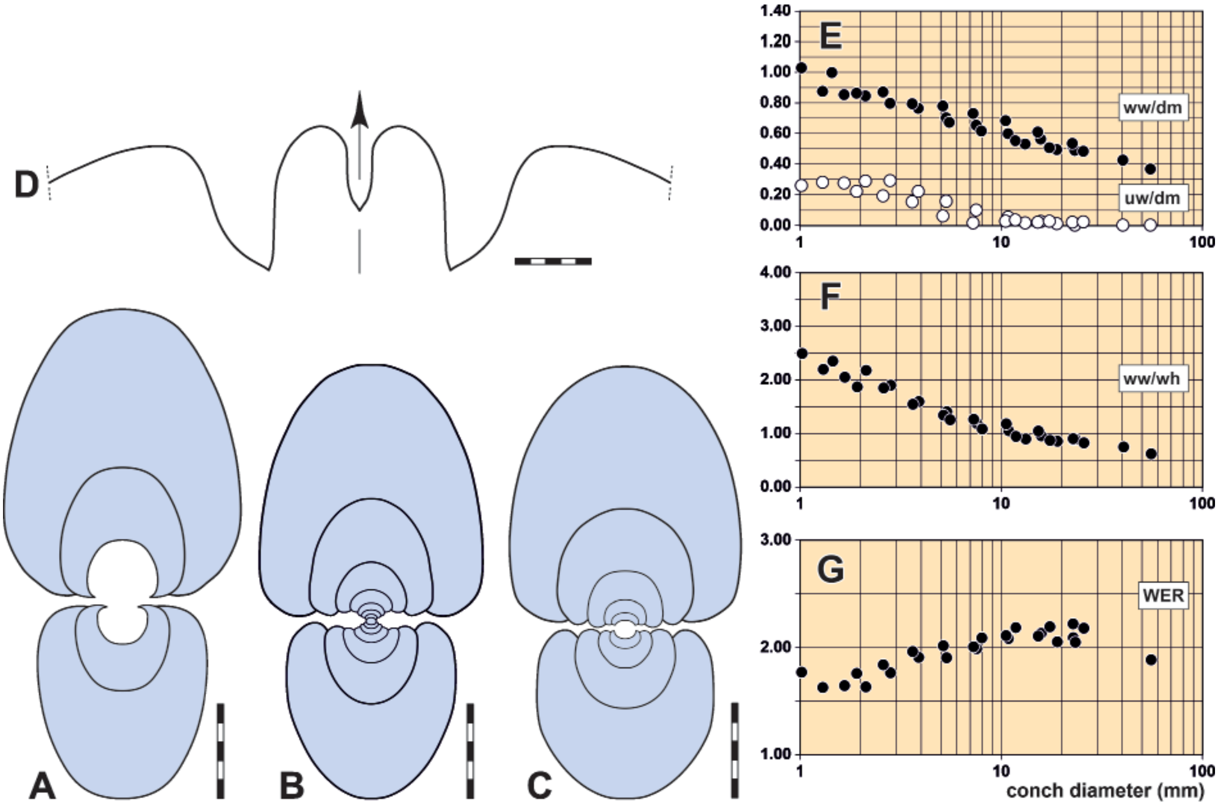

Fig. 58. *Nicimitoceras trochiforme* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. Cross section of specimen MB.C.31129 from bed 2. **B**. Cross section of paratype GPIT-PV-63851 from bed 3d. **C**. Cross section of paratype GPIT-PV-63992 from bed 2. **D**. Suture line of holotype GPIT-PV-63848 from bed 3c, at ww = 17.0 mm, wh = 21.5 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Remarks

Nicimitoceras trochiforme has a similar conch like *N. heterolobatum*, but differs in possessing less widely umbilicate juvenile whorls. The whorl profile of both species also differs; while in *N. trochiforme* the profile is widest near the umbilicus, in *N. heterolobatum* it is widest in the midflank area. In addition, the adventive lobe is very asymmetrical in *N. trochiforme*, but almost V-shaped in *N. heterolobatum*.

Nicimitoceras subacre (Vöhringer, 1960)
Figs 59–60; Tables 55–56

Imitoceras subacre Vöhringer, 1960: 120, pl. 1 fig. 5, text-fig. 2.

Imitoceras subacre – Weyer 1977: 169, pl. 2 fig. 5.
Nicimitoceras subacre – Korn 1993: 585; 1994: 53, text-figs 58c–d, 59c, 60c, 64d.

non *Imitoceras* (*Imitoceras*) *subacre* – Ruan 1981: 73, pl. 16 figs 13–15, 18–20.

Diagnosis

Species of *Nicimitoceras* with a conch reaching 70 mm diameter. Conch thinly pachyconic, involute at 5 mm dm (ww/dm ~0.65; uw/dm ~0.10); thickly discoidal, involute at 15 mm dm (ww/dm ~0.55; uw/dm ~0.00); thinly discoidal, involute at 30 mm dm (ww/dm ~0.40; uw/dm = 0.00). Whorl profile at 30 mm dm weakly compressed (ww/wh ~0.70); coiling rate high (WER ~2.10). Venter broadly rounded in the early stage, narrowly rounded in the preadult and adult stage. Growth lines extremely fine, with convex course. Without constrictions on the shell surface; without internal shell thickenings. Suture line with V-shaped external lobe and twice as deep, symmetrically V-shaped adventive lobe with blunt base.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b/c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 1 fig. 5) and Korn (1994: text-fig. 58c); re-illustrated here in Fig. 59B; GPIT-PV-63854.

Paratypes

GERMANY • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-63852, GPIT-PV-63853, GPIT-PV-63855.

Additional material

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31130.1–2.

Description

Holotype GPIT-PV-63854 is a rather well-preserved specimen with almost 33 mm conch diameter, showing both the shell ornament and the suture line (Fig. 59B). The conch has the shape of a thick lens (ww/wh = 0.37); the umbilicus is closed and the coiling rate is high (WER = 2.04). Remains of the shell indicate that its surface is almost smooth; there are no constrictions or internal shell thickenings. Only parts of the suture line can be seen; there is an adventive lobe that is rounded at its base.

Paratype GPIT-PV-63853 has a corroded body chamber and therefore only very small shell remains are preserved; they show lamellar growth lines in the ventrolateral area. The internal mould does not show constrictions. The suture line has a narrow external lobe with slightly divergent flanks. It is about two thirds the depth of the much wider, blunt and V-shaped adventive lobe (Fig. 60B).

Paratype GPIT-PV-63852 also has a corroded body chamber and no shell remains are preserved; moreover, the internal mould does not show constrictions. The specimen shows a weak indication of a narrower venter only at its maximum conch diameter of 39 mm.

Specimen MB.C.31130.1 is an incomplete but otherwise rather well-preserved specimen with nearly 43 mm conch diameter (Fig. 59C). It is slightly stouter than the type material (ww/dm = 0.42; ww/wh = 0.72) but otherwise closely resembling. The specimen shows the transition from the continuously rounded venter to the significantly narrowed venter only on the last volution. The shell of the specimen appears to be smooth.

The sectioned paratype GPIT-PV-63855 gives insight into the ontogenetic conch development from the earliest juvenile stage up to a conch diameter of 37 mm; however, some parts of the last whorls had to be reconstructed (Fig. 60A). The whorl profile changes continuously during ontogeny. An initial crescent-shaped whorl profile is replaced by a C-shaped (2–4 mm dm) and followed by a horseshoe-shaped (5–8 mm dm) profile; finally, the conch shape is suboxyconic with convex flanks and a subacute venter.

The ontogenetic trajectories of the conch parameters ww/dm and ww/wh are rather simple and show a continuous decrease of the values during ontogeny (Fig. 60C–D). Between 2 and 4 mm conch diameter, the ww/dm ratio decreases from ~0.90 to ~0.40 and the ww/wh ratio from ~2.20 to ~0.65. In contrast to this, the WER has a similar value of around 1.70 up to about 5 mm conch diameter, followed by an increase to more than 2.00 at 9 mm dm (Fig. 60E). Thereafter it remains rather stable.

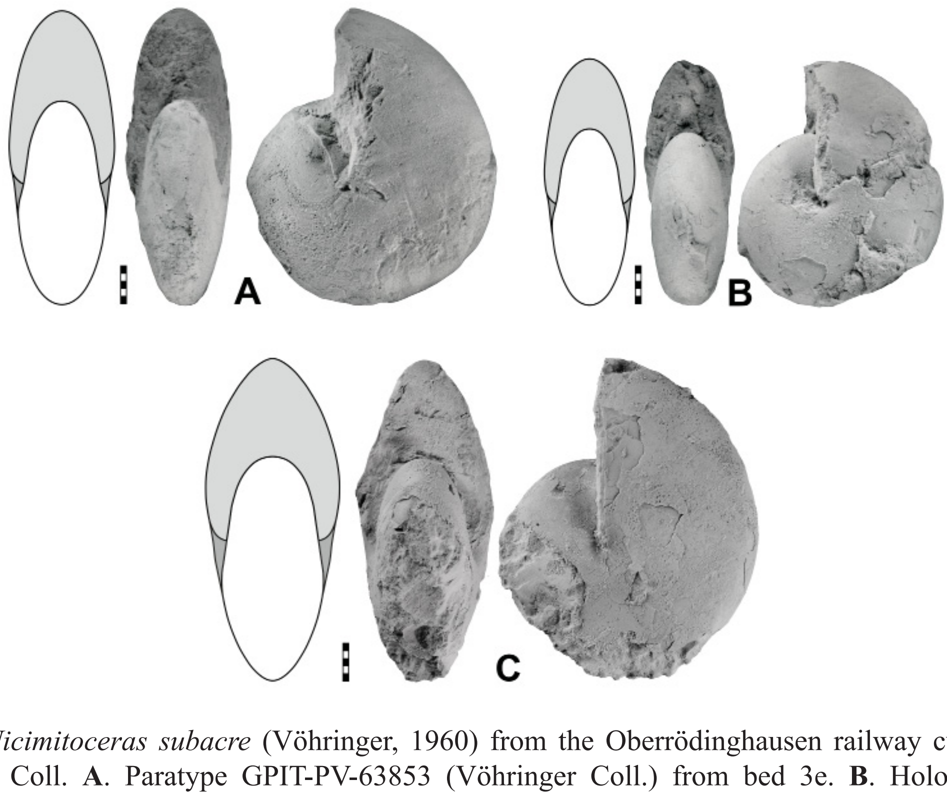

Fig. 59. *Nicimitoceras subacre* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Paratype GPIT-PV-63853 (Vöhringer Coll.) from bed 3e. **B**. Holotype GPIT-PV-63854 (Vöhringer Coll.) from bed 3b/c. **C**. Specimen MB.C.31130.1 (Weyer 1993–1994 Coll.) from bed 3d1b. Scale bar units = 1 mm.

Table 55. Conch measurements, ratios and rates of *Nicimitoceras subacre* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31130.1	42.6	17.9	24.8	0.0	13.0	0.42	0.72	0.00	2.07	0.48
GPIT-PV-63852	41.4	16.0	25.1	0.00	12.95	0.39	0.64	0.00	2.12	0.48
GPIT-PV-63853	39.8	14.7	22.7	0.0	11.9	0.37	0.65	0.00	2.03	0.48
GPIT-PV-63855	37.1	14.2	21.6	0.5	11.7	0.38	0.66	0.01	2.13	0.46
GPIT-PV-63854	32.6	12.1	18.7	0.4	9.8	0.37	0.65	0.01	2.04	0.48

Table 56. Conch ontogeny of *Nicimitoceras subacre* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subinvolute (ww/dm ~0.80; uw/dm ~0.20)	moderately depressed; very strongly embracing (ww/wh ~1.85; IZR ~0.45)	low (WER ~1.70)
5 mm	thinly pachyconic; involute (ww/dm ~0.65; uw/dm ~0.10)	weakly depressed; very strongly embracing (ww/wh ~1.25; IZR ~0.50)	moderate (WER ~1.80)
15 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.90; IZR ~0.45)	high (WER ~2.10)
30 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.70; IZR ~0.45)	high (WER ~2.10)

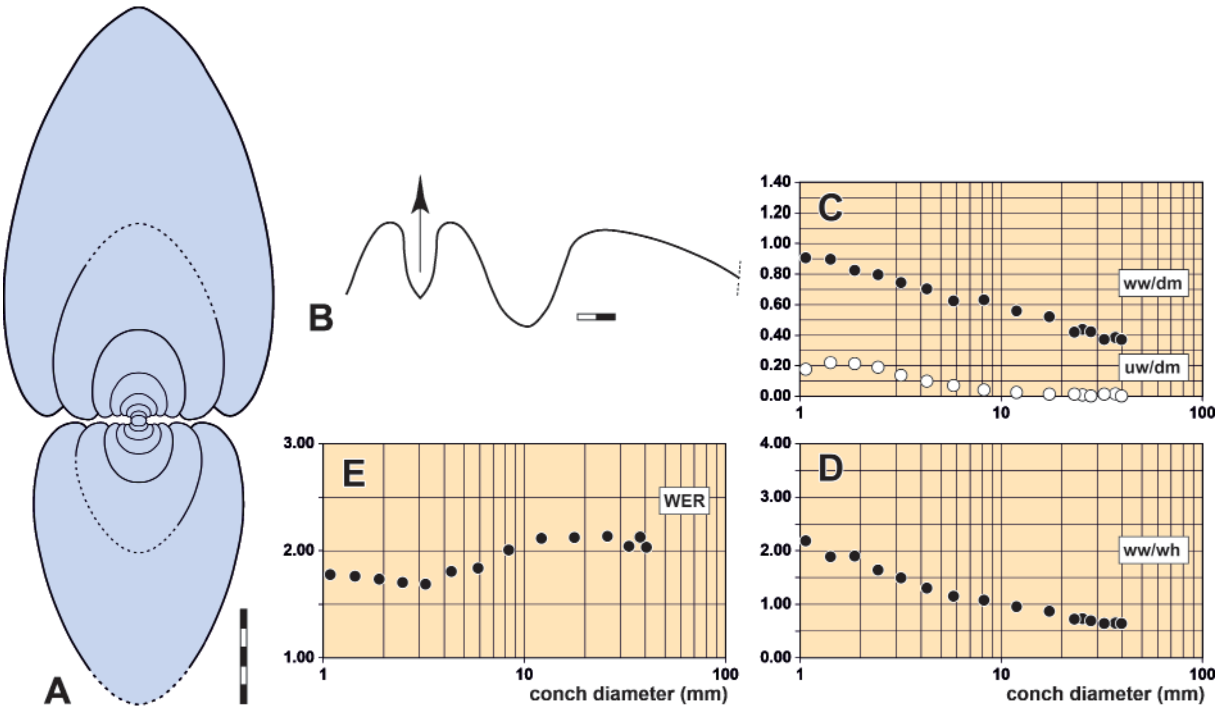

Fig. 60. *Nicimitoceras subacre* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63855 from bed 3e. **B**. Suture line of paratype GPIT-PV-63853 from bed 3e, at ww = 12.5 mm, wh = 14.0 mm. **C**–**E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Remarks

Nicimitoceras subacre is easily distinguished from the other species of the genus *Nicimitoceras*, but also from the species of the closely related genus *Stockumites*, by the very broad, blunt adventive lobe. From *N. heterolobatum* with similar conch morphology, *N. subacre* is also distinguished by the subinvolute juvenile stage, which is evolute in *N. heterolobatum*.

Nicimitoceras acre (Vöhringer, 1960)
Fig. 61; Tables 57–58

Imitoceras acre Vöhringer, 1960: 121, pl. 1 fig. 6, text-fig. 3.

Imitoceras acre – Bartzsch & Weyer 1988a: 134, text-fig. 2/1.
Nicimitoceras acre – Korn 1994: 56, text-figs 58e, 60d. — Sprey 2002, pl. 4 fig. 1.
? *Aganides carinatus* – Schmidt 1925: 535, pl. 19 fig. 3.

non 1981 *Imitoceras* (*Imitoceras*) *acre* – Ruan: 72, pl. 15 figs 3–5.

Diagnosis

Species of *Nicimitoceras* with a conch reaching 70 mm diameter. Conch thinly discoidal and involute at 30 mm dm (ww/dm ~0.35; uw/dm = 0.00). Whorl profile at 30 mm dm weakly compressed (ww/wh ~0.60); whorl expansion in the adult stage rate very high (WER ~2.30). Venter narrowly rounded in the preadult stage, acute in the adult stage. Growth lines extremely fine, with convex course. Without constrictions on the shell surface; without internal shell thickenings. Suture line with V-shaped external lobe and twice as deep, symmetrically V-shaped adventive lobe with angular base.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 1 fig. 6), Korn (1994: text-fig. 58e) and Sprey (2002: pl. 4 fig. 1); re-illustrated here in Fig. 61A; GPIT-PV-63856.

Paratypes

GERMANY • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63857–GPIT-PV-63859.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31131 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Korn 1991 Coll.; MB.C.31132 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31133.

Description

Holotype GPIT-PV-63856, 49 mm in diameter (Fig. 61A), is a lenticular conch (ww/dm = 0.29) with a closed umbilicus and a very high coiling rate (WER = 2.31). On the last whorl, the transition from a narrowly rounded venter to an oxyconic venter takes place. Only small portions of the shell are preserved, they show extremely fine growth lines that extend with a low ventrolateral projection across the outer flank. There are neither shell constrictions nor internal shell thickenings. The suture line has a narrowly V-shaped external lobe with somewhat convex flanks. The lobe is little more than half as deep as the adventive lobe, which is V-shaped with convex flanks (Fig. 61C).

Table 57. Conch measurements, ratios and rates of *Nicimitoceras acre* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63856	48.6	13.9	28.7	0.0	16.6	0.29	0.48	0.00	2.31	0.42
GPIT-PV-63856	32.0	10.7	18.9	0.0	–	0.33	0.57	0.00	–	–
GPIT-PV-63859	30.4	10.5	17.0	0.0	9.9	0.35	0.62	0.00	2.20	0.42
GPIT-PV-63859	20.3	8.3	12.5	0.0	–	0.41	0.66	0.00	–	–

Table 58. Conch ontogeny of *Nicimitoceras acre* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
30 mm	extremely discoidal; involute (ww/dm ~0.35; uw/dm ~0.00)	weakly compressed; strongly embracing (ww/wh ~0.60; IZR ~0.42)	high (WER ~2.20)
50 mm	extremely discoidal; involute (ww/dm ~0.30; uw/dm ~0.00)	strongly compressed; strongly embracing (ww/wh ~0.48; IZR ~0.42)	Very high (WER ~2.30)

Paratype GPIT-PV-63859 is a medium-sized specimen (30 mm dm) that still shows the non-acute venter of the preadult stage. It is extremely discoidal (ww/dm = 0.35) with the umbilicus completely closed. The venter is narrowly rounded (Fig. 61B). No shell remains are preserved in this specimen.

Remarks

Nicimitoceras acre is easily distinguished from the other species of the genus by its oxyconic conch form. Species of the genus *Acutimitoceras* have a superficially similar conch, but unlike *N. acre*, they are characterised by an attached keel. The suture lines of *Acutimitoceras* species have a deep external lobe, in contrast to the short external lobe in *Nicimitoceras*.

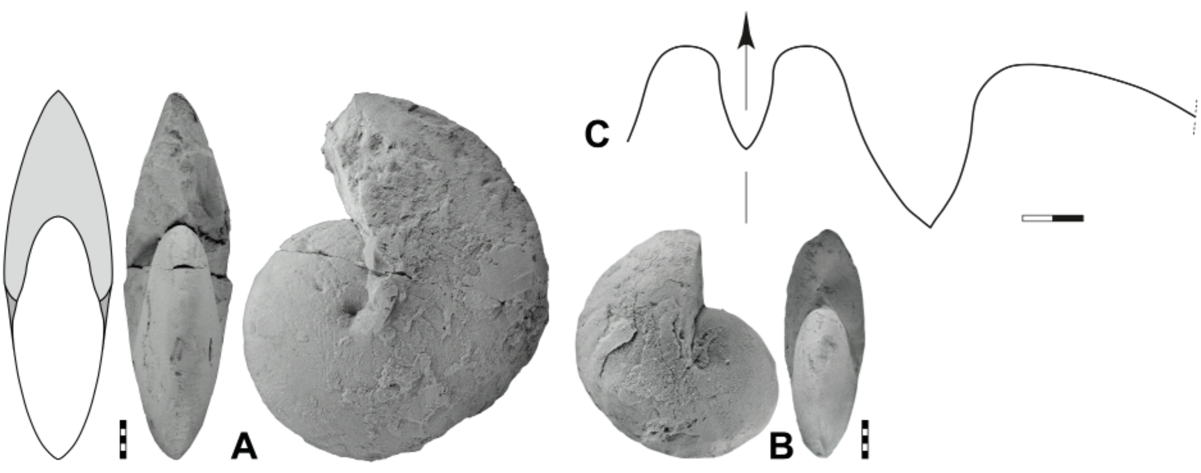

Fig. 61. *Nicimitoceras acre* (Vöhringer, 1960), from the Oberrödinghausen railway cutting, bed 2. **A**. Holotype GPIT-PV-63856 (Vöhringer Coll.). **B**. Paratype GPIT-PV-63859 (Vöhringer Coll.). **C**. Suture line of holotype GPIT-PV-63856, at ww = 11.0 mm, wh = 15.5 mm. Scale bar units = 1 mm.

Nicimitoceras heterolobatum (Vöhringer, 1960)
Figs 62–64; Tables 59–62

Imitoceras heterolobatum Vöhringer, 1960: 136, pl. 3 fig. 4, text-fig. 15.

Prionoceras (*Imitoceras*) *heterolobatum* – Weyer 1965: pl. 7 fig. 3.
Nicimitoceras heterolobatum – Korn 1994: 57, text-figs 58b, g, 59d–f, 60e–f.
Acutimitoceras (*Streeliceras*) *heterolobatum* – Becker 1996: 37.

Diagnosis (widely umbilicate morphotype)

Species of *Nicimitoceras* with a conch reaching 70 mm diameter. Conch thinly discoidal, subevolute at 5 mm dm (ww/dm ~0.45; uw/dm ~0.40); thinly discoidal, involute at 15 mm dm (ww/dm ~0.45; uw/dm ~0.03); thinly discoidal, involute at 30 mm dm (ww/dm ~0.40; uw/dm = 0.02). Whorl profile at 30 mm dm weakly compressed (ww/wh ~0.75); coiling rate moderate (WER ~1.95). Venter broadly rounded in the early stage, narrowly rounded in the preadult and adult stage. Growth lines extremely fine, with convex course. Without constrictions on the shell surface; internal shell thickenings restricted to the venter and outer flanks. Suture line with lanceolate external lobe and twice as deep, symmetrically V-shaped adventive lobe with angular base.

Diagnosis (narrowly umbilicate morphotype)

Species of *Nicimitoceras* with a conch reaching 70 mm diameter. Conch thinly discoidal, subinvolute at 5 mm dm (ww/dm ~0.50; uw/dm ~0.20); thinly discoidal, involute at 15 mm dm (ww/dm ~0.50; uw/dm ~0.00); thinly discoidal, involute at 30 mm dm (ww/dm ~0.40; uw/dm ~0.00). Whorl profile at 30 mm dm weakly compressed (ww/wh ~0.70); coiling rate high (WER ~2.05). Venter broadly rounded in the early stage, narrowly rounded in the preadult and adult stage. Growth lines extremely fine, with convex course. Without constrictions on the shell surface; internal shell thickenings restricted to the venter and outer flanks. Suture line with lanceolate external lobe and twice as deep, symmetrically V-shaped adventive lobe with angular base.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b/c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 3 fig. 4) and Korn (1994: text-fig. 58b); re-illustrated here in Fig. 62; GPIT-PV-63893.

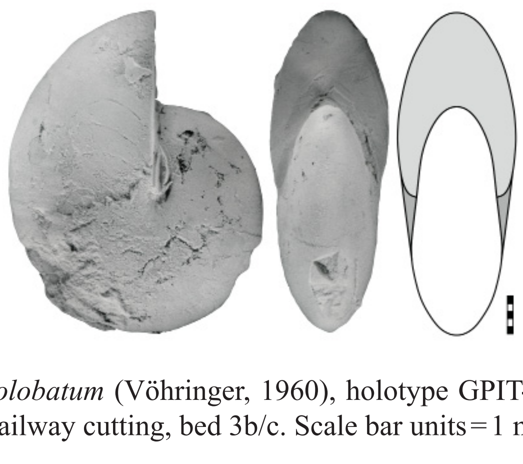

Fig. 62. *Nicimitoceras heterolobatum* (Vöhringer, 1960), holotype GPIT-PV-63893 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 3b/c. Scale bar units = 1 mm.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63869, GPIT-PV-63895 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3; Vöhringer Coll.; GPIT-PV-63897 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-63898, GPIT-PV-63977.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; MB.C.31134 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31135.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; MB.C.31136 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; MB.C.31137 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; MB.C.31138.1–3 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; MB.C.31139.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway

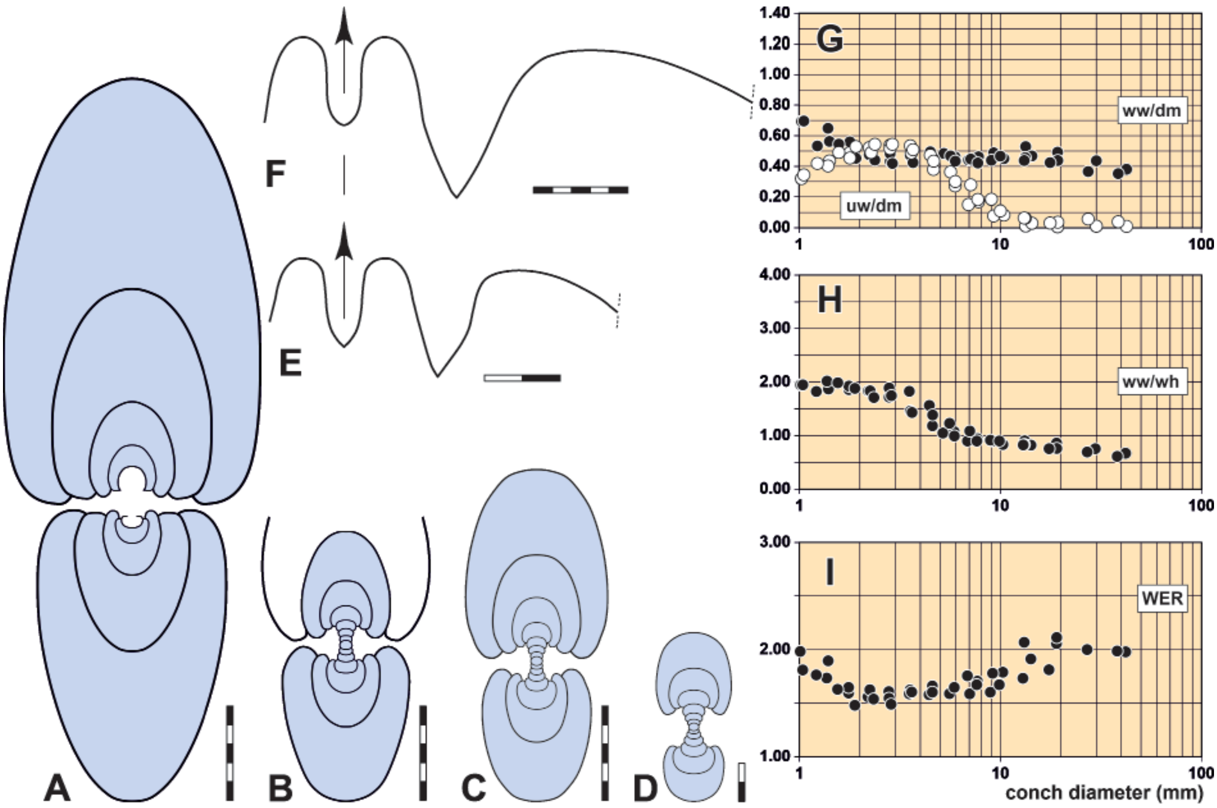

Fig. 63. *Nicimitoceras heterolobatum* (Vöhringer, 1960) from the Oberrödinghausen railway cutting (widely umbilicate morphotype). **A**. Cross section of paratype GPIT-PV-63897 from bed 3e. **B**. Cross section of paratype GPIT-PV-63977 from bed 3c. **C**. Cross section of specimen MB.C.31139.1 from bed 3d. **D**. Cross section of specimen MB.C.31135.1 from bed 2. **E**. Suture line of specimen MB.C.31139.1 from bed 3d, at ww = 7.3 mm, wh = 8.1 mm. **F**. Suture line of holotype GPIT-PV-63893 from bed 3b/c, at dm = 36.7 mm, ww = 16.0 mm, wh = 22.5 mm. **G**–**I**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; MB.C.31140.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31141.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31142 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31143 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 32; Weyer & Korn 2000 Coll.; MB.C.5257.

Description

Holotype GPIT-PV-63893 is a complete conch with a diameter of 42 mm; it is fully septate and partly covered with shell material (Fig. 62). It has the shape of a thick lentil (ww/dm = 0.38), a completely closed umbilicus and a moderately high aperture (WER = 1.98). The shape of the whorl profile shows that this is widest in the inner flank area, from where the flanks weakly converge towards the umbilicus

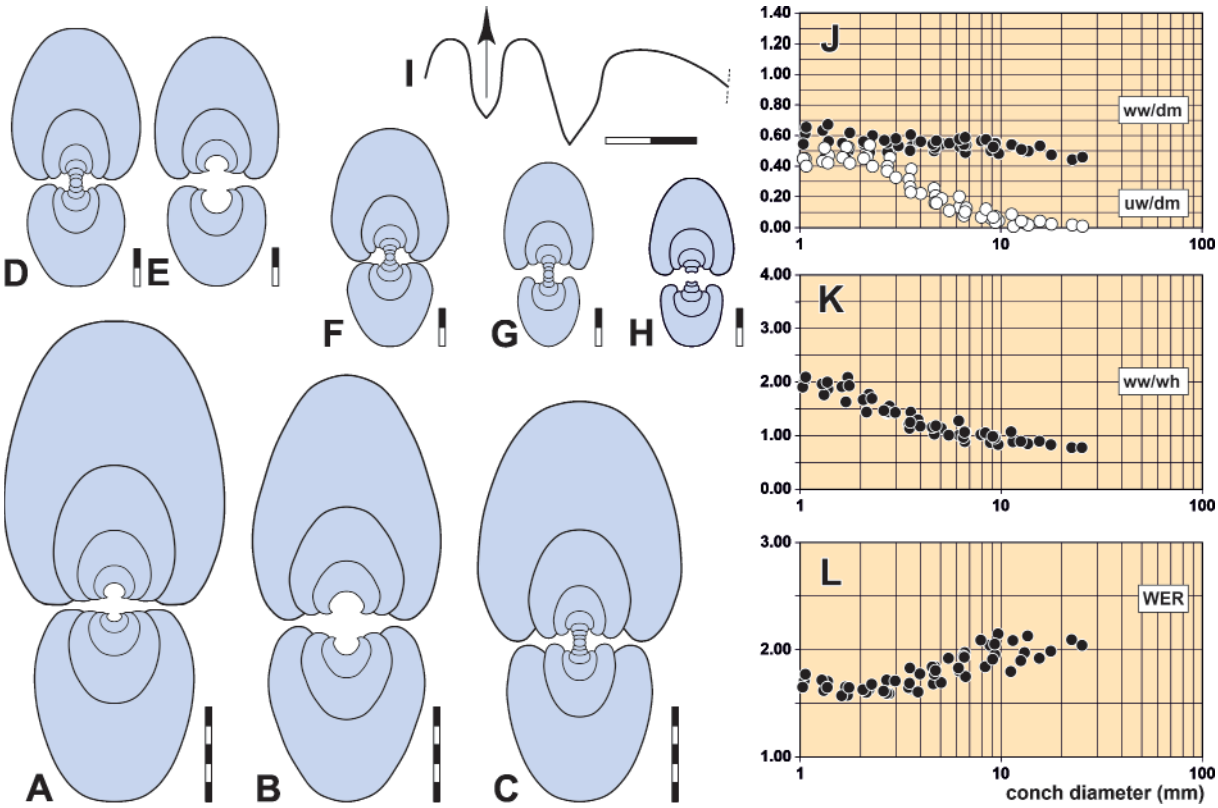

Fig. 64. *Nicimitoceras heterolobatum* (Vöhringer, 1960) from the Oberrödinghausen railway cutting (narrowly umbilicate morphotype). **A**. Cross section of specimen MB.C.31140.1 from unknown bed. **B**. Cross section of specimen MB.C.31140.2 from unknown bed. **C**. Cross section of specimen MB.C.31142 from bed 3b. **D**. Cross section of specimen MB.C.31138.1 from bed 3c. **E**. Cross section of specimen MB.C.31134 from bed 1. **F**. Cross section of specimen MB.C.31138.2 from bed 3c. **G**. Cross section of specimen MB.C.31135.2 from bed 2. **H**. Cross section of paratype GPIT-PV-63898 from bed 3e. **I**. Suture line of paratype GPIT-PV-63898 from bed 3e, at dm = 9.5 mm, ww = 5.8 mm, wh = 5.6 mm. **J–L**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

and more strongly converge toward the narrowly rounded venter. The shell is almost smooth and there are no constrictions on shell and internal mould.

The suture line of the holotype has a very small external lobe with parallel flanks and a rounded base. On the flank follow a small inverted U-shaped ventrolateral saddle, 1.5 times as wide as the external lobe and the adventive lobe. This is the dominant element of the suture line; it is twice as deep and wide as the external lobe. It is almost symmetric and V-shaped with weakly curved flanks (Fig. 63F).

The material can be separated into two groups with respect to the umbilical width of the inner whorls. In the first group, the uw/dm ratio exceeds a value of 0.50 at 2 mm conch diameter and at 5 mm diameter, the uw/dm ratio is still about 0.40 (Fig. 63G–I). In the second group, the uw/dm ratio reaches 0.45 at 2 mm diameter, but already at 5 mm diameter it amounts only 0.20 caused by stronger overlap upon the preceding whorls (Fig. 64J–L).

Vöhringer already produced four cross sections, of which he used only one for his publication (Vöhringer 1960: text-fig. 15a). This belongs to the morphogroup with widely umbilicate juvenile whorls. These sectioned specimens are MB.C.31135.1 (9 mm dm; Fig. 63D), GPIT-PV-63977 (14 mm dm; Fig. 63B) MB.C.31139.1 (18 mm dm; Fig. 63C) and GPIT-PV-63897 (36 mm dm, but only up to 18 mm dm sufficiently preserved; Fig. 63A). Specimen GPIT-PV-63977 shows the very short interval of evolute inner whorls, which reach at a conch diameter of about 2 mm a uw/dm ratio of 0.50 for only two volutions, followed by a rapid decrease of the uw/dm ratio to only 0.03 at 14 mm dm.

The ontogenetic trajectories can be described using the four sectioned specimens. The ww/dm ratio has a weakly triphasic ontogeny, in which the second phase is characterised by a stagnant ww/dm ratio of 0.45–0.50 between 3 and 20 mm conch diameter. The coiling rate shows, after an early juvenile decrease to WER = 1.60 at 2 mm conch diameter, a continuous increase to 2.10 at 20 mm diameter. It remains with minor changes, up to 42 mm diameter, at this level (Fig. 63G–I).

The second morphogroup is represented by eight cross sections (Fig. 64A–H), most of which were already produced by Vöhringer. They show that the variation is rather small in the ww/dm, uw/dm and ww/wh ratios, while the coiling rate is rather variable. The specimens have the highest uw/dm ratio at 2 mm conch diameter and thereafter, the umbilicus is almost completely closed until a conch diameter of 10 mm.

Remarks

Nicimitoceras heterolobatum does not seem to be a rare species in the section of Oberrödinghausen, but most of the specimens are rather small (less than 20 mm conch diameter). These smaller specimens, of which numerous cross sections have been made, can be classified into two morphogroups based on the width of the umbilicus. The problem with this subdivision is that the holotype cannot be assigned because the geometry of the inner whorls is not known. This problem must remain unsolved at present. The close morphological agreement of the rather large sectioned specimen GPIT-PV-63897 with the holotype suggests that the holotype belongs to the morphogroup with very evolute inner whorls.

There are several species of *Nicimitoceras* with similar preadult adult morphology but with different ontogenetic trajectories in the Hangenberg Limestone. One of them is *N. trochiforme*, which possesses a much shorter widely umbilical early juvenile stage than *N. heterolobatum*, of which specimens of both morphogroups have a longer widely umbilicate juvenile stage.

Table 59. Conch measurements, ratios and rates of *Nicimitoceras heterolobatum* (Vöhringer, 1960) from Oberrödinghausen, widely umbilicate morphogroup.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63893	42.1	16.1	24.1	0.5	12.2	0.38	0.67	0.01	1.98	0.49
GPIT-PV-63897	38.23	13.57	22.18	1.65	11.11	0.35	0.61	0.04	1.99	0.50
GPIT-PV-63869	18.7	9.4	10.3	0.2	5.6	0.50	0.91	0.01	2.05	0.45
MB.C.31139.1	17.54	7.49	9.95	0.61	4.51	0.43	0.75	0.03	1.81	0.55
GPIT-PV-63977	14.26	6.70	8.18	0.47	3.96	0.47	0.82	0.03	1.91	0.52
MB.C.31135.1	8.92	3.94	4.32	1.68	1.88	0.44	0.91	0.19	1.60	0.57

Table 60. Conch measurements, ratios and rates of *Nicimitoceras heterolobatum* (Vöhringer, 1960) from Oberrödinghausen, narrowly umbilicate morphogroup.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31143	29.66	14.31	17.63	0.64	9.84	0.48	0.81	0.02	2.24	0.44
MB.C.31142	21.15	10.66	12.67	0.23	6.79	0.50	0.84	0.01	2.17	0.46
MB.C.31138.1	13.62	6.78	7.99	0.25	4.29	0.50	0.85	0.02	2.13	0.46
MB.C.31134	13.14	6.52	7.49	0.40	3.79	0.50	0.87	0.03	1.97	0.49
MB.C.31138.2	11.50	6.15	6.98	0.10	3.54	0.54	0.88	0.01	2.09	0.49
MB.C.31135.2	9.70	4.67	5.62	0.43	3.08	0.48	0.83	0.04	2.15	0.45
GPIT-PV-63898	8.87	4.44	5.10	0.53	2.66	0.50	0.87	0.06	2.04	0.48

Table 61. Conch ontogeny of *Nicimitoceras heterolobatum* (Vöhringer, 1960) from Oberrödinghausen, widely umbilicate morphogroup.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm ~0.50; uw/dm ~0.50)	moderately depressed; moderately embracing (ww/wh ~1.85; IZR ~0.25)	low (WER ~1.55)
5 mm	thinly discoidal; subevolute (ww/dm ~0.45; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.25; IZR ~0.40)	low (WER ~1.60)
15 mm	thinly discoidal; involute (ww/dm ~0.45; uw/dm ~0.03)	weakly compressed; very strongly embracing (ww/wh ~0.80; IZR ~0.50)	moderate (WER ~1.95)
30 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.02)	weakly compressed; very strongly embracing (ww/wh ~0.75; IZR ~0.50)	moderate (WER ~1.95)

Table 62. Conch ontogeny of *Nicimitoceras heterolobatum* (Vöhringer, 1960) from Oberrödinghausen, narrowly umbilicate morphogroup.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm ~0.55; uw/dm ~0.45)	moderately depressed; weakly embracing (ww/wh ~1.65; IZR ~0.25)	low (WER ~1.60)
5 mm	thinly discoidal; subinvolute (ww/dm ~0.50; uw/dm ~0.20)	weakly depressed; strongly embracing (ww/wh ~1.10; IZR ~0.45)	low to moderate (WER ~1.75)
15 mm	thinly discoidal; involute (ww/dm ~0.50; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.80; IZR ~0.50)	high (WER ~2.10)
30 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.00)	weakly compressed; very strongly embracing (ww/wh ~0.70; IZR ~0.50)	high (WER ~2.05)

Subfamily **Imitoceratinae** Ruzhencev, 1950

Diagnosis

Subfamily of the family Prionoceratidae with the sutural formula E A L U I; external lobe pouched, usually asymmetric adventive lobe V-shaped, pointed. Conch in the juvenile stage subinvolute; adult stage involute. Coiling rate rarely low, usually high to very high (WER = 2.00–2.50). Shell ornament with fine to very coarse growth lines, without ribs.

Subfamily composition

The subfamily comprises three genera: *Imitoceras* Schindewolf, 1923 (17 or 18 species); *Irinoceras* Ruzhencev, 1947 (11 species); *Triimitoceras* Korn, Bockwinkel, Ebbighausen & Klug, 2003 (3 species).

Remarks

The subfamily Imitoceratinae was not excluded as valid in the revision of the *Treatise* by Kullmann (2009), but was included in the synonymy of the Prionoceratinae instead. Following this view would mean that the Prionoceratinae are most probably a polyphyletic taxon with quite heterogeneous content.

Morphology

Two of the three genera of the Imitoceratinae, namely *Imitoceras* and *Irinoceras*, show a similar morphology with thickly discoidal, fully involute conch with a high coiling rate. This morphology did not change throughout evolutionary history; the clade can be considered morphologically very conservative. Only the third genus *Triimitoceras*, which appears briefly in the late Tournaisian, deviates from this (Korn *et al.* 2003a, 2010a). It is characterised by small conchs with a low coiling rate, but shows the suture line of *Imitoceras*. They are probably dwarf forms that may represent a progenetic side branch.

Ontogeny

The ontogeny is best known from specimens of the genus *Imitoceras* from localities in Morocco and Algeria (Bockwinkel & Ebbighausen 2006; Korn *et al.* 2010a). It differs only slightly from discoidal species of *Stockumites* and *Nicimitoceras*. General ontogenetic trends are the closure of the umbilicus already in the juvenile stage, the continuously more slender conch and the increase in the coiling rate.

Phylogeny

Bockwinkel & Ebbighausen (2006) illustrated the transition between *Nicimitoceras* and *Imitoceras* using co-occurring species from the Anti-Atlas of Morocco. Their newly established species *I. oxydentale* already shows all the typical characteristics of *Imitoceras* (short, pouched external lobe, strongly convergent flanks), but at the same time a conch ontogeny that corresponds to that of *Nicimitoceras* (e.g., *N. heterolobatum*). The derivation of *Imitoceras* from *Nicimitoceras* can therefore be considered very likely.

Stratigraphic occurrence

The oldest representatives of the subfamily Imitoceratinae are known to occur in the younger part of the early Tournaisian. During the middle and late Tournaisian, it is still present in many ammonoid assemblages, but the subfamily is quite irregularly distributed in Viséan and Serpukhovian strata. *Irinoceras* is a rather important component of the ammonoid assemblages of the late Viséan and Serpukhovian in the South Urals (Ruzhencev & Bogoslovskaya 1971).

Geographic occurrence

The subfamily is widely distributed and mainly known from Ireland (de Koninck 1882), Central Europe (de Koninck 1844; Holzapfel 1889; Nicolaus 1963; Korn 2006), the Cantabrian Mountains (Kullmann

1963), Serbia (Stevanović & Kullmann 1962; Korn & Sudar 2016), North Africa (Korn *et al.* 2003a, 2010a, 2010b; Bockwinkel & Ebbighausen 2006), the South Urals (Ruzhencev 1947; Ruzhencev & Bogoslovskaya 1971), Tajikistan (Nikolaeva 1994, 1995), Xinjiang (Wang 1983), Tibet (Liang 1976), Eastern Australia (Campbell & Engel 1963; Campbell *et al.* 1983), British Columbia (Work *et al.* 2000) and the American Midcontinent (Hall 1860; Miller & Gurley 1896; Smith 1903; Miller & Collinson 1951; Miller & Garner 1955; Gordon 1965)

Genus ***Imitoceras*** Schindewolf, 1923

Type species

Ammonites rotatorius de Koninck, 1844: 565; original designation.

Genus diagnosis

Genus of the Imitoceratinae with large discoidal conch, reaching a diameter of 150 mm. Conch subinvolute or subevolute in early juveniles; umbilicus closes completely early in ontogeny. Coiling rate moderate to high (WER = 1.70–2.20). Suture line with slightly pouched, often very narrow external lobe; ventrolateral saddle strongly asymmetric and ventrally inclined; adventive lobe usually asymmetric and V-shaped with convex ventral flank and concave dorsal flank; adventive lobe much deeper than the external lobe (after Korn *et al.* 2010b, modified).

Genus composition

Central Europe (de Koninck 1844; Schindewolf 1926a): *Ammonites rotatorius* de Koninck, 1844; ?*Imitoceras Wurmi* Schindewolf, 1926.

North Africa (Bockwinkel & Ebbighausen 2006; Korn *et al.* 2010a, 2010b): *Imitoceras oxydentale* Bockwinkel & Ebbighausen, 2006; *Imitoceras altilobatum* Korn, Ebbighausen & Bockwinkel, 2010; *Imitoceras dimidium* Korn, Bockwinkel & Ebbighausen, 2010; *Imitoceras strictum* Korn, Bockwinkel & Ebbighausen, 2010.

Tibet (Liang 1976): *Imitoceras orientale* Liang, 1976; *Imitoceras xizangense* Liang, 1976.

British Columbia (Work *et al.* 2000): *Imitoceras tardum* Work & Nassichuk in Work, Nassichuk & Richards, 2000.

American Midcontinent (Hall 1860; Winchell 1862; Miller 1891; Miller & Gurley 1896; Smith 1903; Miller & Collinson 1951; Gordon 1965): *Goniatites Ixion* Hall, 1860; *Goniatites propinquus* Winchell, 1862; *Goniatites indianensis* Miller, 1891; *Goniatites Jessiae* Miller & Gurley, 1896; *Aganides discoidalis* Smith, 1903; *Imitoceras abundans* Miller & Collinson, 1951; *Imitoceras brevilobatum* Miller & Collinson, 1951; *Imitoceras lentiforme* Miller & Collinson, 1951; *Imitoceras sinuatum* Gordon, 1965.

Remarks

Many of the species of *Imitoceras* require revision; it is not clear if all the species listed above really belong to the genus. *Imitoceras* possesses a set of sutural characters that clearly separates it from other genera, (1) the slightly pouched external lobe, (2) the strongly asymmetric, ventrally inclined ventrolateral saddle and (3) the asymmetric adventive lobe. *Irinoceras* has a much stronger pouched external lobe, and the possibly ancestral genus *Nicimitoceras* has a lanceolate external lobe. *Triimitoceras* has a rather symmetric adventive lobe and is also distinguished from *Imitoceras* by its conch ontogeny with a low coiling rate (Korn *et al.* 2010b).

Imitoceras initium sp. nov.
urn:lsid:zoobank.org:act:F4100C55-64E5-48AF-8EDC-87CDA35580F1
Fig. 65; Table 63

Diagnosis

Species of *Imitoceras* with a conch reaching 60 mm diameter. Conch at 50 mm dm discoidal, involute (ww/dm ~0.45; uw/dm ~0.05); whorl profile at 30 mm dm weakly compressed (ww/wh ~0.75); coiling rate very high (WER ~2.30). Venter rounded, umbilical margin rounded, flanks strongly convergent. Growth lines very fine, narrow-standing, with slightly biconvex course. Weak constrictions on the shell surface of the inner flank. Suture line with a weakly pouched external lobe and a V-shaped adventive lobe.

Etymology

After Latin '*initium*' = 'the beginning'; because of the position of the species at the base of a long-ranging evolutionary lineage.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, west of railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; illustrated in Fig. 65; MB.C.31144.

Description

Holotype MB.C.31144 is well preserved and has a conch diameter of 52 mm (Fig. 65A). It is thinly discoid with a slightly opened umbilicus (ww/dm = 0.43; uw/dm = 0.05) and has a compressed whorl profile that is widest at the rounded umbilical margin; it has fairly strongly converging flanks and a rounded venter. The coiling rate is very high (WER = 2.30). The shell bears barely visible, extremely faint growth lines with a biconvex course and also a shell constriction limited to the inner flank. The suture line has a weakly pouched external lobe that is about two-thirds the depth of the nearly symmetric V-shaped adventive lobe (Fig. 65B).

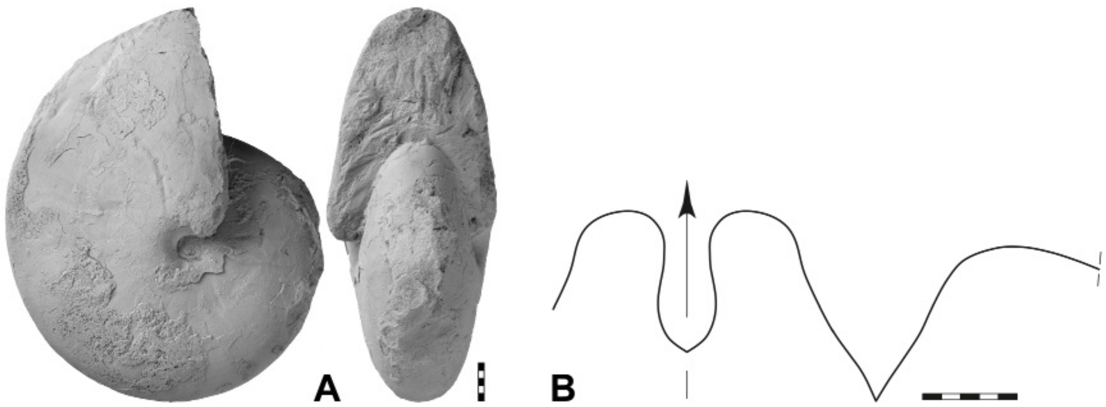

Fig. 65. *Imitoceras initium* sp. nov., holotype MB.C.31144 (Korn 1977 Coll.) from the forestry road cutting west of the Oberrödinghausen railway cutting. **A**. Lateral and dorsal view. **B**. Suture line, at ww = 14.0 mm, wh = 15.4 mm. Scale bar units = 1 mm.

Table 63. Conch measurements, ratios and rates of *Imitoceras initium* sp. nov. from Oberrödinghausen and Oese.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31144	52.0	22.2	29.6	2.6	17.7	0.43	0.75	0.05	2.30	0.40
MB.C.31144	34.2	16.6	19.0	2.0	–	0.49	0.87	0.06	–	–

Remarks

The occurrence of the genus *Imitoceras* in the *Gattendorfia* Limestone near Oberrödinghausen was previously unknown, but is actually not a great surprise. Representatives of *Imitoceras* have already been found together with early Tournaisian ammonoids in Guizhou (Sun & Shen 1965; Ruan 1981), originally described as "*Imitoceras planolobatum*" and "*Imitoceras* (*Imitoceras*) *crassum*", and the Anti-Atlas (Bockwinkel & Ebbighausen 2006).

The only specimen available is unique in the ammonoid assemblage from Oberrödinghausen because of its high coiling rate of 2.30. Such a value is rarely reached by other members of the prionoceratid ammonoids. In the subfamily Acutimitoceratinae, the whorl expansion rate is normally between 1.70 and 1.90 in *Stockumites* and between 1.90 and 2.05 in *Nicimitoceras*.

Of these genera, only *Nicimitoceras* has a short external lobe like in *Imitoceras initium* sp. nov. However, *I. initium* is stouter than the size-equivalent holotypes of other *Nicimitoceras* species from Oberrödinghausen: its ww/dm ratio is 0.43 at 52 mm dm in *I. initium*, while the value in *N. heterolobatum*, for example, is 0.36 at 54 mm dm. In addition, the whorl profile shows rapidly converging flanks in *I. initium*, which tend to be subparallel in species of *Nicimitoceras*.

A superficially similar species to *Imitoceras initium* sp. nov. is *Acutimitoceras procedens* from the Stockum limestone equivalent of the Müssenberg (Korn 1981). This also shows a high coiling rate, rapidly convergent flanks, and a shell ornament with weak growth lines and constrictions. The holotype of this species is much stouter (ww/dm = 0.54 at 33 mm dm) than holotype MB.C.31144 of *A. initium* (ww/dm = 0.43 at 52 mm dm). This difference cannot be explained by the advanced ontogenetic evolution towards a more slender conch in specimen MB.C.31144, as this has half a whorl in front of the largest diameter, a ww/dm ratio of only 0.47 at 36 mm conch diameter.

Subfamily **Voehringeritinae** Bartzsch & Weyer, 1988

[nom. transl. Korn (1994: 63), pro Voehringeritini Bartzsch & Weyer, 1988]

Diagnosis

Subfamily of the family Prionoceratinae with subevolute to evolute inner whorls, adult stage involute, thinly discoidal with acute venter. Suture line with divided external lobe; sutural formula (E_1 E_m E_1) A L U I.

Subfamily composition

Voehringerites Manger, 1971 (1 species).

Remarks

Morphology, ontogeny

The morphology and ontogeny of the conch geometry is very similar to that of the genus *Acutimitoceras*; the conch is oxyconic and the juvenile whorls have a fairly wide umbilicus. The most important distinguishing character is the divided external lobe.

Phylogeny

According to current knowledge, the subfamily, represented by only one species, is to be regarded as a direct descendant of the genus *Acutimitoceras*. The external lobe, which was already slightly widened in *A. ucatum* sp. nov., was divided in *Voehringerites*. In this regard, *Voehringerites* follows an evolutionary pathway that has occurred independently several times in the evolution of Palaeozoic ammonoids. Similar scenarios involving a division of the external lobe in oxyconic conchs have also been described in the early Devonian family Auguritidae (Chlupáč & Turek 1983) and the middle Devonian family Pinacitidae (Klug & Korn 2002).

It is noteworthy that only a little later than in *Voehringerites*, in the area of the boundary between the early and the middle Tournaisian, another independent line of development of acute ammonoids led to a division of the external lobe. This is the subfamily Karagandoceratinae Ruzhencev, 1960, in which, in contrast to the Voehringeritinae, the external lobe is much smaller than the adventive lobe (Librovitch 1940). Bartzsch & Weyer (1988a) therefore postulated the origin of the Karagandoceratinae in *Nicimitoceras acre*.

Stratigraphic and geographic occurrence

The subfamily is so far only known from the basal *Gattendorfia* Limestone (earliest Tournaisian) of the Rhenish Mountains.

Genus ***Voehringerites*** Manger, 1971

Type species

Karagandoceras peracutum Vöhringer, 1960: 166; original designation.

Genus diagnosis

Genus of the subfamily Voehringeritinae with discoidal conch and high coiling rate (WER ~2.15); inner whorls evolute. Ornament with nearly straight growth lines.

Genus composition

Only the type species.

Remarks

Voehringerites is the oldest Carboniferous genus with a subdivided external lobe; it is easily distinguished from the other genera of the early Tournaisian in the Rhenish Mountains by this character. In the absence of the suture line, it could be confused with *Acutimitoceras ucatum* sp. nov., but this species has very coarse growth lines and an acute but less sharp venter.

Voehringerites peracutus (Vöhringer, 1960)
Figs 66–67; Tables 64–65

Karagandoceras peracutum Vöhringer, 1960: 166, pl. 1 fig. 3, text-fig. 43.

Voehringerites peracutum – Manger 1971: 36, pl. 12 figs 4, 7, text-figs 3a, 4.
Voehringerites peracutus – Weyer 1972: 345. — Bartzsch & Weyer 1988a: 138. — Korn 1994: 65, text-figs 31f–g, 63a, 71b. — Korn & Weyer 2003: 99, text-figs 14k, 15. — Sprey 2002: 53, text-fig. 18b. — Becker & Weyer 2004: 20, text-figs 4f, 10–13.

non *Voehringerites peracutus* – Korn 1981: 524, text-fig. 5.

Diagnosis

Species of *Voehringerites* with a conch reaching 60 mm diameter. Conch thickly discoidal, subinvolute at 5 mm dm (ww/dm ~0.55; uw/dm ~0.20); extremely discoidal, involute at 15 mm dm (ww/dm ~0.32; uw/dm ~0.05); extremely discoidal, involute at 25 mm dm (ww/dm ~0.28; uw/dm = 0.00). Whorl profile at 30 mm dm strongly compressed (ww/wh ~0.45); coiling rate high (WER ~2.15). Venter broadly rounded in the early stage, galeate in the subadult stage and sharply acute in the adult stage. Growth lines fine with weakly biconvex course. Without constrictions on the shell surface; without internal shell thickenings.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; illustrated by Vöhringer (1960: text-fig. 43), Manger (1971: text-fig. 4) and Korn (1994: text-fig. 31f); re-illustrated here in Fig. 66A; GPIT-PV-63958.

Paratype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63966.

Additional material

GERMANY • 14 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; MB.C.3723.1, MB.C.3723.2, MB.C.3724.3-14 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5b; Weyer 1993–1994 Coll.; MB.C.3724.1, MB.C.3724.2, MB.C.31145 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5c; Weyer 1993–1994 Coll.; MB.C.3725, MB.C.31146.1–2 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 72; Weyer 1993–1994 Coll.; MB.C.5245.1.

Description

Both the holotype GPIT-PV-63958 (Fig. 66A) and the paratype GPIT-PV-63966 (Fig. 66B) are fragments that reveal little more than that they belong to an extremely discoidal, sharply keeled ammonoid. In the paratype, the shell ornament is better preserved and shows slightly sigmoidal growth lines, which are reinforced like ribs on the keel of the conch.

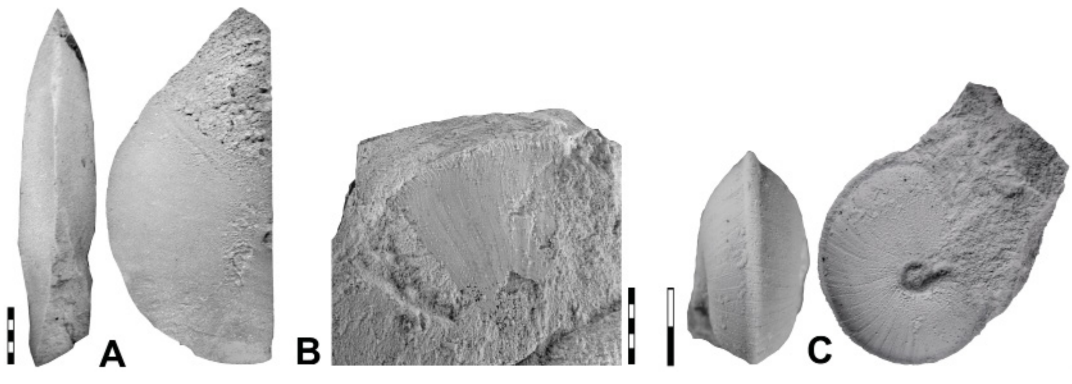

Fig. 66. *Voehringerites peracutus* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63958 (Vöhringer Coll.) from bed 5. **B**. Paratype GPIT-PV-63966 (Vöhringer Coll.) from bed 5. **C**. Specimen MB.C.3723.1 (Weyer 1993–1994 Coll.) from bed 5a2. Scale bar units = 1 mm.

The cross section of the holotype is well-preserved and allows the study of whorls from the initial stage to a conch diameter of 19.5 mm (Fig. 67A). Up to a diameter of 3 mm, the whorl profile is kidney-shaped; thereafter the formation of a ventral keel begins and already at 4.8 mm dm the venter is galeate. At about this diameter, the umbilicus begins to close. On the last half whorl, the galeate shape of the venter is abandoned and transformed into a simple, sharply keeled shape.

The small specimen MB.C.3723.1 already has a galeate venter with a clearly attached keel at 6.4 mm conch diameter (Fig. 66C). The shell shows rather coarse growth lines with a concave course across the flank.

Remarks

Voehringerites peracutus differs from all other species from the *Gattendorfia* Limestone of Oberrödinghausen by the divided external lobe. Similar in the conch shape is *Acutimitoceras ucatum* sp. nov., especially in the juvenile stage, but this species does not have the distinct keel. A distinct keel is present in *A. acutum* and *A. paracutum* sp. nov., but these two species show biconvex growth lines, whereas these are almost straight in *V. peracutus*.

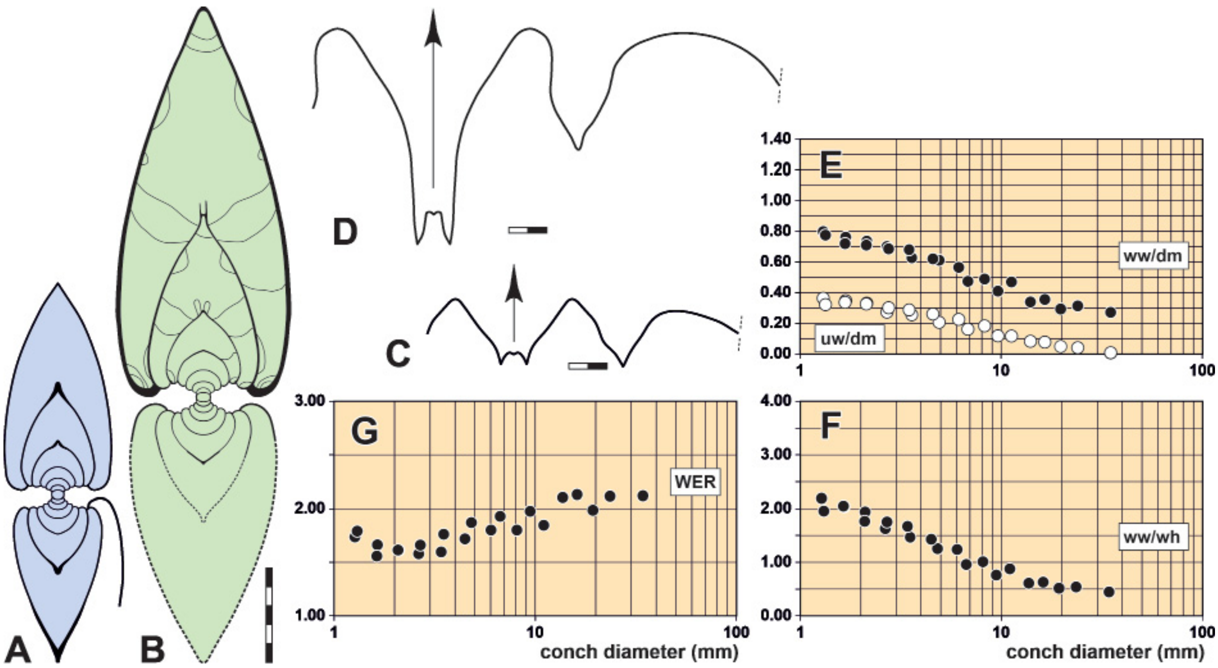

Fig. 67. *Voehringerites peracutus* (Vöhringer, 1960); B, D after Korn & Weyer (2003). **A**. Cross section of holotype GPIT-PV-63958 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 5. **B**. Cross section of specimen MB.C.5245.1 (Weyer 1993–1994 Coll.) from the Hasselbachtal section, bed 72. **C**. Suture line of holotype GPIT-PV-63958 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 5, at dm = 21.5 mm, ww = 6.8 mm, wh = 12.0 mm. **D**. Suture line of specimen MB.C.5245.1 (Weyer 1993–1994 Coll.) from the Hasselbachtal section, bed 72, at dm = 34.0 mm, ww = 8.8 mm, wh = 19.5 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 64. Conch measurements, ratios and rates of *Voehringerites peracutus* (Vöhringer, 1960) from Hasselbachtal and Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.5245-1	34.4	9.3	20.6	0.2	10.8	0.27	0.45	0.01	2.13	0.48
GPIT-PV-63958	19.4	5.7	10.9	0.9	5.7	0.29	0.52	0.05	1.99	0.48
MB.C.3723.1	6.4	3.2	3.4	1.0	–	0.50	0.94	0.16	–	–

Table 65. Conch ontogeny of *Voehringerites peracutus* (Vöhringer, 1960) from Oberrödinghausen and Hasselbachtal.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.70; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.90; IZR ~0.40)	low (WER ~1.60)
5 mm	thickly discoidal; subinvolute (ww/dm ~0.55; uw/dm ~0.20)	weakly depressed; very strongly embracing (ww/wh ~1.25; IZR ~0.45)	moderate (WER ~1.90)
15 mm	extremely discoidal; involute (ww/dm ~0.32; uw/dm ~0.05)	weakly compressed; very strongly embracing (ww/wh ~0.60; IZR ~0.45)	high (WER ~2.10)
30 mm	extremely discoidal; involute (ww/dm ~0.28; uw/dm ~0.00)	strongly compressed; very strongly embracing (ww/wh ~0.45; IZR ~0.45)	high (WER ~2.15)

Family **Gattendorfiidae** Bartzsch & Weyer, 1987

[nom. transl. Korn (1994: 69), ex Gattendorfiinae Bartzsch & Weyer, 1987]

Diagnosis

Family of the superfamily Prionoceratoidea with the sutural formula E A L U I; external lobe lanceolate or slightly pouched; adventive lobe deep, V-shaped or lanceolate and pointed; the lateral lobe has a position on the umbilical wall. Conch in the juvenile stage subevolute or evolute; adult stage involute to evolute, but usually subinvolute. Shell ornament with fine to coarse growth lines, often with rursiradiate direction. Ribs occur in several independent lineages in varying morphology.

Included subfamilies

Gattendorfiinae Bartzsch & Weyer, 1987; Pseudarietitinae Bartzsch & Weyer, 1987.

Remarks

In the Treatise revision, Kullmann (2009) expressed a view of the family Gattendorfiidae that is clearly different from previously published concepts (Bartzsch & Weyer 1987, 1988a; Korn 1994; Korn & Klug 2002). His scheme differs, on the one hand, in that the gattendorfiid and pseudarietitid clades are not considered as sister groups and, on the other hand, in that genera such as *Acutimitoceras* and *Stockumites* are also placed in the family Gattendorfiidae. The subfamily Acutimitoceratinae is treated there as a junior synonym of the family Gattendorfiidae.

The definition of the family Gattendorfiidae as done by Kullmann (2009) contains some problems. It states that the family is characterised by a “shell surface with rursiradiate growth lines or ribbing”; however, this only applies to some representatives (*Gattendorfia*, *Zadelsdorfia*, *Weyerella*, *Gattenpleura*). This does not apply to those genera that we place in the subfamily Acutimitoceratinae. The biggest problem with this scheme, however, is that it cuts the evolutionary line from *Stockumites* to *Nicimitoceras* to *Imitoceras* and, by placing the latter genus in the family Prionoceratidae, would make the family Gattendorfiidae a polyphyletic unit.

Subfamily **Gattendorfiinae** Bartzsch & Weyer, 1987

Diagnosis

Subfamily of the family Gattendorfiidae with subevolute to evolute inner whorls, adult stage subinvolute to evolute. Ornament usually with coarse rursiradiate growth lines; in some species with radial folds but usually without sharp ribs.

Subfamily composition

In total, about 75 species of the Gattendorfiinae have been described so far. They belong to the genera: *Gattendorfia* Schindewolf, 1920 (10 species); *Kazakhstania* Librovitch, 1940 (9 species); *Zadelsdorfia* Weyer, 1972 (32 species); *Gattenpleura* Weyer, 1976 (3 species); *Hasselbachia* Korn & Weyer, 2003 (4 species) and *Weyerella* Bockwinkel & Ebbighausen, 2006 (17 species).

Remarks

Morphology

The morphology within the subfamily Gattendorfiinae is very diverse and it is hardly possible to find a common character for all species. Such a character could possibly be the rursiradiate course of the growth lines.

All species of the subfamily share the character of widely umbilicate juvenile whorls; however, the umbilicus is almost never completely closed during ontogeny. Therefore, the morphology of the adult stage is highly variable and can range from serpenticonic (*Kazakhstania* and some species of *Gattendorfia*) to moderately umbilicate and molariform (*Weyerella*) to goniatitoid with a narrow umbilicus (*Zadelsdorfia*). Almost all species of the Gattendorfiinae have a low coiling rate (WER usually between 1.50 and 1.75 and only rarely higher).

The ornament often consists of rather coarse, mostly rursiradiate growth lines on the flank, which form a wide ventral sinus of varying depth. Spiral lines are rare (*Weyerella reticulum*) and ribs appear in *Gattenpleura* and some species of *Gattendorfia*. Species of the genera *Gattendorfia* and *Kazakhstania* often have shell constrictions; in *Hasselbachia* they are limited to the flanks as short notches.

Ontogeny

In the subfamily Gattendorfiinae, the complexity of ontogeny depends on the adult conch shape. While species with an almost serpenticonic adult stage show very simple ontogenetic trajectories, species with a goniatitoid adult stage (*Gattendorfia*, *Zadelsdorfia*, *Gattenpleura*, *Hasselbachia*) usually have very complex ontogenetic trajectories. This was demonstrated using the example of *Zadelsdorfia crassa* by Korn & Vöhringer (2004); in this species the trajectory of the ww/dm ratio is conspicuously triphasic. There is also a very marked change in whorl profiles during ontogeny; in *Z. crassa*, kidney-shaped, trapezoidal, circular, and horseshoe-shaped whorl profiles occur in succession.

Phylogeny

The origin of the subfamily Gattendorfiinae (and the entire family Gattendorfiidae) has not yet been satisfactorily clarified. This is at least partly owing to the fact that in the lowest part of the *Gattendorfia* Limestone several species of *Gattendorfia* (*G. subinvoluta*, *G. rhenana* sp. nov., *G. immodica* sp. nov.) and *Gattenpleura* (*G. pfeifferi*) with quite complex morphology appear almost simultaneously. Two hypotheses may be discussed here:

(1) An origin from the subfamily Prionoceratinae: Vöhringer (1960: 179) thought that it is possible that *Gattendorfia* could have originated from *Mimimitoceras varicosum* via *Kornia sphaeroidalis*. This assumption is mainly based on the interpretation that the presence of shell constrictions is an important character. This hypothesis could be strengthened by another argument not mentioned by Vöhringer – the low coiling rate in the gattendorfiids. This hypothesis states that the main morphological novelty in the Gattendorfiinae is the widely umbilicate juvenile whorl.

(2) An origin from the subfamily Acutimitoceratinae: this hypothesis was suggested by Korn (1986); the concept was taken over by Kullmann (2009) in the subdivision of the Prionoceratoidea. The hypothesis is based on the assumption that the evolute juvenile whorls are an important character and were passed from *Stockumites* to *Gattendorfia*. This hypothesis could be supported by the fact that several species of *Gattendorfia* have rounded trapezoidal whorl profiles in the juvenile whorls, similar to, for example, the stratigraphically early species *Stockumites hilarum*.

The intra-subfamily phylogenetic relationships also do not appear clear. The common character of the rursiradiate growth lines in almost all representatives of the Gattendorfiinae can be taken as evidence that it is at least a monophyletic unit. There may be several evolutionary lineages, (1) *Gattendorfia–Zadelsdorfia*, (2) *Gattendorfia–Kazakhstania*, (3) *Gattenpleura–Weyerella* and (4) *Gattenpleura–Hasselbachia*. This includes the hypothesis that *Weyerella* with the genuinely simple conch morphology and faint ornament is not the ancestor of the obviously much more complex *Gattenpleura*, but on the contrary is the descendent of *Gattenpleura* and characterised by simplification of conch and ornament. The origin of *Gattenpleura* remains unclear.

Stratigraphic occurrence

Species of the subfamily Gattendorfiinae are known from strata of the early and middle Tournaisian. *Gattendorfia*, *Gattenpleura* and *Hasselbachia* are obviously restricted to the early Tournaisian, while *Zadelsdorfia*, *Weyerella* and *Kazakhstania* also extend from the early Tournaisian into the middle Tournaisian.

Geographic occurrence

Species of the Gattendorfiinae are nearly worldwide distributed and were described from the Rhenish Mountains (Schmidt 1924, 1925; Vöhringer 1960; Korn 1994, 2006; Becker 1997; Korn & Weyer 2003; Korn & Vöhringer 2004; Becker *et al.* 2021), Thuringian Mountains (Schindewolf 1924, 1926a, 1952; Pfeiffer 1954; Weyer 1976, 1977; Bartzsch & Weyer 1982, 1986, 1987, 1988a, 1988b, 1996), Upper Franconia (Münster 1839; Schindewolf 1923), Silesia (Weyer 1965; Dzik 1997), the Carnic Alps (Korn 1992b; Schönlaub *et al.* 1992), the Montagne Noire (Korn & Feist 2007). They are also known from Anti-Atlas (Korn *et al.* 2002; Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007), western Algeria (Conrad 1984; Ebbighausen *et al.* 2004), the South Urals (Popov 1975; Popov & Kusina 1997), Karaganda (Librovitch 1940) and Mongolia (Kusina & Lazarev 1994). In China they were described from Xinjiang (Sheng 1984; Ruan 1995), Tibet (Liang 1976) as well as Guizhou (Ruan 1981) and in the United States from Montana (Gordon 1986), New Mexico (Gordon 1986), Iowa (Furnish & Manger 1973), Indiana (Smith 1903; Gutschick & Treckman 1957), Kentucky (Work & Mason 2005, 2009), Michigan (Miller & Garner 1955), Missouri (Miller & Collinson 1951) and Ohio (Smith 1903; Manger 1971).

Genus ***Gattendorfia*** Schindewolf, 1920

Type species

Goniatites subinvolutus Münster, 1839: 23; original designation.

Diagnosis

Genus of the Gattendorfiinae with a discoidal to pachyconic conch with low to moderately high coiling rate (WER = 1.50–1.90); inner whorls subevolute to evolute, adult stage subevolute to evolute. Ornament with convex or slightly biconvex, rursiradiate growth lines, shell with or without constrictions. Suture line with deep, lanceolate external lobe; adventive lobe usually symmetric.

Genus composition

Central Europe (Münster 1839; Schindewolf 1924, 1952; Vöhringer 1960): *Goniatites subinvolutus* Münster, 1839; *Gattendorfia ventroplana* Schindewolf, 1924 [synonym of *Gattendorfia subinvoluta*]; *Gattendorfia tenuis* Schindewolf, 1952; *Gattendorfia costata* Vöhringer, 1960; *Gattendorfia rhenana* sp. nov.; *Gattendorfia bella* sp. nov.; *Gattendorfia valdevoluta* sp. nov.; *Gattendorfia schmidti* sp. nov.; *Gattendorfia corpulenta* sp. nov.; *Gattendorfia immodica* sp. nov.

Remarks

Gattendorfia and *Zadelsdorfia* are closely related genera and it is obviously not easy to separate them clearly. This is mainly due to the fact that the ontogeny of many species is poorly known. Both genera contain species that have a more or less widely opened umbilicus even in the adult stage. The juvenile and preadult stages are usually evolute, while the uw/dm ratio can range between 0.20 and 0.50 in the adult stage among the species. The species of *Gattendorfia* and *Zadelsdorfia* can be subdivided into different groups with their characteristics such as conch shape (slender – stout), adult umbilical width (low – high), shape of the umbilical margin (rounded – subangular – angular), shell constrictions (absent – convex – concavo-convex) and growth lines (fine – lamellar). There is no obvious covariation of these characters. It is easiest to group the species according to the ww/dm and uw/dm ratios in the adult stage:

(1) Forms with discoidal conch shape and moderately wide umbilicus in the adult stage: *G. subinvoluta*, *G. rhenana* sp. nov., *G. schmidti* sp. nov.

(2) Forms with discoidal conch shape and wide umbilicus in the adult stage: *G. bella* sp. nov., *G. valdevoluta* sp. nov.

(3) Forms with pachyconic conch shape and wide umbilicus in the adult stage: *G. costata*, *G. immodica* sp. nov.

(4) Forms with pachyconic to globular conch shape and moderately wide umbilicus in the adult stage: *Z. crassa*, *Z. oblita* sp. nov.

The genus *Zadelsdorfia* was proposed by Weyer (1972) with the type species *Gattendorfia asiatica* Librovitch, 1940; it was introduced to include gattendorfiid ammonoids with a pouched external lobe. At the time it seemed to be restricted to the Middle Tournaisian, but in the meantime it has been demonstrated that Early Tournaisian species, among them *G. crassa* and several North African species, also possess a pouched external lobe (Korn 1994; Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007).

Korn & Feist (2007) regarded *Zadelsdorfia* as a junior synonym of *Gattendorfia*. However, it appears to be justified to separate the two genera on the basis of the shape of the external lobe (lanceolate in *Gattendorfia* but pouched in *Zadelsdorfia*) and the conch ontogeny (*Gattendorfia* has a widely umbilicate conch in adulthood, while in *Zadelsdorfia* the umbilicus is narrow in the adult stage). Furthermore, the adventive lobe tends to be asymmetric in *Zadelsdorfia*, while it is almost symmetric in *Gattendorfia*.

Bockwinkel & Ebbighausen (2006) separated the group of "*Gattendorfia molaris*" as an independent genus *Weyerella*. *Gattendorfia* differs from *Weyerella* primarily in the size of the conch, which in *Gattendorfia* reaches more than 50 mm diameter, while conchs of *Weyerella* usually do not exceed 25 mm. Another distinguishing feature is the width of the umbilicus in the juvenile stage; in *Gattendorfia* the umbilicus is very wide (> 0.55 of the diameter), whereas the uw/dm ratio in *Weyerella* only reaches a maximum of 0.50. According to Bockwinkel & Ebbighausen (2006), "*Weyerella* differs from typical *Gattendorfia* in the mode of umbilicus, closing with an overlap of the whorls over the preceding and in the platyconic conch shape of the adult conch."

Gattendorfia rhenana sp. nov.
urn:lsid:zoobank.org:act:6E306806-364B-4DCE-8CA2-AFC203EC54E9
Figs 8A, 68–69; Tables 66–67

Gattendorfia subinvoluta – Schindewolf 1952: 295 fig. 15. — Vöhringer 1960: 151, pl. 5 fig. 5, text-figs 26, 35. — Korn 1994: 71, text-figs 64b–c, 65a, 66a, 67c, 68c; 2006: text-fig. 3j. — Luppold *et al*. 1994: text-fig. 15b. — Korn & Feist 2007: 107, text-fig. 6e, g. — Korn & Weyer 2003: 100, pl. 2 figs 10–11, text-fig. 14g. — Kullmann 2009: text-fig. 3.1. — Korn & Klug 2015: text-fig. 12.6.1. — Becker *et al*. 2021: text-fig. 3l–m.

Diagnosis

Species of *Gattendorfia* with a conch reaching 70 mm diameter. Conch at 7 mm dm thickly discoidal, evolute (ww/dm ~0.45; uw/dm ~0.55); at 15 mm dm thickly discoidal, evolute (ww/dm ~0.55; uw/dm ~0.50); at 40 mm dm thickly discoidal, subevolute (ww/dm ~0.55; uw/dm ~0.40). Whorl profile in the juvenile stage trapezoidal, at 40 mm dm moderately depressed (ww/wh ~1.60); coiling rate moderately high (WER ~1.90). Venter broadly rounded throughout ontogeny, umbilical margin narrowly rounded in the adult stage. Growth lines fine, wide-standing, with convex course. Weak constrictions on the shell surface and prominent internal shell thickenings. Suture line with narrowly lanceolate external lobe and broadly lanceolate adventive lobe.

Etymology

Named after the occurrence of the species in the Rhenish Mountains.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 5 fig. 5a) and Korn (1994: text-fig. 66a); re-illustrated here in Fig. 68; GPIT-PV-63940.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63939, GPIT-PV-63946 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; MB.C.31147.1–2 •

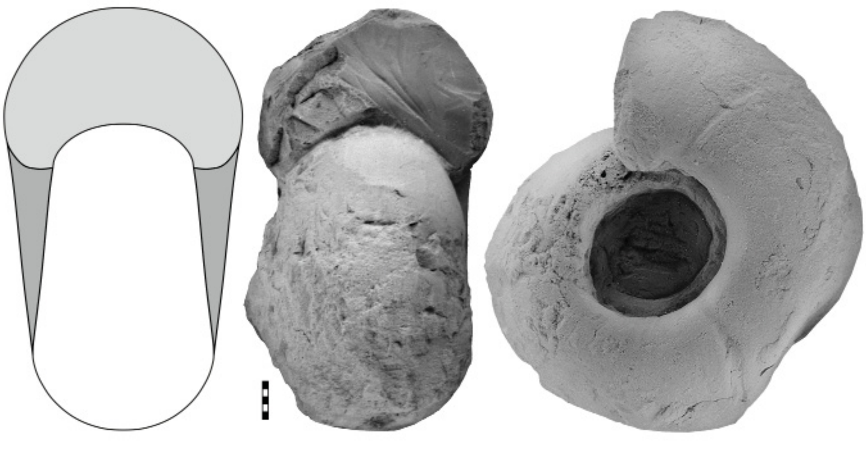

Fig. 68. *Gattendorfia rhenana* sp. nov.; holotype GPIT-PV-63940 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 5. Scale bar units = 1 mm.

1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31148 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6b; Weyer 1993–1994 Coll.; MB.C.31149.1–2 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 71; Weyer 1993–1994 Coll.; MB.C.5244.1 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 80; Weyer 1993–1994 Coll.; MB.C.5247.1.

Description

Holotype GPIT-PV-63940 is a moderately well-preserved specimen with 56 mm conch diameter; it is partly covered by shell remains (Fig. 68). It is thickly discoidal with a crescent-shaped, depressed whorl profile with a rounded umbilical margin and convex flanks continuing into the broadly arched venter. The specimen possesses fine growth lines and faint constrictions, which begin at the umbilical margin, from where they curve back to form a broad, shallow sinus on the venter. They are spaced at intervals of approximately 90 degrees and follow the course of the growth lines (Fig. 69C).

The sectioned paratype GPIT-PV-63946 allows the study of conch ontogeny in the growth interval between 5 and 28 mm diameter (Fig. 69A). In this growth interval, the conch becomes somewhat stouter (ww/dm increases from ~0.40 to ~0.60), while the umbilicus becomes narrower (uw/dm decreases from ~0.55 to ~0.40). The whorl profile changes from rounded trapezoidal to broad oval, but the last half whorl then shows a greater increase in whorl height. This is also expressed in the coiling rate (WER increases to ~1.90). The suture line has a lanceolate, weakly pouched external lobe, an evenly rounded, symmetrical ventrolateral saddle and a lanceolate lateral lobe (Fig. 69B).

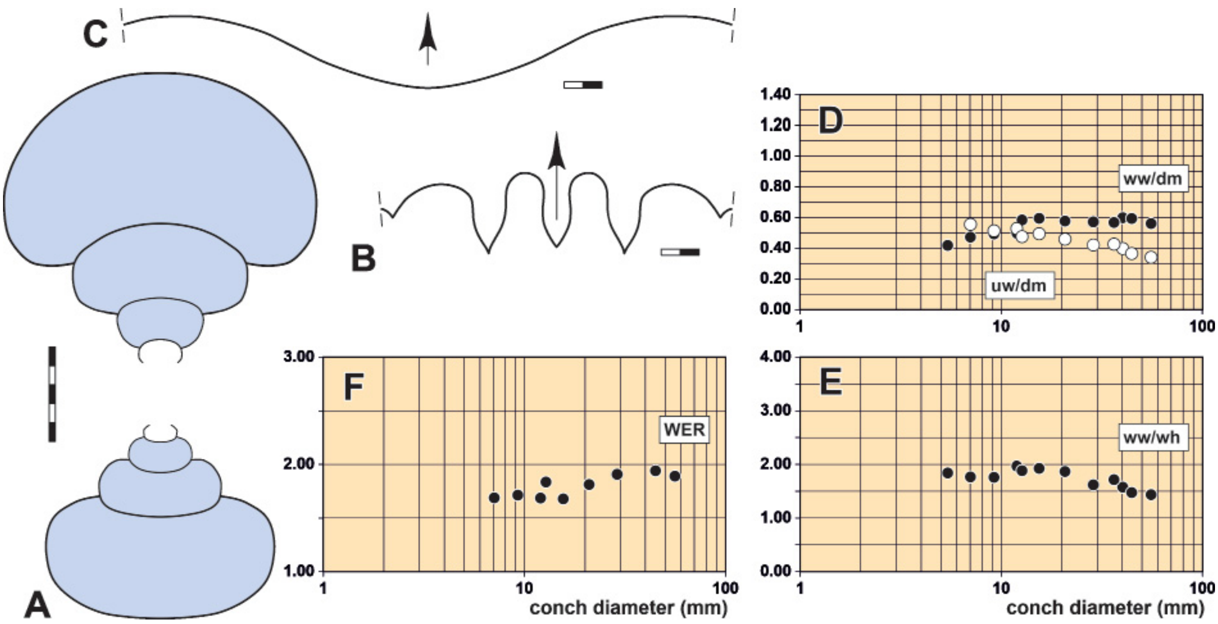

Fig. 69. *Gattendorfia rhenana* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63946 from bed 5. **B**. Suture line of paratype GPIT-PV-63946 from bed 5, at ww = 11.5 mm, wh = 6.0 mm. **C**. Growth line course of holotype GPIT-PV-63940 from bed 5, at ww ~ 32.0 mm, wh = 18.0 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 66. Conch measurements, ratios and rates of *Gattendorfia rhenana* sp. nov. from Oberrödinghausen and Hasselbachtal.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63940	55.8	31.4	21.8	19.1	15.2	0.56	1.44	0.34	1.89	0.30
GPIT-PV-63946	28.8	16.5	10.2	12.2	7.9	0.57	1.62	0.42	1.91	0.22
MB.C.5244.1	12.72	7.45	3.95	6.06	3.33	0.59	1.89	0.48	1.85	0.16
MB.C.5244.1	11.87	6.43	3.89	5.16	3.04	0.54	1.65	0.43	1.81	0.22

Table 67. Conch ontogeny of *Gattendorfia rhenana* sp. nov. from Oberrödinghausen and Hasselbachtal.

dm	conch shape	whorl cross section shape	whorl expansion
7 mm	discoidal; evolute (ww/dm ~0.45; uw/dm ~0.55)	moderately depressed; weakly embracing (ww/wh ~1.75; IZR ~0.15)	low (WER ~1.70)
15 mm	thickly discoidal; evolute (ww/dm ~0.58; uw/dm ~0.50)	moderately depressed; moderately embracing (ww/wh ~1.95; IZR ~0.25)	low (WER ~1.70)
30 mm	thickly discoidal; subevolute (ww/dm ~0.55; uw/dm ~0.40)	moderately depressed; moderately embracing (ww/wh ~1.65; IZR ~0.25)	moderate (WER ~1.90)
50 mm	thickly discoidal; subevolute (ww/dm ~0.55; uw/dm ~0.35)	weakly depressed; moderately embracing (ww/wh ~1.45; IZR ~0.25)	moderate (WER ~1.90)

Remarks

Specimens of the new species were usually attributed to *Gattendorfia subinvoluta* (Vöhringer 1960; Korn 1994). However, *G. subinvoluta* has a much more slender conch (ww/dm ~0.42 at 62 mm dm) than *G. rhenana* sp. nov., where the ww/dm ratio is ~0.56 at 56 mm dm. Such a difference can hardly be explained by intraspecific variation. However, both species are easier to distinguish by the shell constrictions developed in *G. rhenana*, which are absent in *G. subinvoluta*. Furthermore, *G. subinvoluta* has very coarse growth lines, which are fine in *G. rhenana*. Such differences in *G. subinvoluta* were explained by Becker with the "biogeographic separation through a narrow oceanic system". *Gattendorfia rhenana* differs from *G. schmidti* sp. nov. in the convex course of the growth lines and shell constrictions (concavo-convex in *G. schmidti*) and all other species with discoidal conch in the narrower umbilicus of the adult stage and the stouter conch.

Gattendorfia bella sp. nov.
urn:lsid:zoobank.org:act:4E3879AA-60BF-456A-938F-F71F8700C9B9
Figs 70–71; Tables 68–69

Gattendorfia tenuis – Vöhringer 1960: 153, text-fig. 29. — Korn 1994: 75, text-figs 66f, h.

Diagnosis

Species of *Gattendorfia* with a conch reaching 60 mm diameter. Conch at 5 mm dm thinly discoidal, evolute (ww/dm ~0.40; uw/dm ~0.55); at 15 mm dm thinly discoidal, evolute (ww/dm ~0.40; uw/dm ~0.50); at 40 mm dm thinly discoidal, evolute (ww/dm ~0.40; uw/dm ~0.50). Whorl profile in the juvenile stage depressed oval, at 40 mm dm weakly depressed (ww/wh ~1.35); coiling rate low (WER ~1.75). Venter broadly rounded throughout ontogeny, umbilical margin broadly rounded throughout ontogeny. Growth lines lamellar, wide-standing, with convex course. Deep constrictions on the shell surface and prominent internal shell thickenings.

Etymology

From the Latin '*bella*' = 'pretty'; referring to the regular conch shape and ornament.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; illustrated in Fig. 70A; MB.C.31151.1.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63942 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63989 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; MB.C.31150 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31151.2.

Description

Holotype MB.C.31151.1 is a rather well-preserved specimen with 37 mm conch diameter, showing two complete whorls (Fig. 70B). The conch is thinly discoidal and evolute (ww/dm = 0.43; uw/dm = 0.48) with rather a low coiling rate (WER = 1.74). The whorl profile is kidney-shaped (ww/wh = 1.28) with a broadly rounded venter that merges continuously with the rounded flanks and the rounded umbilical wall.

Large areas of the specimen are covered with shell remains. These show lamellar growth lines, which are already directed backwards at the umbilical seam; they extend in this direction across the flank and then form a shallow ventral sinus (Fig. 71D). The growth lines are coarsest on the flank, while they are only visible as fine lines on the venter. Shell constrictions spaced at slightly more than 90 degrees extend parallel to the growth lines. These constrictions are more prominent on the inner mould than on the shell surface.

The cross sections of specimens MB.C.31150 (30.5 mm dm; Fig. 71A), GPIT-PV-63942 (25.5 mm dm; Fig. 71B) and GPIT-PV-63989 (17 mm dm; Fig. 71C) show that the conch morphology experiences only minor changes above a conch diameter of 5 mm (Fig. 71E–G). The relative umbilical width remains the same at a value of about 0.50 and the ratio of whorl width and whorl height decreases only slightly from a value of 1.50 to 1.40. The coiling rate increases from 1.50 to 1.70.

Fig. 70. *Gattendorfia bella* sp. nov. from the Oberrödinghausen railway cutting. **A**. Paratype MB.C.31151.2 (Weyer 1993–1994 Coll.) from bed 3e. **B**. Holotype MB.C.31151.1 (Weyer 1993–1994 Coll.) from bed 3e. Scale bar units = 1 mm.

Table 68. Conch measurements, ratios and rates of *Gattendorfia bella* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31151.2	50.2	21.2	15.8	25.6	12.2	0.42	1.34	0.51	1.75	0.23
MB.C.31151.1	36.9	15.7	12.3	17.7	8.9	0.43	1.28	0.48	1.74	0.29
MB.C.31150	30.5	14.1	10.1	11.9	7.2	0.46	1.38	0.39	1.71	0.29
GPIT-PV-63942	25.5	11.0	8.0	11.4	6.3	0.43	1.38	0.45	1.77	0.21
GPIT-PV-63989	17.2	6.8	4.8	8.6	3.4	0.39	1.40	0.50	1.56	0.29

Remarks

Gattendorfia bella sp. nov. can easily be distinguished from the other species of the genus because the conch ontogeny undergoes only insignificant changes; all other species show a marked decrease in relative umbilical width from about 15 mm conch diameter onwards, while the umbilicus in *G. bella* retains about the same opening rate. A similar species is only *G. valdevoluta* sp. nov.; however, in this species the growth lines are much finer and the umbilicus is more open in the juvenile stage (uw/dm ~0.65 at 5 mm dm in contrast to ~0.55 in *G. bella*).

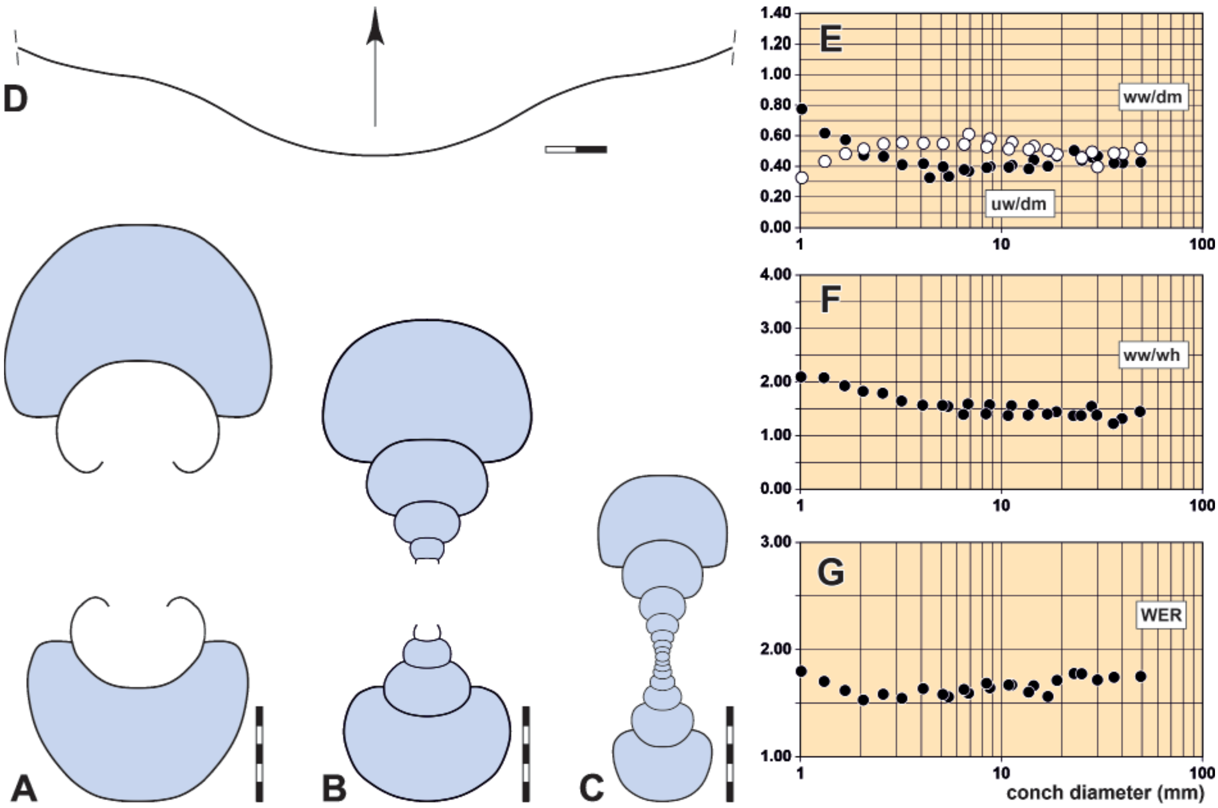

Fig. 71. *Gattendorfia bella* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype MB.C.31150 (Vöhringer Coll.) from bed 3b. **B**. Cross section of paratype GPIT-PV-63942 (Vöhringer Coll.) from bed 3d. **C**. Cross section of paratype GPIT-PV-63989 (Vöhringer Coll.) from bed 5. **D**. Growth line course of holotype MB.C.31151.1 (Weyer 1993–1994 Coll.) from bed 3e, at dm = 30.6 mm, ww = 8.5 mm, wh = 13.8 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 69. Conch ontogeny of *Gattendorfia bella* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm ~0.50; uw/dm ~0.50)	moderately depressed; moderately embracing (ww/wh ~1.75; IZR ~0.20)	low (WER ~1.55)
5 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.55)	moderately depressed; moderately embracing (ww/wh ~1.60; IZR ~0.20)	low (WER ~1.55)
15 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.50)	weakly depressed; moderately embracing (ww/wh ~1.45; IZR ~0.20)	low (WER ~1.65)
30 mm	thinly discoidal; subevolute (ww/dm ~0.40; uw/dm ~0.42)	weakly depressed; moderately embracing (ww/wh ~1.40; IZR ~0.20)	low (WER ~1.70)

Gattendorfia valdevoluta sp. nov.

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Figs 72–73; Tables 70–71

Gattendorfia tenuis – Vöhringer 1960: 153, text-fig. 28. — Korn 1994: 75, text-figs 66e.

Diagnosis

Species of *Gattendorfia* with a conch reaching 50 mm diameter. Conch at 5 mm dm extremely discoidal, very evolute (ww/dm ~0.30; uw/dm ~0.65); at 15 mm dm thinly discoidal, evolute (ww/dm ~0.40; uw/dm ~0.50); at 40 mm dm thinly discoidal, subevolute (ww/dm ~0.40; uw/dm ~0.40). Whorl profile in the juvenile stage depressed oval, at 40 mm dm weakly depressed (ww/wh ~1.10); coiling rate low (WER ~1.70). Venter broadly rounded throughout ontogeny, umbilical margin narrowly rounded in the adult stage. Growth lines fine, narrow-standing, with convex course. Deep constrictions on the shell surface, prominent internal shell thickenings.

Etymology

From the Latin '*valte*' = 'very' and '*evoluta*' = 'evolute'; referring to the extremely evolute juvenile conch.

Fig. 72. *Gattendorfia valdevoluta* sp. nov. from the Oberrödinghausen railway cutting. **A**. Holotype MB.C.31155 (Weyer 1993–1994 Coll.) from bed 3d2. **B**. Paratype MB.C.31154 (Weyer 1993–1994 Coll.) from bed 2b. Scale bar units = 1 mm.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; illustrated in Fig. 72A; MB.C.31155.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63996 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; MB.C.31152 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; MB.C.31153 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2b; Weyer 1993–1994 Coll.; MB.C.31154.

Description

Holotype MB.C.31155 has a diameter of 17 mm and is preserved with some shell remains (Fig. 72A). The conch is serpenticonic with a very wide umbilicus (ww/dm = 0.42; uw/dm = 0.55). The whorl profile is kidney-shaped (ww/wh = 1.46) with broadly rounded venter and flanks; the umbilical margin is broadly rounded and the umbilical wall is convex. The shell bears fine growth lines, which are slightly directed

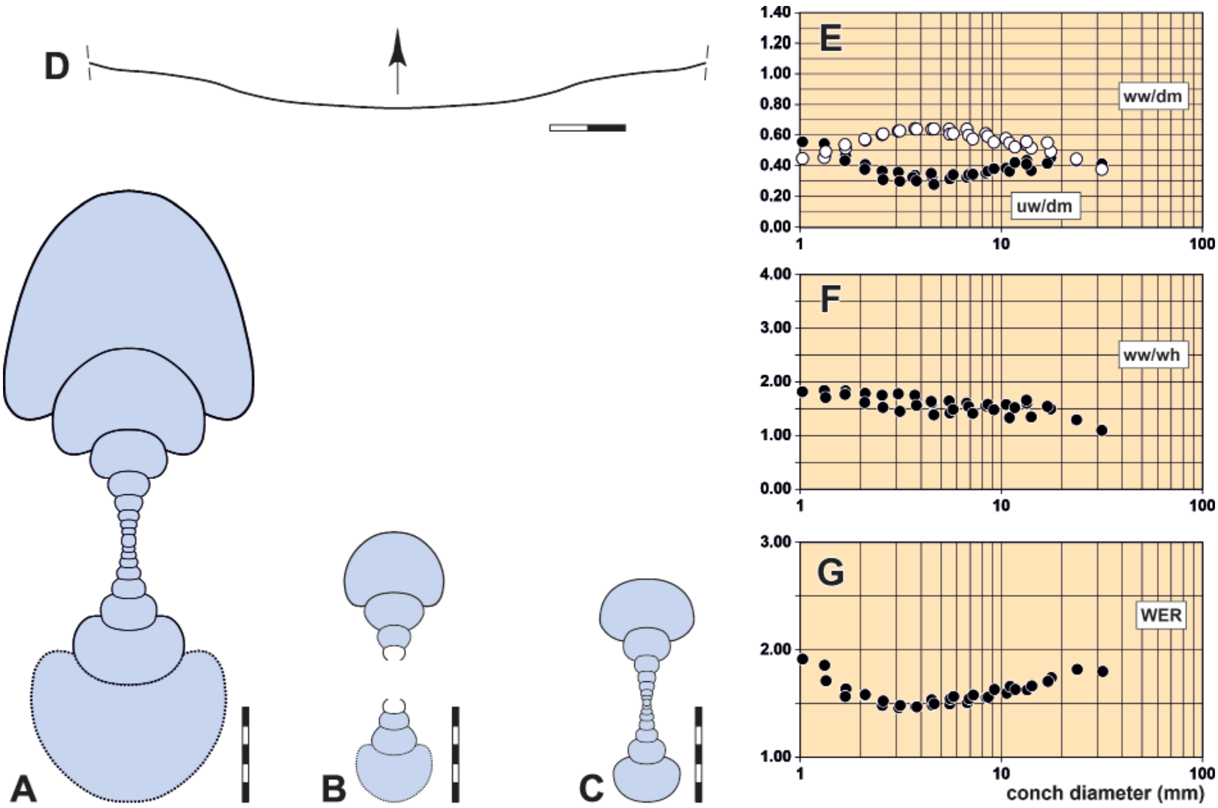

Fig. 73. *Gattendorfia valdevoluta* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63996 (Vöhringer Coll.) from bed 2. **B**. Cross section of paratype MB.C.31152 (Vöhringer Coll.) from bed 3a. **C**. Cross section of paratype MB.C.31153 (Vöhringer Coll.) from bed 3d. **D**. Growth line course of holotype MB.C.31155 (Weyer 1993–1994 Coll.) from bed 3d2, at dm = 17.0 mm, ww = 7.0 mm, wh = 4.8 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 70. Conch measurements, ratios and rates of *Gattendorfia valdevoluta* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63996	32.1	13.2	12.1	12.1	8.1	0.41	1.09	0.38	1.80	0.32
MB.C.31155	17.1	7.1	4.9	9.4	4.0	0.42	1.46	0.55	1.70	0.18
MB.C.31152	14.2	5.2	3.9	7.3	3.2	0.37	1.34	0.52	1.66	0.18
MB.C.31153	11.8	4.9	3.3	6.1	2.5	0.42	1.52	0.52	1.63	0.22

Table 71. Conch ontogeny of *Gattendorfia valdevoluta* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.55)	moderately depressed; weakly embracing (ww/wh ~1.75; IZR ~0.12)	low (WER ~1.55)
5 mm	extremely discoidal; very evolute (ww/dm ~0.30; uw/dm ~0.65)	moderately depressed; weakly embracing (ww/wh ~1.60; IZR ~0.12)	low (WER ~1.55)
15 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.50)	weakly depressed; moderately embracing (ww/wh ~1.45; IZR ~0.20)	low (WER ~1.70)
30 mm	thinly discoidal; subevolute (ww/dm ~0.40; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.10; IZR ~0.30)	moderate (WER ~1.80)

backwards on the flank and run with a very shallow sinus across the venter (Fig. 73D). There are several shell constrictions that follow the course of the growth lines. These constrictions are arranged in nearly regular distances of 90 degrees, so they have a position almost at the same angle on the last two whorls.

Paratype MB.C.31154 has 11 mm diameter and is serpenticonic like the inner whorls of the holotype (Fig. 72B). A difference from the holotype is, however, that the specimen has irregularly distributed constrictions; the last two of them are arranged at right angles to each other.

The sectioned specimen GPIT-PV-63996 shows the ontogenetic development of the conch morphology from the initial stage to 32 mm diameter (Fig. 73A). The conch begins with a serpenticonic morphology and has a rounded-trapezoidal whorl profile that changes into a broad oval profile at about 7 mm conch diameter. At about 14 mm diameter there is a rapid increase in whorl height and at 32 mm diameter, the width of the profile is only slightly greater than the height. At this stage there is already quite a distinct umbilical edge from which the flanks converge to the relatively narrow venter.

The ontogenetic trajectories show moderate changes in the cardinal conch parameters (Fig. 73E–G). The ww/dm and uw/dm trajectories are biphasic and run diametrically; the ww/dm ratio is lowest at about 4 mm dm (~0.30), while the uw/dm ratio is highest (~0.65). At 18 mm dm, both values are about equal (~0.50). The width of the whorl profile decreases smoothly from ~1.80 to ~1.50 between 2 and 20 mm conch diameter; thereafter the decrease is slightly more rapid to ~1.10 at 32 mm dm.

Remarks

Gattendorfia valdevoluta sp. nov. is, according to present knowledge, the species of the genus with the widest umbilical opening in the juvenile stage; the uw/dm ratio exceeds the value of ~0.65 at 5 mm conch diameter. This ratio reaches, in other discoidal species, only ~0.55 in *G. rhenana* sp. nov. and *G. bella* sp. nov. or ~0.60 in *G. schmidti* sp. nov. However, *G. valdevoluta* clearly differs from *G. schmidti* in the course of the constrictions, which are almost straight and slightly backwardly directed on the flank in *G. valdevoluta*, but in *G. schmidti* they extend with a concavo-convex course.

Gattendorfia schmidti sp. nov.
urn:lsid:zoobank.org:act:7AE42990-A874-40D5-998E-5D9DC76284E2
Figs 74–75; Tables 72–73

Gattendorfia subinvoluta – Schmidt 1924: 151, pl. 8 figs 7–8; 1925: 535, pl. 19 fig. 8.
Gattendorfia tenuis – Vöhringer 1960: 153, pl. 5 fig. 6, text-fig. 38. —Weyer 1965: 447, pl. 6 fig. 1. — Bartzsch & Weyer 1986: pl. 2 fig. 2. — Korn 1994: 75, text-figs 65b, 66g, 67d, 68b; 2006: text-fig. 3i.
Gattendorfia involuta – Becker in Becker *et al*. 2021: 409.

Diagnosis

Species of *Gattendorfia* with a conch reaching 70 mm diameter. Conch at 5 mm dm thinly discoidal, very evolute (ww/dm ~0.40; uw/dm ~0.60); at 15 mm dm thickly discoidal, evolute (ww/dm ~0.50; uw/dm ~0.45); at 40 mm dm thickly discoidal, subinvolute (ww/dm ~0.50; uw/dm ~0.25). Whorl profile in the juvenile stage depressed oval, at 40 mm dm circular (ww/wh ~1.00); coiling rate moderately high (WER ~1.85). Venter broadly rounded throughout ontogeny, umbilical margin narrowly rounded in the adult stage. Growth lines lamellar, wide-standing, with concavo-convex course. Deep constrictions on the shell surface and prominent internal shell thickenings. Suture line with lanceolate, very weakly pouched external lobe and V-shaped adventive lobe.

Etymology

Named after Hermann Schmidt (1892–1978) in appreciation of his studies on the Devonian–Carboniferous boundary.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 5 fig. 6), Korn (1994: text-fig. 65b) and Korn (2006: text-fig 3i); re-illustrated here in Fig. 74A; GPIT-PV-63952.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; GPIT-PV-63951 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63882 •

Fig. 74. *Gattendorfia schmidti* sp. nov. from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63952 (Vöhringer Coll.) from bed 1. **B**. Paratype MB.C.31157.1 (Vöhringer Coll.) from bed 3c. Scale bar units = 1 mm.

3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31156.1–3 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; MB.C.31157.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31158.1–2.

Description

Holotype GPIT-PV-63952 is a moderately preserved specimen with a 56 mm diameter of the conch. A part of the aperture is broken off, so that the illustration shown here (Fig. 74A) seems to figure a smaller specimen than that shown by Vöhringer (1960: pl. 5 fig. 6). The specimen is, at 40 mm diameter, thickly discoidal and subinvolute (ww/ dm = 0.47; uw/dm = 0.23) with a moderately high coiling rate (WER = 1.84). The umbilical margin is quite distinct and separates the almost vertical umbilical wall from the evenly convex flanks, which converge to the continuously rounded venter.

Only small shell remains are preserved on the holotype. It can be assumed that the growth lines extend parallel to the prominent constrictions, which are arranged at 90 degrees. These run in an almost straight line across the flank, forming a low ventrolateral projection and bending back to form a deeper ventral

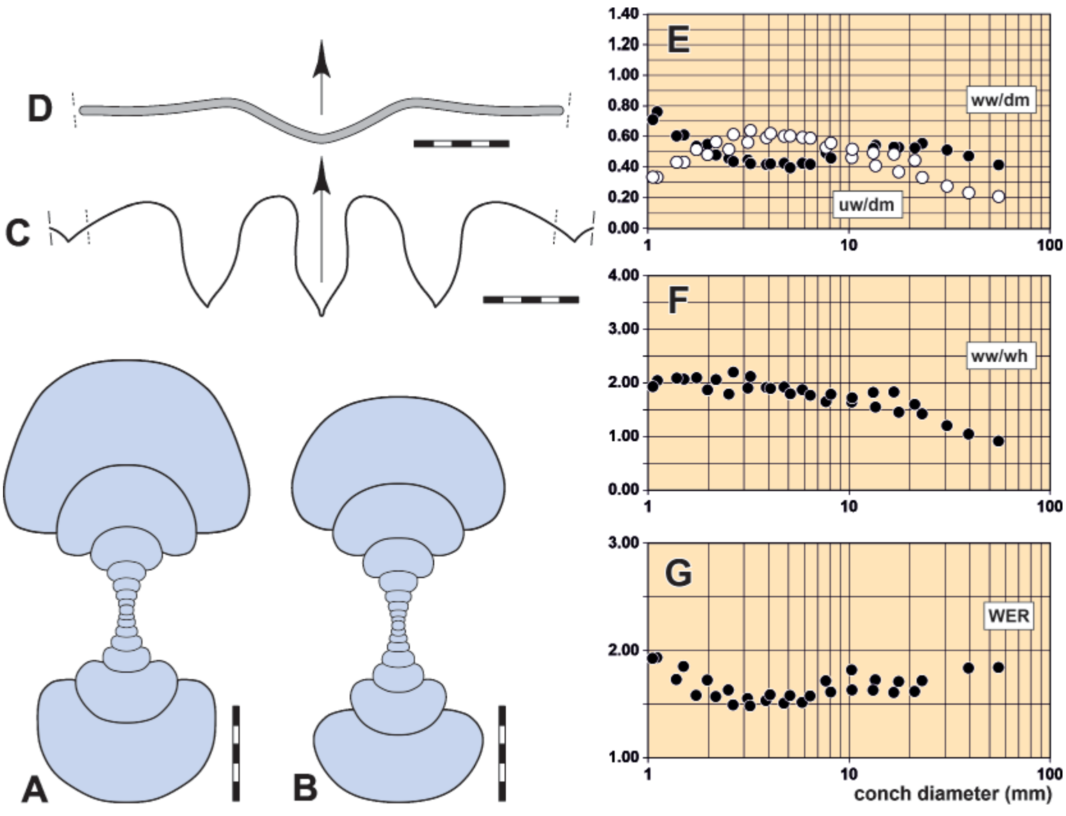

Fig. 75. *Gattendorfia schmidti* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype MB.C.31156.1 (Vöhringer Coll.) from bed 2. **B**. Cross section of paratype MB.C.31157.2 (Vöhringer Coll.) from bed 3c. **C**. Suture line of holotype GPIT-PV-63952 (Vöhringer Coll.) from bed 1, at ww = 16.5 mm, wh = 9.5 mm. **D**. Constriction course of holotype GPIT-PV-63952 (Weyer 1993–1994 Coll.) from bed 1, at ww = 16.5 mm, wh = 9.5 mm. **E**–**G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 72. Conch measurements, ratios and rates of *Gattendorfia schmidti* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63952	56.5	23.4	25.8	11.6	14.9	0.41	0.91	0.21	1.84	0.42
GPIT-PV-63952	40.0	18.9	18.2	9.2	10.5	0.47	1.04	0.23	1.84	0.42
MB.C.31156.1	23.3	13.0	9.1	7.7	5.6	0.56	1.42	0.33	1.72	0.39
MB.C.31157.2	21.4	11.2	7.0	9.5	4.6	0.52	1.60	0.44	1.62	0.35

Table 73. Conch ontogeny of *Gattendorfia schmidti* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm ~0.50; uw/dm ~0.50)	moderately depressed; moderately embracing (ww/wh ~1.90; IZR ~0.15)	low (WER ~1.60)
5 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.60)	moderately depressed; moderately embracing (ww/wh ~1.80; IZR ~0.15)	low (WER ~1.55)
15 mm	thickly discoidal; subevolute (ww/dm ~0.50; uw/dm ~0.40)	moderately depressed; strongly embracing (ww/wh ~1.75; IZR ~0.30)	low (WER ~1.70)
30 mm	thickly discoidal; subinvolute (ww/dm ~0.50; uw/dm ~0.25)	weakly depressed; strongly embracing (ww/wh ~1.25; IZR ~0.40)	moderate (WER ~1.80)
30 mm	thinly discoidal; subinvolute (ww/dm ~0.42; uw/dm ~0.20)	weakly compressed; strongly embracing (ww/wh ~0.90; IZR ~0.40)	moderate (WER ~1.85)

sinus (Fig. 75D). The suture line is typical of *Gattendorfia* and has a lanceolate external lobe with weakly curved flanks and a weakly asymmetrical, narrowly V-shaped adventive lobe (Fig. 75C).

The cross sections of paratypes MB.C.31156.1 and MB.C.31157.2 show the ontogenetic development of the conch up to a diameter of 23 mm (Fig. 75A–B). Both show very evolute inner whorls; the uw/dm ratio ranges from 0.55 to 0.60 between 2 and 8 mm conch diameter. Later in ontogeny, the whorls start to overlap the preceding whorl more strongly and already at 23 mm diameter, the uw/dm ratio has decreased to a value of ~0.33. Paratype MB.C.31156.1 shows, at this diameter, already the transformation of the broad-oval whorl profile of the juvenile stage into the adult stage with a distinctly pronounced umbilical margin.

Remarks

The specimen chosen here as the holotype of the new species *Gattendorfia schmidti* sp. nov. was already determined by Becker (in Becker *et al.* 2021) as the neotype of the species "*Gattendorfia involuta* Schindewolf, 1924". However, this determination seriously complicated the problematic nomenclatorial circumstances of that species. For this reason, it is necessary to review and discuss the course of the research history concerning the species "*Gattendorfia involuta*".

In his brief discussion of the ammonoid occurrences of Saalfeld in Thuringia, Schindewolf (1924: 105) stated that he distinguished three species of *Gattendorfia*, namely *G. subinvoluta* and the two new species *G. ventroplana* and *G. involuta*. However, he has described and illustrated only *G. ventroplana* (Schindewolf 1923: 409, pl. 16, fig. 10, text-fig. 14b), although under the species *G. subinvoluta*. For the third species *G. involuta* he provided only a brief, uninformative definition: "*G. involuta* nov. sp., eine gegenüber *G. subinvoluta* flacher scheibenförmige, enger genabelte und hochmündigere Spezies." = "*G. involuta* nov. sp., a species more thinly discoidal, more closely umbilicate and more high-apertured than *G. subinvoluta*." Schindewolf did not explain where the material of "*G. involuta*" came from; however, it is very likely that it either came from Gattendorf or Saalfeld. It is important to mention that at that time Schindewolf still held the view that the *Gattendorfia* Stufe was older than the *Wockluneria* Stufe.

Schindewolf (1926b: 92) then explained that after writing his article on the ammonoid assemblages of Saalfeld (Schindewolf 1924), he had the opportunity to study the Devonian–Carboniferous boundary section near Wocklum in the Rhenish Mountains in greater detail. During this visit he realised that the *Gattendorfia* Stufe is not older but younger than the *Wockluneria* Stufe.

Schindewolf (1952: 297) discussed again his previously established third species "*Gattendorfia involuta* Schindewolf, 1924". In this discussion, he stated that this species had no valid name and that he would refer to it as the new species *Gattendorfia tenuis*. In this article, he described and illustrated a specimen of 73 mm diameter from Saalfeld as the type for that species. He also said that he had previously owned excellently preserved specimens from Oberrödinghausen in the Rhenish Mountains and Ebersdorf (Dzikowiec) in Silesia. A rather well-preserved specimen from Ebersdorf, collected by Schindewolf in 1918 and described as *Gattendorfia tenuis* by Weyer (1965. 447), belongs to the new species *G. schmidti* sp. nov. described here. From what has already been said above, it is clear that these specimens Schindewolf mentioned did not belong to the type series.

Vöhringer (1960: 153) used the species name *G. tenuis* for specimens from Oberrödinghausen, which however belong to three different species. He presented a specimen with a diameter of 57 mm as a photograph and also cross sections of two other, smaller specimens. The assignment of his large specimen to *G. tenuis* is astonishing, because this specimen deviates considerably from the holotype in the direction of the constrictions. Nevertheless, this concept was accepted by Korn (1994, 2006).

Becker (in Becker *et al.* 2021: 409) saw the need to revive the hitherto unused species name "*Gattendorfia involuta* Schindewolf, 1924" and designated specimen GPIT-PV-63952, illustrated by Vöhringer (1960: pl. 5 fig. 6) as *G. tenuis*, as the neotype for "*G. involuta*". However, this procedure is to be criticised for several reasons:

1. The neotype does not come from the type region. The claim by Becker that Schindewolf possessed syntypes from Oberrödinghausen (and that this is one of the two type localities) is not correct (see above), since Schindewolf only carried out extensive studies in the Rhenish Mountains Devonian–Carboniferous boundary sections after writing his 1924 article.
2. With the determination of a neotype from another region, the species "*G. involuta*" would become a widespread species by definition, but not by empirical data.
3. The same is true for the stratigraphic range of the species. All ammonoid specimens from Gattendorf come from the lowest part of the *Gattendorfia* Limestone (regional *Acutimitoceras acutum* Zone), while the "neotype" comes from the highest bed of the *Gattendorfia* Limestone (*Eocanites delicatus* Zone). With the neotype proposal, *Gattendorfia involuta* would become a long-ranging species by definition, not by empirical data.
4. The determination of a neotype is unnecessary, because a specimen of "*G. involuta*" personally labelled by Schindewolf is present in the collection of the Museum für Naturkunde, Berlin; this specimen was probably taken by him when he moved from Marburg to Berlin in 1927.
5. The illustration of another supposedly "typical" specimen by Becker (in Becker *et al.* 2021: text-fig. 15) adds to the confusion. The poorly preserved specimen is from the basal bed of the Hangenberg Limestone, while the proposed neotype is from the highest bed of the unit. The specimen cannot be considered typical at all because it does not seem to have constrictions like the proposed neotype.

The new species *Gattendorfia schmidti* sp. nov. is based on a specimen found by Vöhringer and named by him as *G. tenuis*. Vöhringer stated that he had 22 specimens of this species; of these he sectioned several specimens and illustrated two of them. However, these two differ in their growth trajectories and are attributed here to other species (*G. bella* sp. nov., *G. valdevoluta* sp. nov.). *Gattendorfia schmidti* differs from *G. tenuis* in the course of growth lines and constrictions, which in *G. schmidti* are concavo-convex and form a ventrolateral projection, whereas in *G. tenuis* they run with a convex curve across the flanks and merge continuously into the ventral sinus. In addition, the constrictions in *G. tenuis* are limited to the outer half of the flank and the venter, whereas in *G. schmidti* they already begin at the umbilicus. *Gattendorfia schmidti* has a stouter conch than *G. tenuis*; the ww/dm ratio is about 0.40 in *G. schmidti* but only 0.32 in *G. tenuis*.

Gattendorfia costata Vöhringer, 1960
Fig. 76; Table 74

Gattendorfia costata Vöhringer, 1960: 152, pl. 5 fig. 7.

Gattendorfia costata – Bartzsch & Weyer 1982: 19, text-fig. 4.2. — Korn 1994: 73, text-fig. 65c.

non *Gattendorfia costata* Vöhringer 1960: 152, text-figs 27, 37 (only). — Weyer 1977: 173, pl. 1 figs 1, 7. — House 1985a: 126, pl. 6.7.14 fig. d. — Gordon 1986: 18, text-figs 6.1–6.3, 8.3. — Korn 1994: 73, text-figs 66d, 67a (only). — Dzik 1997: 107, text-fig. 28f. — Korn & Weyer 2003: 100, text-fig. 14h–i. — Korn *et al*. 2003b: 1125, text-fig. 3b. — Sprey 2002: pl. 4 fig. 7.

Diagnosis
Species of *Gattendorfia* with a conch reaching 50 mm diameter. Conch at 30 mm dm thickly pachyconic, evolute (ww/dm ~0.80; uw/dm ~0.45). Whorl profile at 30 mm dm extremely depressed (ww/wh ~2.85); coiling rate very low (WER ~1.48). Venter broadly rounded, umbilical margin narrowly rounded. Without constrictions on the shell surface and without internal shell thickenings, with short ribs on the umbilical margin.

Material examined

Holotype
GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; illustrated by (Vöhringer 1960: pl. 5 fig. 7), Korn (1994: text-fig. 65c) and Sprey (2002: pl. 4 fig. 7); re-illustrated here in Fig. 76; GPIT-PV-63941.

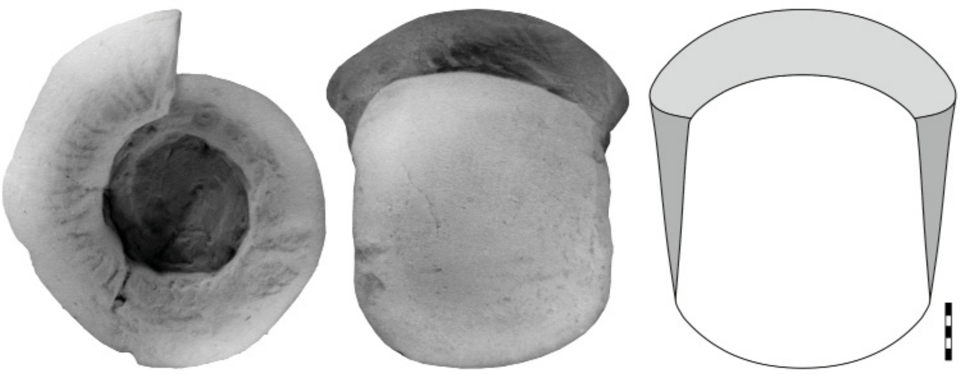

Fig. 76. *Gattendorfia costata* Vöhringer, 1960 from the Oberrödinghausen railway cutting; photographs and dorsal view reconstruction of holotype GPIT-PV-63941 (Vöhringer Coll.) from bed 2. Scale bar units = 1 mm.

Table 74. Conch measurements, ratios and rates of *Gattendorfia costata* Vöhringer, 1960 from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63941	31.7	26.8	9.6	14.1	5.7	0.84	2.79	0.44	1.49	0.40

Description

Holotype GPIT-PV-63941 is a rather poorly preserved specimen with 32 mm diameter of the conch (Fig. 76). It is partly ground and therefore shows hardly any remains of the shell. The conch is barrel-shaped (ww/dm = 0.84) with a very broadly rounded venter, a rather narrowly rounded umbilical margin and a convex umbilical wall. The umbilicus is rather wide (uw/dm = 0.44) and the coiling rate is very low (WER = 1.49). Little can be said about the ornament; short, blunt riblets are formed on the umbilical margin.

Remarks

Vöhringer (1960) merged at least three morphological easily distinguishable species under the name *Gattendorfia costata*. (1) The first of these, defined by the holotype, is characterised by a wide umbilicus (uw/dm ~0.45) and weak nodes on the raised umbilical margin. (2) The second of these species, described here as *G. corpulenta* sp. nov., has a much narrower umbilicus with a uw/dm ratio of ~0.30, such as the cross section which he published (Vöhringer 1960: text-fig. 27) and short backwardly directed ribs. (3) The third, not explicitly mentioned by Vöhringer (1960) and described here as *Zadelsdorfia oblita* sp. nov., also has a much narrower umbilicus (uw/dm = 0.30) and lacks ribs but possesses concavo-convex internal shell thickenings. Another separating criterion to distinguish between *G. costata* and *G. corpulenta* is the course of the constrictions, which are concavo-convex with a ventrolateral projection and a rather narrow ventral sinus in *G. costata* but with convex course without ventrolateral projection and with broad ventral sinus in the new species *G. corpulenta*.

Gattendorfia corpulenta sp. nov.

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Figs 77–78; Tables 75–76

Gattendorfia crassa – Schindewolf 1952: 296, pl. 2 fig. 5, text-figs 16–17.

Gattendorfia costata – Vöhringer 1960: 152, text-figs 27, 37. — Dzik: 107, text-fig. 28f. — Weyer 1977: 173, pl. 1 figs 1, 7. — Korn 1994: 73, text-figs 66d, 67a. — Korn & Weyer 2003: 100, text-fig. 14h–i.

Diagnosis

Species of *Gattendorfia* with a conch reaching 70 mm diameter. Conch at 5 mm dm thickly discoidal, evolute (ww/dm ~0.58; uw/dm ~0.50); at 15 mm dm thinly pachyconic, subevolute (ww/dm ~0.70; uw/dm ~0.40); at 40 mm dm thickly pachyconic, subinvolute (ww/dm ~0.75; uw/dm ~0.25). Whorl profile in the juvenile stage crescent-shaped, at 40 mm dm moderately depressed (ww/wh ~1.65); coiling rate moderately high (WER ~1.85). Venter broadly rounded throughout ontogeny, umbilical margin narrowly rounded in the adult stage. Growth lines fine, wide-standing, with convex course. Weak constrictions on the shell surface and weak internal shell thickenings; sharp, short ribs on the inner flank. Suture line with lanceolate external lobe and V-shaped adventive lobe.

Etymology

From the Latin '*corpulenta*', referring to the stout conch.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; illustrated in Fig. 77A; MB.C.31160.1.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; GPIT-PV-63950 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63896, GPIT-PV-63936 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; MB.C.31159 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; MB.C.31160.1–3 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; MB.C.31161 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; MB.C.31162 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Korn 1982 Coll.; MB.C.31163 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31164 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 76; Weyer 1993–1994 Coll.; MB.C.5247.4.

Description

Holotype MB.C.31160.1 is a specimen, which had been sectioned already by Vöhringer, but it has no internal whorls preserved. The specimen has a diameter of 44 mm and is thickly pachyconic and subinvolute (ww/dm = 0.74; uw/dm = 0.24) with a narrowly rounded umbilical margin, a convex umbilical wall and broadly rounded flanks and venter (Fig. 77A). There are fine, sharp ribs on the umbilical margin, spaced 1.5 to 2 mm apart, which extend over a distance of about 8 mm on the flanks. The ribs are directed slightly backwards. A faint constriction is visible, also directed backwards, forming a broad, shallow sinus across the venter.

Paratype MB.C.31164 is a fragment of a specimen of 40 mm conch diameter (Fig. 77B). The conch morphology can only be partially reconstructed, but it apparently differs only slightly from the holotype. Remains of the shell on the inner half of the flank are preserved, showing lamellar growth lines with a backward course. An internal shell thickening also has a posteriorly directed course.

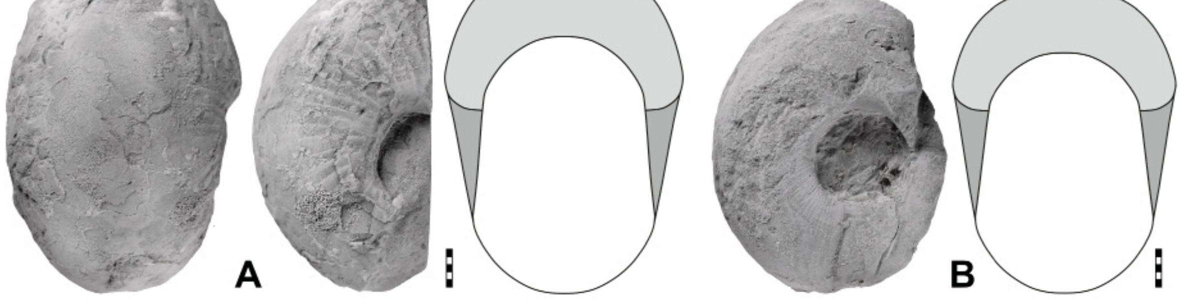

Fig. 77. *Gattendorfia corpulenta* sp. nov. from the Oberrödinghausen railway cutting; photographs and dorsal view reconstructions. **A**. Holotype MB.C.31160.1 (Vöhringer Coll.) from bed 3.4. **B**. Paratype MB.C.31164 (Weyer 1993–1994 Coll.) from bed 3e. Scale bar units = 1 mm.

Paratype GPIT-PV-63896 is a sectioned specimen with 27.7 mm diameter of the conch; it allows the study of five whorls (Fig. 78B). The section shows that the conch becomes continuously stouter in the interval between 5 and 27 mm diameter (ww/dm increases from ~0.50 to ~0.85). The whorl profile is very similar in all whorls, only the last half whorl shows a more pronounced subangular umbilical margin. The suture line of this paratype has a lanceolate external lobe with weakly divergent flanks, an inverted U-shaped ventrolateral saddle and an asymmetric adventive lobe with steep ventral and sigmoidally curved dorsal flank (Fig. 78D).

Paratype MB.C.31162 is another sectioned specimen showing the morphological development of the conch geometry of all whorls up to a diameter of 15 mm (Fig. 78C). It complements paratype GPIT-PV-63896; it is remarkable that the whorl profile shows almost no ontogenetic changes.

The diagrams of the ontogenetic trajectories show an inconsistent picture with respect to the cardinal conch parameters (Fig. 78E-G). The ww/dm trajectory is triphasic, with the first phase describing a decrease in the ww/dm ratio from about 0.90 at 1 mm dm to a minimum of ~0.47 at 5 mm dm; the second phase describing an increase to ~0.85 at 27.7 mm dm. The third phase with reduction of the ww/dm ratio is only visible in specimens over 30 mm in diameter. The uw/dm curve is biphasic and runs diametrically to the ww/dm curve. It shows the highest value of ~0.58 at a diameter of 5 mm. In contrast, the ww/wh trajectory does hardly change between 1 and 27 mm conch diameter and ranges between

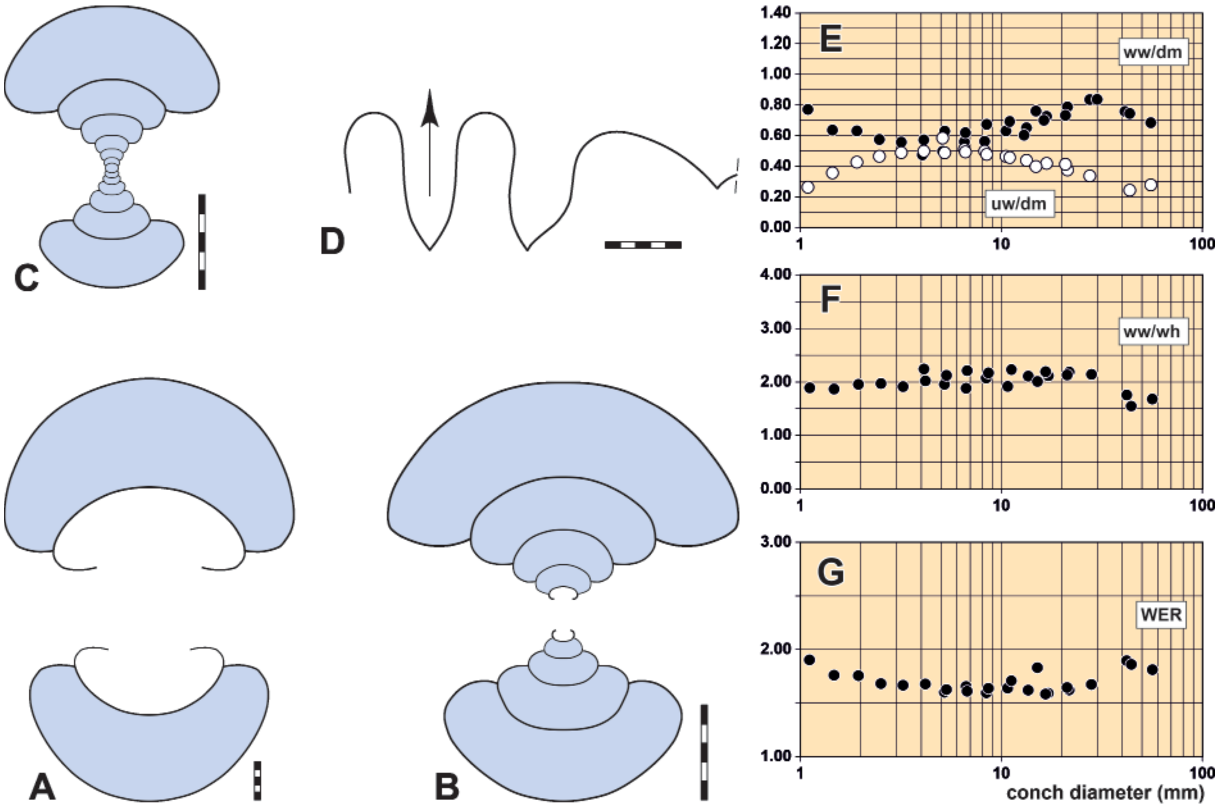

Fig. 78. *Gattendorfia corpulenta* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype MB.C.31159 (Vöhringer Coll.) from bed 3b. **B**. Cross section of paratype GPIT-PV-63896 (Vöhringer Coll.) from bed 3d. **C**. Cross section of paratype MB.C.31162 (Vöhringer Coll.) from an unknown bed. **D**. Suture line of paratype GPIT-PV-63896 from bed 3d, at dm = 30.6 mm, ww = 4.5 mm, wh = 13.0 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 75. Conch measurements, ratios and rates of *Gattendorfia corpulenta* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31159	55.9	38.2	22.9	15.1	14.4	0.68	1.67	0.27	1.81	0.37
MB.C.31160.1	43.8	32.6	21.2	10.3	11.7	0.74	1.54	0.24	1.86	0.45
GPIT-PV-63896	27.7	23.2	10.8	9.2	6.3	0.84	2.14	0.33	1.67	0.42
MB.C.31160.2	20.9	15.3	7.2	8.5	4.6	0.73	2.13	0.41	1.64	0.36
MB.C.31162	14.9	11.3	5.6	5.8	3.9	0.76	2.01	0.39	1.83	0.31

Table 76. Conch ontogeny of *Gattendorfia corpulenta* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; subevolute (ww/dm ~0.60; uw/dm ~0.40)	moderately depressed; moderately embracing (ww/wh ~1.95; IZR ~0.20)	low (WER ~1.70)
5 mm	thickly discoidal; evolute (ww/dm ~0.55; uw/dm ~0.50)	strongly depressed; moderately embracing (ww/wh ~2.05; IZR ~0.25)	low (WER ~1.60)
15 mm	thinly pachyconic; subevolute (ww/dm ~0.70; uw/dm ~0.40)	strongly depressed; strongly embracing (ww/wh ~2.10; IZR ~0.40)	low (WER ~1.60)
30 mm	thickly pachyconic; subevolute (ww/dm ~0.80; uw/dm ~0.30)	strongly depressed; strongly embracing (ww/wh ~2.15; IZR ~0.40)	low (WER ~1.70)
50 mm	thinly pachyconic; subinvolute (ww/dm ~0.70; uw/dm ~0.25)	moderately depressed; strongly embracing (ww/wh ~1.60; IZR ~0.40)	moderate (WER ~1.80)

1.85 and 2.25. Only with larger specimens over 40 mm diameter does the value decrease to 1.50–1.75. The WER trajectory is monophasic and shows a slow increase from 1.50 at 2 mm diameter to 1.67 at 27 mm dm.

Remarks

Gattendorfia corpulenta sp. nov. differs from most species of the genus by its stout conch form. *Gattendorfia corpulenta* differs in the narrower umbilicus from *G. costata*; at 30 mm dm, the uw/dm ratio is ~0.30 in *G. corpulenta*, but ~0.45 in *G. costata*. A superficially rather similar species is *Z. oblita* sp. nov., but this has constrictions that are clearly concavo-convex in their course.

Superficially, *Zadelsdorfia crassa* is also similar, but at a conch diameter of 30 mm more slender (ww/dm ~0.65) than *G. corpulenta* (ww/dm ~0.80); *Z. crassa* does not possess ribs and has a pouched external lobe.

Gattendorfia immodica sp. nov.

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Fig. 79; Table 77

Diagnosis

Species of *Gattendorfia* with a globular, evolute conch (ww/dm ~0.90; uw/dm ~0.50) at 10 mm dm. Whorl profile at 10 mm dm extremely depressed (ww/wh ~3.00); coiling rate low (WER ~1.65). Venter flattened, umbilical margin pronounced. Without constrictions on the shell surface and without internal shell thickenings, with parabolic ribs on the umbilical margin.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; illustrated in Fig. 79; MB.C.31165.

Etymology

From the Latin adjective ‘*immodica*’ = ‘immoderate’, referring to the extraordinary conch shape.

Description

Holotype MB.C.31165 (nearly 11 mm dm) demonstrates the spectacular conch morphology of the immature stage (Fig. 79). It has the shape of a thick barrel (ww/dm ~0.90) and is evolute (uw/dm ~0.50) with a strongly depressed whorl profile (ww/wh ~3.00). Furthermore, the whorl profile possesses a raised umbilical wall that is accompanied on the umbilical and the flank side by an incurved shell portion of the shell wall. It separates the sinuous umbilical wall from the broad, flattened area of flanks and venter.

The shell surface bears lamellar growth lines running backwards along the umbilical wall; they are coarsest where they cross the raised umbilical margin. They extend in a broad and low arc across the venter. The umbilical wall of the last half volution bears six ribs, which turn back sharply, much more so than the growth lines, and thicken near the umbilical margin to form parabolic nodes. The penultimate whorl, visible in the umbilicus, also has nodes, but they are much sharper and less strongly directed backwards.

Remarks

There is no other ammonoid species known from the early Tournaisian that resembles *Gattendorfia immodica* sp. nov. The striking morphology in the juvenile stage, has not been seen in any other species of *Gattendorfia* in a cross section.

The only species that could be considered for comparison is *G. costata*, which is only known from Oberrödinghausen by one specimen of 30 mm conch diameter. The holotype of this species does not show the geometry of the inner whorls. However, it is very likely that the specimen from Saalfeld figured by Bartzsch & Weyer (1982: text-fig. 4.2) really belongs to *G. costata*; this specimen allows for the study of some inner whorls, which here have a rounded umbilical margin.

Table 77. Conch measurements, ratios and rates of *Gattendorfia immodica* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31165	10.9	9.7	3.3	5.4	2.5	0.90	2.98	0.50	1.67	0.25

Fig. 79. *Gattendorfia immodica* sp. nov. from the Oberrödinghausen railway cutting; photographs and dorsal view reconstruction of holotype MB.C.31165 (Weyer 1993–1994 Coll.) from bed 5a2. Scale bar units = 1 mm.

Genus ***Zadelsdorfia*** Weyer, 1972

Type species

Gattendorfia asiatica Librovitch, 1940: 49; original designation.

Diagnosis

Genus of the Gattendorfiinae with a usually thickly discoidal to globular conch with low to moderately high coiling rate (WER = 1.50–1.90); inner whorls subevolute or evolute, adult stage subinvolute or involute. Ornament with convex or slightly biconvex, rursiradiate growth lines, shell with or without constrictions. Suture line with deep slightly pouched external lobe; adventive lobe usually asymmetric.

Genus composition

Central and South Europe (Schmidt 1924; Schindewolf 1926a; Korn & Feist 2007): *Gattendorfia crassa* Schmidt, 1924; ? *Imitoceras apertum* Schindewolf, 1926; *Gattendorfia nazairensis* Korn & Feist, 2007; *Zadelsdorfia oblita* sp. nov.

North Africa (Ebbighausen *et al.* 2004; Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007): *Gattendorfia jacquelinae* Ebbighausen, Bockwinkel, Korn & Weyer, 2004; *Zadelsdorfia debouaaensis* Bockwinkel & Ebbighausen, 2006; *Gattendorfia lhceni* Ebbighausen & Bockwinkel, 2007; *Gattendorfia gisae* Ebbighausen & Bockwinkel, 2007; *Zadelsdorfia zana* sp. nov.

Urals and Central Asia (Librovitch 1940; Liang 1976; Popov & Kusina 1997): *Gattendorfia asiatica* Librovitch, 1940; *Gattendorfia nuraensis* Librovitch, 1940; *Gattendorfia subaperta* Librovitch, 1940; *Gattendorfia yaliana* Liang, 1976; *Gattendorfia occlusa* Librovitch, 1940; *Gattendorfia applanata* Librovitch, 1940; *Gattendorfia kazakhstanica* Librovitch, 1940; *Gattendorfia reticulata* Librovitch, 1940; *Gattendorfia* (*Zadelsdorfia*) *acricula* Ruan, 1995; *Gattendorfia* (*Zadelsdorfia*) *artilobata* Ruan, 1995; *Gattendorfia* (*Zadelsdorfia*) *hoboksarica* Ruan, 1995; *Gattendorfia* (*Zadelsdorfia*) *lanceolata* Ruan, 1995; *Gattendorfia* (*Zadelsdorfia*) *popanoides* Ruan, 1995; *Gattendorfia parapplanata* Sheng, 1984; ?*Gattendorfia uralica* Librovitch in Popov & Kusina, 1997.

North America (Winchell 1870; Miller 1891; Miller & Youngquist 1947; Miller & Collinson 1951; Miller & Garner 1955; Gutschick & Treckman 1957): *Goniatites Andrewsi* Winchell, 1870; *Goniatites Ohiensis* Winchell, 1870; ?*Goniatites Brownensis* Miller, 1891; *Gattendorfia bransoni* Miller & Youngquist, 1947; *Gattendorfia mehli* Miller & Collinson, 1951; *Gattendorfia minusculum* Miller & Collinson, 1951; *Gattendorfia stummi* Miller & Garner, 1955; ?*Gattendorfia alteri* Gutschick & Treckman, 1957.

Remarks

Zadelsdorfia is closely related to *Gattendorfia* and a sharp line of separation cannot be drawn according to the current knowledge of many of the species. *Zadelsdorfia* can best be separated from *Gattendorfia* by the pouched external lobe (almost parallel-sided in *Gattendorfia*), the asymmetric adventive lobe (almost symmetric in *Gattendorfia*) and the adult conch with a rather distinct closure of the umbilicus.

Zadelsdorfia crassa (Schmidt, 1924)
Figs 80–85; Tables 78–79

Gattendorfia crassa Schmidt, 1924: 151, pl. 8 figs 9–11.

Gattendorfia crassa – Schmidt 1925: 535, pl. 19 fig. 9. — Librovitch 1940: pl. 4 fig. 4. — Pfeiffer 1954: 100, pl. 7 fig. 3. — Vöhringer 1960; 154, pl. 4 figs 1–4, pl. 5 fig. 8, text-figs 30, 36. — Weyer 1965: 447, pl. 7 fig. 1. — Popov 1975: 115, pl. 36 fig. 9, pl. 46 fig. 8. — Bartzsch & Weyer 1982: 21, text-fig. 6. — House 1985a: 126, pl. 6.7.14 fig. c. — Bartzsch & Weyer 1986: pl. 2 fig. 3. — Korn 1994: 73, text-figs 66b–c, 67b, 68a, 69a–d; 2006: text-fig 3k. — Dzik 1997: 107, text-fig. 28g. — Kullmann 2000: text-fig. 4k. — Sprey 2002: 53, text-fig. 18e. — Korn & Vöhringer 2004: 426, text-figs 3–4, 6.

non *Gattendorfia crassa* – Librovitch 1940: 45, pl. 4 figs 1–3. — Schindewolf 1952: 296, pl. 2 fig. 5. — Bockwinkel & Ebbighausen 2006: 109, text-figs 26, 27g–j.

Diagnosis

Species of *Zadelsdorfia* with a conch reaching 70 mm diameter. Conch at 5 mm dm thinly discoidal, very evolute (ww/dm = 0.35–0.45; uw/dm = 0.60–0.65); at 15 mm dm thickly discoidal to thinly pachyconic, evolute (ww/dm = 0.55–0.65; uw/dm = 0.45–0.55); at 40 mm dm thickly discoidal to thinly pachyconic, subinvolute (ww/dm = 0.55–0.65; uw/dm ~0.20–0.30). Whorl profile in the juvenile stage depressed oval, at 40 mm dm weakly depressed (ww/wh = 1.20–1.50); coiling rate low to moderately high (WER = 1.60–1.80). Venter flattened in the juvenile stage, umbilical margin subangular in the adult stage. Growth lines lamellar, wide-standing, with convex course. Faint constrictions on the shell surface and prominent internal shell thickenings. Suture line with lanceolate, weakly pouched external lobe and V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schmidt Coll.; illustrated by Schmidt (1924: pl. 8 figs 9–11), Korn & Vöhringer (2004: text-fig. 3) and Korn (2006: text-fig. 3k); re-illustrated here in Fig. 80; BGR X5714.

Additional material

GERMANY • 9 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63924, GPIT-PV-63944–GPIT-PV-63945, GPIT-PV-63947, GPIT-PV-63953–GPIT-PV-63957 • 30 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.5346–MB.C.5358, MB.C.31166.1–17 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; MB.C.31167.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen,

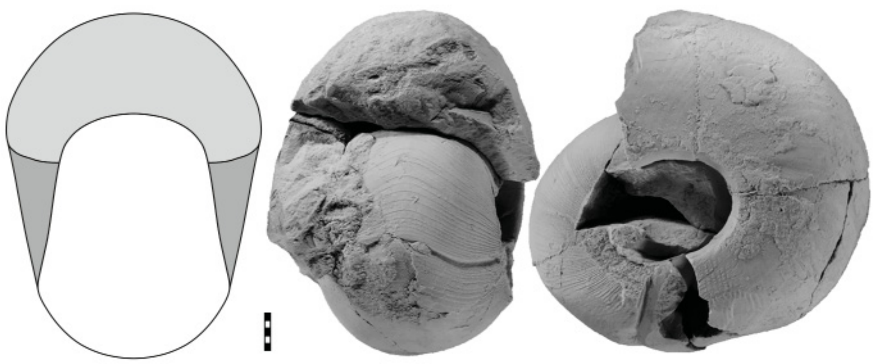

Fig. 80. *Zadelsdorfia crassa* (Schmidt, 1924), holotype BGRB X5714 (Schmidt 1920 Coll.) from the Oberrödinghausen railway cutting. Scale bar units = 1 mm.

railway cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; MB.C.31168 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31169.1–3 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Weyer 1993–1994 Coll.; MB.C.31170 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2a; Weyer 1993–1994 Coll.; MB.C.31171 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31172 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 3b; Korn & Weyer 2000 Coll.; MB.C.31173.

Description

Holotype BGRB X5714 is a slightly deformed specimen with 45 mm conch diameter (Fig. 80) that has fallen apart; however, several pieces of the inner whorls show the characteristic conch and ornamental features of the species. At a diameter of 45 mm, the conch is thinly pachyconic (ww/dm ~0.68 after correction of deformation) and thus belongs to the stouter specimens within the species. The umbilicus is moderately narrow (uw/dm ~0.27); the umbilical margin is subangular and separates the broadly rounded flanks from the steep, slightly flattened umbilical wall. The shell surface bears lamellar, irregularly distributed, sharp growth lines on the flanks with a convex, backwardly directed course. They form a broadly V-shaped ventral sinus. One narrow shell constriction can be seen; it largely follows the course of the growth lines and is present on flanks and venter.

The four specimens GPIT-PV-63953, GPIT-PV-63955, GPIT-PV-63957 and GPIT-PV-63947 give an insight into the conch morphology and intraspecific variation between 30 and 57 mm conch diameter

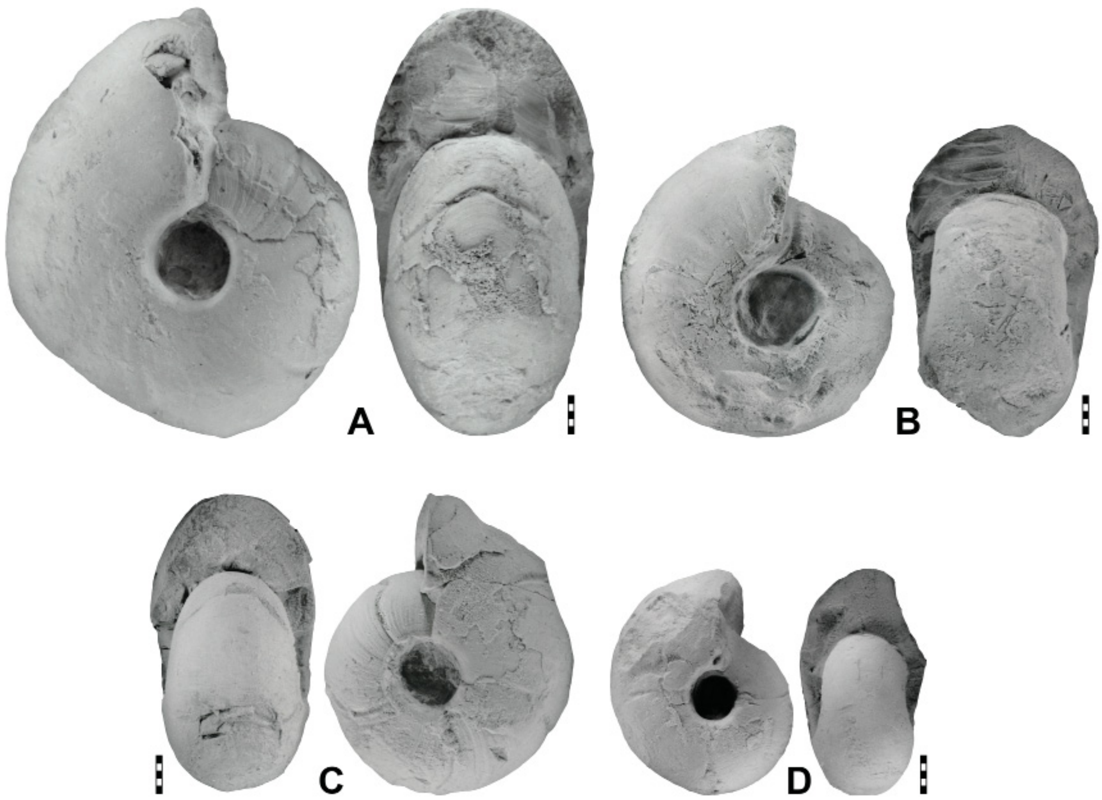

Fig. 81. *Zadelsdorfia crassa* (Schmidt, 1924) from bed 2 of the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. Specimen GPIT-PV-63953. **B**. Specimen GPIT-PV-63955. **C**. Specimen GPIT-PV-63957. **D**. Specimen GPIT-PV-63947. Scale bar units = 1 mm.

(Fig. 81). These specimens show the differences in the width ratio of the conch, in the expression of the growth lines and the constrictions. Specimen GPIT-PV-63953 is most similar to the holotype with regard to the ornament. It has only two constrictions on the last whorl; the first begins on the inner half of the flank and is clearly less pronounced on the shell surface than on the internal mould. The second constriction follows 90 degrees later and is restricted to the venter (Fig. 81A).

The two smaller specimens MB.C.31169.2 (18.8 mm dm; Fig. 83B) and MB.C.31169.1 (23 mm dm; Fig. 83A) demonstrate the variation in the ontogenetic conch development within the species, as outlined by Korn & Vöhringer (2004). The uw/dm ratio is, at 18.8 mm dm, ~0.51 in specimen MB.C.31169.2 but only ~0.40, at 23 mm dm, in specimen MB.C.31169.1, meaning that the latter specimen had a slightly faster ontogenetic development and passed through the evolute stage at a smaller conch diameter. Both specimens show lamellar growth lines with backwardly directed course and shell constrictions of variable strength; they follow the course of the growth lines.

The extensive material with a total of 17 cross sections (Figs 84A–B, 85) allows a detailed study of conch ontogeny and intraspecific variation (Korn & Vöhringer 2004). The trajectories of the individual conch parameters show the following characteristics:

The ontogenetic trajectories of the ww/dm ratio show a triphasic development (Fig. 84E). They describe a rapid decrease in the value to ~0.35 at 5 mm conch diameter, then increasing again to an average value of ~0.70 at 25 mm dm and finally decreasing again to ~0.55 at 55 mm dm. The variation is about the same in all stages of growth.

The uw/dm ratio undergoes striking ontogenetic changes, which can be seen in the illustrations of the cross-sections (Fig. 84E). In the early stages, the umbilicus has a width of ~0.30 of the conch diameter. Up to a diameter of about 3.5 mm, a continuous increase can be observed; between 3.5 and 9 mm diameter, the median value of the uw/dm ratio is greater than 0.60. Specimens larger than 9 mm then show a relatively steady decrease, so that at 40 mm diameter, the umbilicus has a width of only ~0.20 of the conch diameter. This value shows little intraspecific variation; the variation is greatest at the stage between 3 and 15 mm.

Fig. 82. *Zadelsdorfia crassa* (Schmidt, 1924), paratype GPIT-PV-63954 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 2. Photograph of the unwhitened specimen showing exemplary the often poorly preserved shell surface of the material from Oberrödinghausen. Scale bar units = 1 mm.

Table 78. Conch measurements, ratios and rates of *Zadelsdorfia crassa* Schmidt, 1924 from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63954	59.8	30.8	28.7	11.4	15.0	0.52	1.07	0.19	1.78	0.48
GPIT-PV-63953	56.8	30.0	26.4	12.3	14.6	0.53	1.14	0.22	1.81	0.45
BGR X5711	45.1	30.8	19.6	12.4	12.6	0.68	1.57	0.27	1.93	0.36
GPIT-PV-63955	41.9	26.2	17.6	12.1	10.2	0.63	1.49	0.29	1.74	0.42
GPIT-PV-63957	40.5	22.3	19.2	9.2	10.1	0.55	1.16	0.23	1.78	0.47
GPIT-PV-63947	29.8	17.1	13.0	6.7	7.6	0.57	1.31	0.23	1.80	0.42
MB.C.31169.1	23.0	14,2	7,8	9,2	5,6	0,62	1,83	0,40	1,74	0,28
MB.C.31169.2	18.8	12.6	5.3	9.5	4.2	0.67	2.40	0.51	1.65	0.21

Table 79. Conch ontogeny of *Zadelsdorfia crassa* Schmidt, 1924 from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm = 0.45–0.55; uw/dm = 0.45–0.55)	moderately depressed; weakly embracing (ww/wh = 1.60–2.00; IZR ~0.12)	low (WER = 1.55–1.75)
5 mm	thinly discoidal; very evolute (ww/dm = 0.35–0.45; uw/dm = 0.60–0.65)	moderately depressed; weakly embracing (ww/wh = 1.60–2.00; IZR ~0.12)	Very low to low (WER = 1.40–1.55)
15 mm	thickly discoidal to thinly pachyconic; evolute (ww/dm = 0.55–0.65; uw/dm = 0.45–0.55)	moderately to strongly depressed; moderately embracing (ww/wh = 1.80–2.25; IZR ~0.25)	low (WER = 1.55–1.70)
30 mm	thinly pachyconic; subinvolute to subevolute (ww/dm = 0.60–0.72; uw/dm = 0.25–0.35)	weakly to moderately depressed; strongly embracing (ww/wh = 1.30–1.80; IZR ~0.40)	low (WER = 1.60–1.75)
50 mm	Thickly discoidal; subinvolute (ww/dm ~0.55; uw/dm ~0.25)	weakly depressed; strongly embracing (ww/wh ~1.20; IZR ~0.40)	moderate (WER ~1.85)

The ww/wh diagram clearly shows ontogenetic changes in the shape of the whorl profile. After an initial decline, a minimum value (~1.65) is reached at a conch diameter of 2.5 mm. Between 2.5 and 10 mm diameter there is a continuous increase to a median value of ~2.00, while for diameters greater

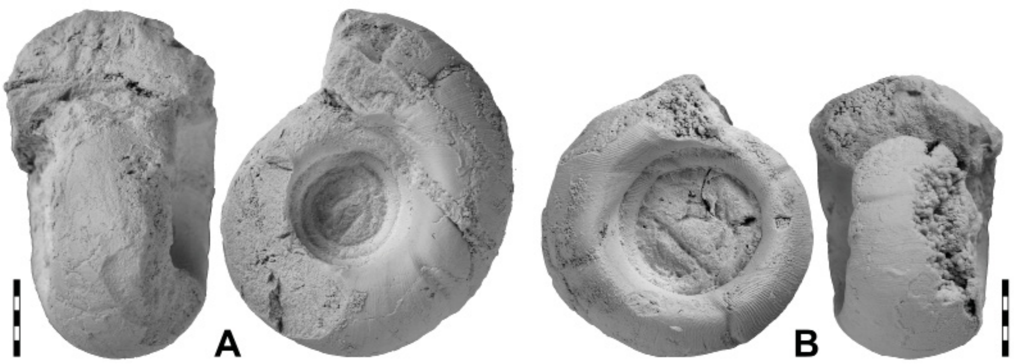

Fig. 83. *Zadelsdorfia crassa* (Schmidt, 1924) from the Oberrödinghausen railway cutting, both Korn 1977 Coll. **A**. Specimen MB.C.31169.1. **B**. Specimen MB.C.31169.2. Scale bar units = 1 mm.

than 15 mm there is a marked decrease to about 1.20 at 40 mm diameter (Fig. 84F). The intraspecific variation is not particularly high at any growth stage. As for the uw/dm ratio, the middle stages, between 7 and 20 mm diameter of the conch, are less variable than for the early juveniles and adults.

During ontogenetic development, the coiling rate (WER) shows only slight fluctuations (Fig. 84G). The coiling rate has highest values in the early juvenile stage at a conch diameter up to 2 mm (median value 1.70–1.80). During early ontogeny, this value decreases to less than 1.50 at stages between 5 and 8 mm diameter, and increases again at the adult stage, reaching a value of ~1.75 at 40 mm conch diameter. The intraspecific variation is relatively low at all growth stages. In the intermediate stages between 4 and 16 mm conch diameter, there is a tendency towards slightly lower variation, but the differences between the growth stages are inconspicuous.

Remarks

Material from the type locality was described in detail by Vöhringer (1960) and in greater detail by Korn & Vöhringer (2004). Thanks to the many well-preserved specimens available, *Zadelsdorfia crassa*

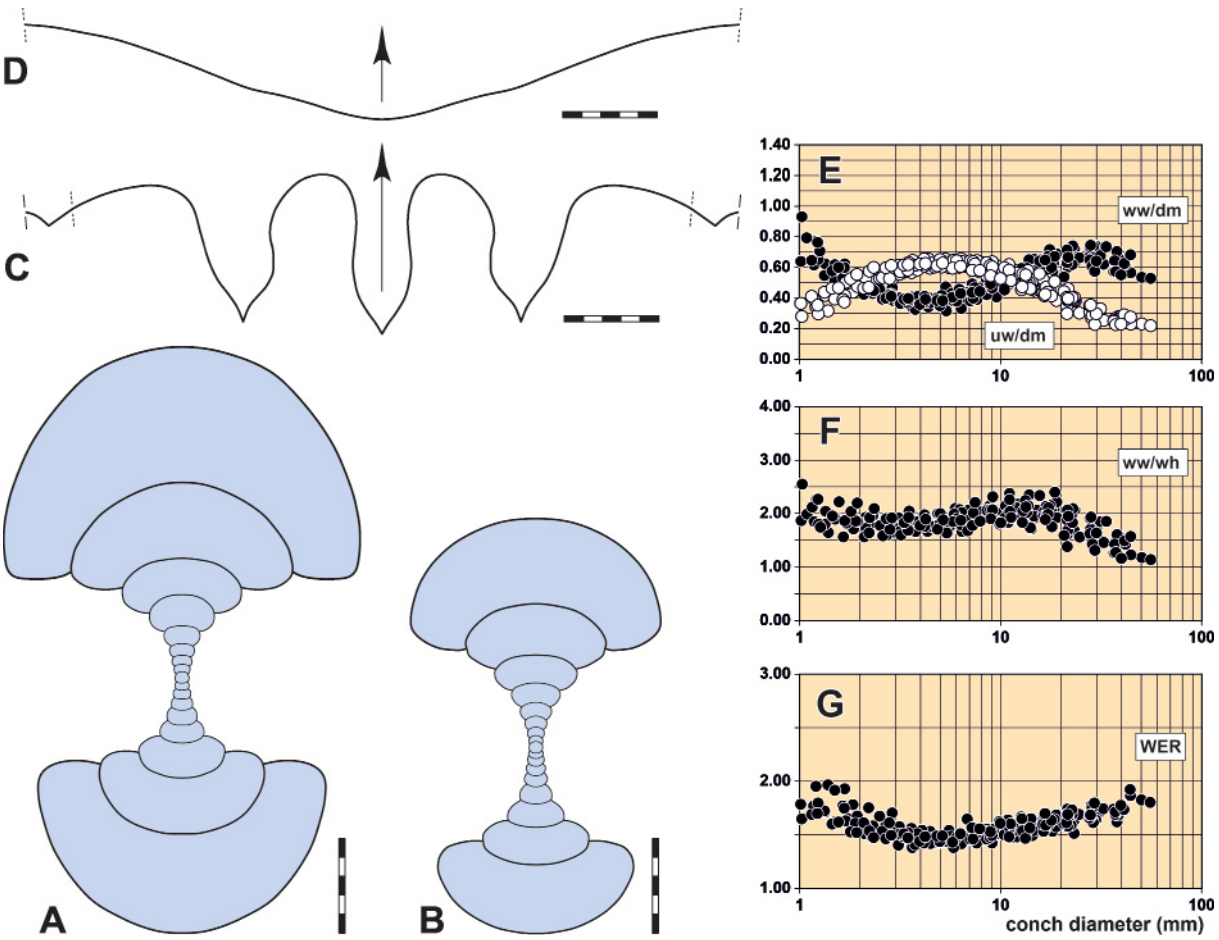

Fig. 84. *Zadelsdorfia crassa* (Schmidt, 1924) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen GPIT-PV-63944 from bed 2. **B**. Cross section of specimen MB.C.5355 from bed 2. **C**. Suture line of specimen GPIT-PV-63955 from bed 2, at dm = 35.0 mm, ww = 23.5 mm, wh = 14.5 mm. **D**. Growth line course of specimen GPIT-PV-63953 from bed 2, at wh = 24.0 mm ww, wh = 16.0 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

is a well-known species and can be characterised by the morphology and ontogenetic development of the conch.

Zadelsdorfia crassa belongs to the stout, in the adult stage rather narrowly umbilicate species of the subfamily Gattendorfiinae and is thus easily distinguishable from most of the other species. Species with stout conch are *G. costata* (with much wider umbilicus) and *Z. oblita* sp. nov. (with concavo-convex constrictions). Among the species from the Rhenish Mountains, *G. corpulenta* sp. nov. has

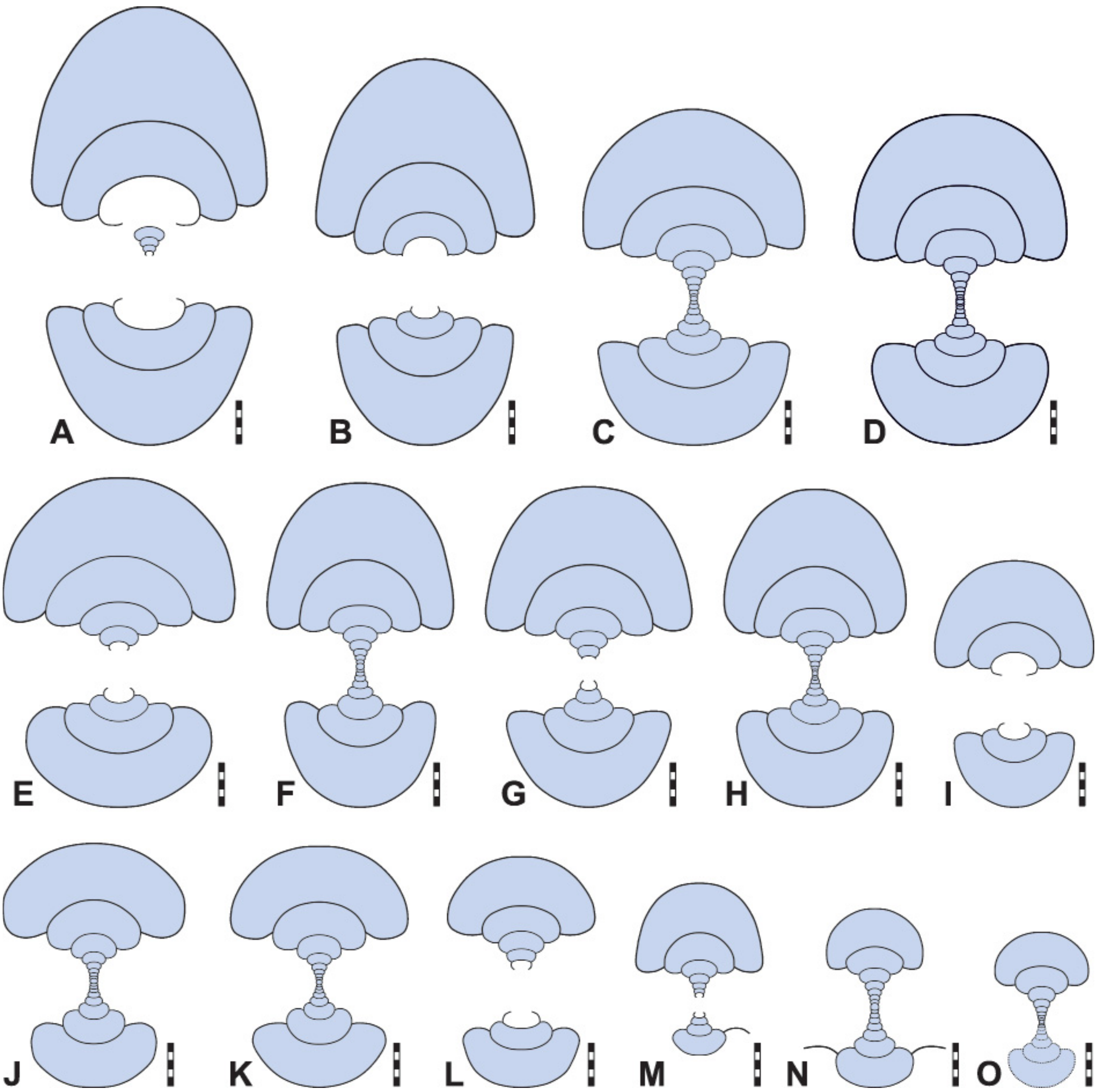

Fig. 85. *Zadelsdorfia crassa* (Schmidt, 1924) from the Oberrödinghausen railway cutting, cross sections, bed 2; all Vöhringer Coll. **A**. Specimen MB.C.5347. **B**. Specimen MB.C.5348. **C**. Specimen MB.C.5346. **D**. Specimen GPIT-PV-63956. **E**. Specimen MB.C.5349. **F**. Specimen MB.C.5353. **G**. Specimen MB.C.5351. **H**. Specimen MB.C.5352. **I**. Specimen MB.C.5350. **J**. Specimen MB.C.31166.1. **K**. Specimen MB.C.5354. **L**. Specimen MB.C.5358. **M**. Specimen MB.C.5357. **N**. Specimen MB.C.5356. **O**. Specimen MB.C.31166.2. Scale bar units = 1 mm.

the most similar morphology, but possesses short, sharp riblets on the inner flank half. Furthermore, *G. corpulenta* is stouter at the adult stage (ww/dm ~0.80 at 30 mm dm, but only ~0.65 in *Z. crassa*).

Zadelsdorfia crassa has been mentioned several times from other regions, but it is not clear whether these specimens actually belong to this species. The following mentions of presumed occurrences of *Z. crassa* are probably not correct:

Librovitch (1940): The specimens shown are much too narrowly umbilicate; they have an almost closed umbilicus and are therefore clearly distinguishable from *Z. crassa*.

Bockwinkel & Ebbighausen (2006): The specimens are smaller than the type material, for example the largest specimen shown has only 18 mm diameter. At this stage, the Moroccan material is a little more narrowly umbilicate. The same applies to the cross sections shown. The main difference, however, can be seen in the course of the constrictions, which in the Anti-Atlas specimens are straight or extend with a very shallow sinus across the flank and form a shallow ventral sinus.

Zadelsdorfia oblita sp. nov.
urn:lsid:zoobank.org:act:97D9ABF0-4091-47B6-B631-F2B1DA85452D
Fig. 86; Table 80

Diagnosis

Species of *Zadelsdorfia* with a conch reaching 50 mm diameter. Conch at 30 mm dm thinly pachyconic, subinvolute (ww/dm ~0.70; uw/dm ~0.30). Whorl profile in the juvenile stage crescent-shaped, at 30 mm dm moderately depressed (ww/wh ~1.75); coiling rate low (WER ~1.60). Venter broadly rounded, umbilical margin narrowly rounded. Growth lines fine, wide-standing, with concavo-convex course. Weak constrictions on the shell surface and prominent internal shell thickenings; sharp, short ribs and coarse spiral lines on the inner flank.

Etymology

From the Latin '*oblita*' = 'forgotten'; because of the undescribed material in the Vöhringer collection.

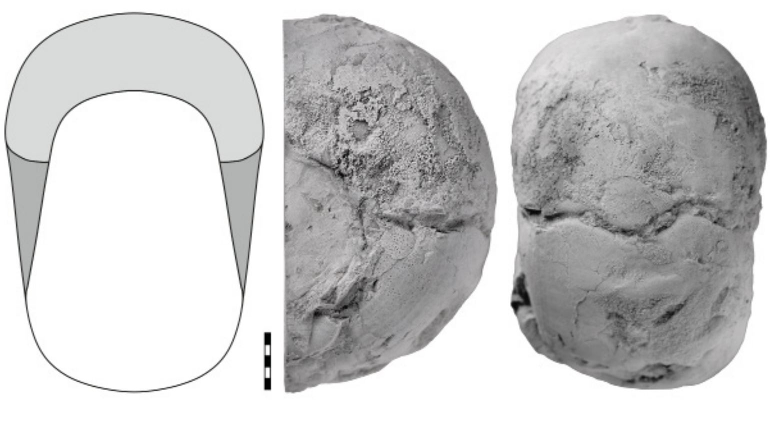

Fig. 86. *Zadelsdorfia oblita* sp. nov. from the Oberrödinghausen railway cutting; photographs and dorsal view reconstruction of holotype MB.C.31174.1 (Vöhringer Coll.) from bed 1. Scale bar units = 1 mm.

Table 80. Conch measurements (partly reconstructed), ratios and rates of *Zadelsdorfia oblita* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31174.1	32.7	22.6	13.0	9.4	6.7	0.69	1.74	0.29	1.58	0.48
MB.C.31174.1	26.0	18.7	10.3	8.3	–	0.72	1.82	0.32	–	–

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; illustrated in Fig. 86; MB.C.31174.1.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; MB.C.31174.2–3.

Description

Holotype MB.C.31174.1 is a specimen that was already sectioned by Vöhringer, but no inner whorls are preserved (Fig. 86). The specimen has a diameter of 33 mm and is thinly pachyconic and subinvolute (ww/dm = 0.69; uw/dm = 0.29) with a rounded umbilical margin, a convex umbilical wall and broadly rounded flanks and venter. The specimen shows moderately well preserved shell remains that appear largely smooth. Weak spiral lines are visible on the flank; they cross the fine, wide-standing growth lines. The shell surface shows a concavo-convex constriction forming a shallow lateral sinus, a distinct ventrolateral projection and a moderately deep ventral sinus.

Remarks

Specimens of the new species were placed in *Gattendorfia costata* by Vöhringer (1960). However, clear differences are present: The holotype of *G. costata* has a rather wide umbilicus with a uw/dm ratio of 0.44 at 32 mm dm, while in *Zadelsdorfia oblita* sp. nov. it is only 0.29. Furthermore, *G. costata* has a pronounced umbilical margin, which is rounded in *Z. oblita*.

Zadelsdorfia oblita sp. nov. differs from all other species of the genus known from the Hangenberg limestone of Oberrödinghausen by the combination of a pachyconic conch and internal shell thickenings, which show a distinct concavo-convex course. Another characteristic to distinguish *Z. oblita* from the other species is the presence of spiral lines.

Zadelsdorfia zana sp. nov.

urn:lsid:zoobank.org:act:8ABDDAC1-F889-4E3B-8F43-00DCB44E17CA

Tables 81–82

Gattendorfia crassa –Bockwinkel & Ebbighausen 2006: 109, text-figs 26, 27g–j.

Diagnosis

Species of *Zadelsdorfia* with a thickly discoidal, very evolute conch at 5 mm dm (ww/dm ~0.50; uw/dm ~0.62); conch at 15 mm dm thinly pachyconic, subevolute (ww/dm ~0.65; uw/dm ~0.35). Whorl profile in the juvenile stage crescent-shaped, at 20 mm dm weakly depressed (ww/wh ~1.45); coiling rate moderately high (WER ~1.85). Venter broadly rounded throughout ontogeny, umbilical margin narrowly rounded in the adult stage. Weak constrictions with concavo-convex course. Suture line with lanceolate, weakly pouched external lobe and lanceolate adventive lobe.

Table 81. Conch measurements, ratios and rates of *Zadelsdorfia zana* sp. nov. from Mfis (Anti-Atlas), from Bockwinkel & Ebbighausen (2006).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.3832.3	19.65	12.53	8.79	5.16	6.19	0.64	1.43	0.26	–	0.30
MB.C.3832.2	17.88	11.63	8.16	4.85	6.09	0.65	1.43	0.27	–	0.25
MB.C.3832.8	11.31	7.32	4.74	4.02	2.85	0.65	1.54	0.35	1.79	0.40
MB.C.3832.5	10.62	7.63	3.85	4.11	2.45	0.72	1.98	0.39	1.69	0.36
MB.C.3832.1	10.28	7.36	4.40	3.31	3.02	0.72	1.67	0.32	–	0.31
MB.C.3832.4	9.01	5.86	3.08	3.93	2.04	0.65	1.90	0.44	1.67	0.34

Table 82. Conch ontogeny of *Zadelsdorfia zana* sp. nov. from Mfis (Anti-Atlas)

dm	conch shape	whorl cross section shape	whorl expansion
3 mm	discoidal; very evolute (ww/dm ~0.45; uw/dm ~0.60)	strongly depressed; moderately embracing (ww/wh ~2.20; IZR ~0.20)	very low (WER ~1.45)
8 mm	thickly discoidal; evolute (ww/dm ~0.55; uw/dm ~0.50)	moderately depressed; strongly embracing (ww/wh ~1.90; IZR = 0.35)	low (WER ~1.55)
15 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.35)	weakly depressed; moderately embracing (ww/wh ~1.45; IZR ~0.25)	low (WER ~1.65)

Etymology

Acronym for a *Zadelsdorfia* species from North Africa.

Material examined

Holotype

MOROCCO • Anti-Atlas, Mfis near Taouz, bed 7; Becker Coll.; illustrated by Bockwinkel & Ebbighausen (2006: text-fig. 27g–h); MB.C.3832.2.

Paratypes

MOROCCO • 7 specimens; Anti-Atlas, Mfis near Taouz, bed 7; Bockwinkel & Ebbighausen Coll.; MB.C.3832.1, MB.C.3832.3 –8.

Description

The species newly described here has been worked on in detail by Bockwinkel & Ebbighausen (2006), so reference can be made here to that description.

Remarks

Zadelsdorfia zana sp. nov. resembles *Z. crassa*, but the ontogenetic transition from the initial serpenticonic stage to the more involute subadult stage occurs at a smaller diameter of the conch (uw/dm ~0.25 at 20 mm dm) compared to *Z. crassa* (uw/dm = 0.35–0.45 at 20 mm dm). In addition, *G. zana* has constrictions, which are straight on the flank, whereas in *Z. crassa* they are directed backwards.

Genus ***Kazakhstania*** Librovitch, 1940

Type species

Gattendorfia (*Kazakhstania*) *karagandaensis* Librovitch, 1940: 68; original designation.

Genus diagnosis

Genus of the Gattendorfiinae with a small, thinly discoidal to pachyconic conch with low coiling rate (WER = 1.50–1.70); all stages evolute, with depressed whorl profile. Shell surface often with constrictions on the outer flank and venter. Suture line with deep, lanceolate or slightly pouched external lobe, which is much deeper than the adventive lobe.

Genus composition

Central Europe (Vöhringer 1960): *Gattendorfia evoluta* Vöhringer, 1960.

North Africa (Bockwinkel & Ebbighausen 2006; Korn *et al.* 2010b): *Kazakhstania nitida* Bockwinkel & Ebbighausen, 2006; *Kazakhstania inaequalis* Korn, Ebbighausen, Bockwinkel, 2010; *Kazakhstania kana* sp. nov.

Central Asia (Librovitch 1940; Kusina & Lazarev 1994; Ruan 1995): *Gattendorfia* (*Kazakhstania*) *depressa* Librovitch, 1940; *Gattendorfia* (*Kazakhstania*) *karagandaensis* Librovitch, 1940; *Kazakhstania mongolica* Kusina in Kusina & Lazarev, 1994; *Gattendorfia* (*Kazakhstania*) *compressa* Ruan, 1995; *Gattendorfia* (*Kazakhstania*) *cuneata* Ruan, 1995; *Gattendorfia* (*Kazakhstania*) *umbilicata* Ruan, 1995.

North America (Morton 1836; Miller & Garner 1955; Work & Mason 2005): *Kazakhstania americana* Miller & Garner, 1955; *Ammonites colubrellus* Morton, 1836; *Kazakhstania mangeri* Work & Mason, 2005.

Remarks

Kazakhstania is easily distinguished from the other genera of the subfamily Gattendorfiinae because of the very wide umbilicus and the depressed whorl profile in all ontogenetic stages. Another distinguishing criterion is the very deep external lobe, which is usually one and a half to two times as deep as the adventive lobe.

Kazakhstania evoluta (Vöhringer, 1960)
Figs 10E, 87–88; Tables 83–84

Gattendorfia evoluta Vöhringer, 1960: 159, pl. 5 fig. 4.

Gattendorfia evoluta – Korn 1994: 74, text-figs 65i, 66l, 67h, 68f. — Sprey 2002, pl. 4 fig. 3.

non *Gattendorfia evoluta* – Bockwinkel & Ebbighausen 2006: 112, text-figs 29, 30e–h.

Diagnosis

Species of *Kazakhstania* with a conch reaching 30 mm diameter. Conch at 15 mm dm thinly discoidal, very evolute (ww/dm ~0.40; uw/dm ~0.65). Whorl profile at 15 mm dm moderately depressed (ww/wh ~1.80); coiling rate very low (WER ~1.48). Venter weakly flattened. Growth lines very fine, narrow-standing, with convex course. Without constrictions on the shell surface. Suture line with very narrowly lanceolate external lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 5 fig. 4), Korn (1994: text-fig. 65i) and Sprey (2002: pl. 4 fig. 3); re-illustrated here in Fig. 87; GPIT-PV-63963.

Paratype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63965.

Additional material

GERMANY • 2 specimens; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 30; Weyer & Korn 2000 Coll.; MB.C.5258.1, MB.C.5258.6.

Description

Holotype GPIT-PV-63963 is a moderately well-preserved specimen with 23 mm conch diameter (Fig. 87). It displays the characteristic conch geometry with a very wide umbilicus (uw/dm = 0.63) and a depressed rectangular whorl profile (ww/wh = 1.88) with a flattened venter and uniformly convex flanks. Shell remains are present in some places; they show very fine growth lines, standing approximately 0.2 mm apart. They are clearly directed backwards from the umbilicus and form a broad ventral sinus (Fig. 88C). The suture line has a very narrow, lanceolate external lobe (Fig. 88B).

The sectioned paratype GPIT-PV-63965 shows only minor ontogenetic changes in conch geometry up to a conch diameter of 14 mm (Fig. 88A). The whorl profile of all whorls larger than 4 mm conch diameter is rounded trapezoidal with a flattened venter. The ontogenetic trajectories are monophasic (Fig. 88D–F); the umbilical width increases slightly in early ontogeny and remains at a very high value above 0.60 from a conch diameter of 5 mm.

Remarks

Kazakhstania evoluta can be distinguished from almost all other species of the genus by the absence of constrictions. Similar in this respect is only *E. kana* sp. nov. from the Anti-Atlas of Morocco; this species, however, has a pouched external lobe that is about twice as wide and is thus clearly different from *K. evoluta*.

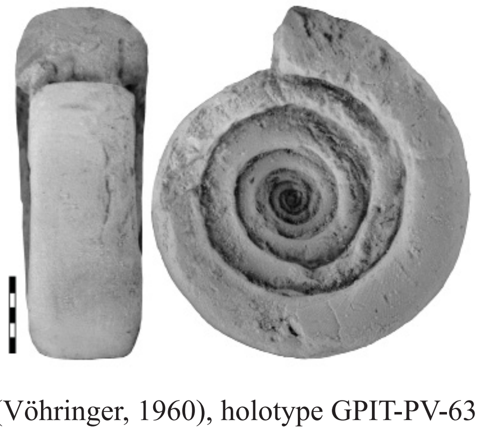

Fig. 87. *Kazakhstania evoluta* (Vöhringer, 1960), holotype GPIT-PV-63963 (Vöhringer Coll.) from the Oberrödinghausen railway cutting, unknown bed. Scale bar units = 1 mm.

Table 83. Conch measurements, ratios and rates of *Kazakhstania evoluta* (Vöhringer, 1960) from Oberrödinghausen and Oese.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63963	23.2	8.7	4.6	14.5	4.2	0.37	1.88	0.63	1.49	0.09
GPIT-PV-63963	19.1	7.5	4.0	12.3	–	0.39	1.88	0.64	–	–
GPIT-PV-63965	14.1	5.0	9.0	8.96	2.5	0.35	1.80	0.64	1.47	0.12
MB.C.5258.1	6.63	2.11	1.51	3.97	1.32	o.32	1.40	0.60	1.56	0.13

Table 84. Conch ontogeny of *Kazakhstania evoluta* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm ~0.55; uw/dm ~0.50)	moderately depressed; moderately embracing (ww/wh ~1.85; IZR ~0.25)	low (WER ~1.70)
5 mm	thinly discoidal; very evolute (ww/dm ~0.40; uw/dm ~0.60)	moderately depressed; weakly embracing (ww/wh ~1.85; IZR ~0.10)	low (WER ~1.55)
10 mm	thinly discoidal; very evolute (ww/dm ~0.40; uw/dm ~0.60)	moderately depressed; weakly embracing (ww/wh ~1.85; IZR ~0.10)	low (WER ~1.50)
20 mm	thinly discoidal; very evolute (ww/dm ~0.40; uw/dm ~0.60)	moderately depressed; weakly embracing (ww/wh ~1.85; IZR ~0.10)	low (WER ~1.50)

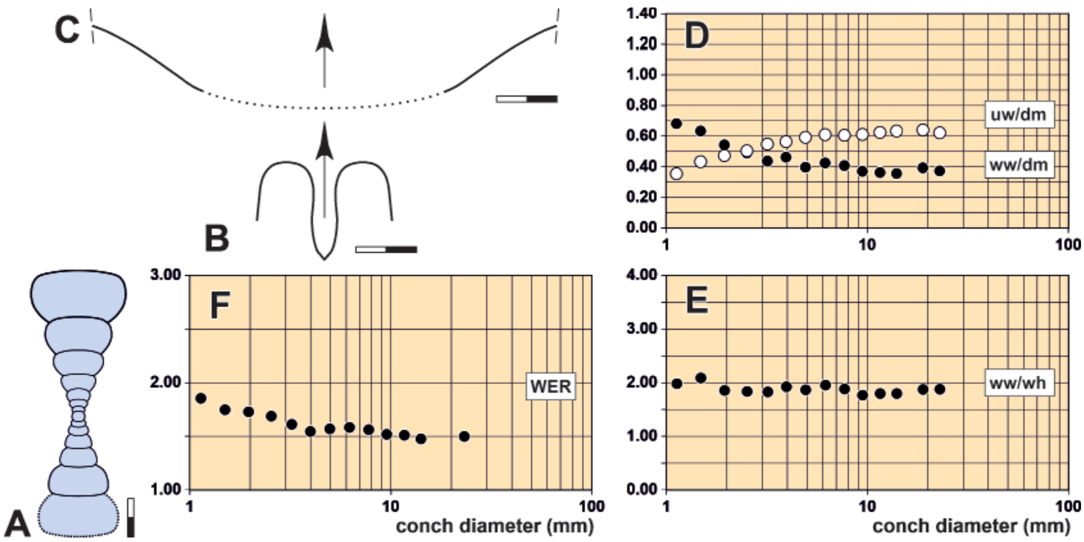

Fig. 88. *Kazakhstania evoluta* (Vöhringer, 1960from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63965 (Vöhringer Coll.) from bed 2. **B**. Suture line of holotype GPIT-PV-63963 (Vöhringer Coll.) from unknown bed, at ww = 5.8 mm, wh = 3.5 mm. **C**. Growth line course of holotype GPIT-PV-63963 (Vöhringer Coll.) from unknown bed, at ww = 8.0 mm, wh = 4.5 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER). Scale bar units = 1 mm.

Kazakhstania kana sp. nov.
urn:lsid:zoobank.org:act:A5012412-0C69-480F-AA08-75059935B6D3
Tables 85–86

Gattendorfia evoluta – Bockwinkel & Ebbighausen 2006: 112, text-figs 29, 30e–h.

Diagnosis

Species of *Kazakhstania* with a conch reaching 20 mm diameter. Conch at 10 mm dm thinly discoidal, extremely evolute (ww/dm ~0.40; uw/dm ~0.65). Whorl profile at 10 mm dm strongly depressed (ww/wh ~2.25); coiling rate very low (WER ~1.48). Venter flattened. Without constrictions on the shell surface. Suture line with very narrowly lanceolate external lobe.

Material examined

Holotype

MOROCCO • Anti-Atlas, Mfis near Taouz, bed 7; Bockwinkel & Ebbighausen Coll.; illustrated by Bockwinkel & Ebbighausen (2006: text-fig. 30e–f); MB.C.3820.1.

Paratypes

MOROCCO • 7 specimens; Anti-Atlas, Mfis near Taouz, bed 7; Bockwinkel & Ebbighausen Coll.; MB.C.3820.2–MB.C.3820.8.

Etymology

An acronym for a *Kazakhstania* species from North Africa.

Description

The species newly described here has been worked on in detail by Bockwinkel & Ebbighausen (2006), so reference can be made here to that description.

Table 85. Conch measurements, ratios and rates of *Kazakhstania kana* sp. nov. from Mfis (Anti-Atlas), from Bockwinkel & Ebbighausen (2006).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.3820.1	9.26	3.87	1.73	5.86	1.66	0.42	2.24	0.63	1.48	0.04
MB.C.3820.4	9.00	3.50	1.88	5.63	1.66	0.39	1.86	0.63	1.50	0.12
MB.C.3820.2	7.21	3.01	1.52	4.47	1.40	0.42	1.98	0.62	1.54	0.08

Table 86. Conch ontogeny of *Kazakhstania kana* sp. nov. from Mfis (Anti-Atlas).

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	discoidal; very evolute (ww/dm ~0.45; uw/dm ~0.65)	strongly depressed; weakly embracing (ww/wh ~2.20; IZR ~0.10)	low (WER ~1.55)
5 mm	thinly discoidal; very evolute (ww/dm ~0.40; uw/dm ~0.65)	moderately depressed; weakly embracing (ww/wh ~1.70; IZR ~0.10)	low (WER ~1.55)
10 mm	thinly discoidal; very evolute (ww/dm ~0.40; uw/dm ~0.60)	strongly depressed; weakly embracing (ww/wh ~2.25; IZR ~0.10)	low (WER ~1.50)

Remarks

Kazakhstania kana sp. nov. resembles *K. evoluta*, but differs in the broader, pouched external lobe, which is lanceolate and very narrow in *K. evoluta*. The other species of the genus have constrictions and are thus separated from *K. kana*.

Genus *Gattenpleura* Weyer, 1976

Type species

Gattenpleura bartzschi Weyer, 1976: 846; original designation.

Diagnosis

Genus of the Gattendorfiinae with a discoidal conch with low coiling rate (WER = 1.50–1.75); inner whorls subevolute or evolute, adult stage subinvolute to subevolute. Whorl profile with a depression on the inner flank, umbilical margin raised. Ornament with convex or slightly biconvex, rursiradiate growth lines, shell with or without constrictions. Some species with shallow radial riblets. Suture line with deep, lanceolate or narrowly V-shaped external lobe (as deep as the adventive lobe).

Genus composition

Gattenpleura bartzschi Weyer, 1976; *Gattenpleura pfeifferi* Weyer, 1976; *Gattendorfia concava* Vöhringer, 1960.

Remarks

Gattenpleura was established by Weyer (1976) for forms that differ from *Gattendorfia* in two characters, namely the dorsolateral groove and the presence of riblet-like, splitting radial folds on the shell. Here, we change this original definition in such a way that the dorsolateral groove is regarded as a key distinguishing character from *Gattendorfia* and especially from *Weyerella*. This means that "*Gattendorfia concava*" is also assigned to *Gattenpleura*. Weyer (1976) had already pointed out the close relationship; according to this, "*Gattendorfia concava*" should be an almost direct ancestor of "*Gattendorfia molaris*".

Gattenpleura concava (Vöhringer, 1960) comb. nov.
Figs 10C, 89–90; Tables 87–88

Gattendorfia concava Vöhringer, 1960: 157, pl. 5 fig. 2, text-fig. 32.

Gattendorfia concava – Korn 1994: 74, text-figs 65d, 66k, 67f. — Kullmann 2000: text-fig. 4l; 2009: text-fig. 3.6c. — Korn & Weyer 2003: 100, pl. 2 figs 16–17.

Diagnosis

Species of *Gattenpleura* with a conch reaching 30 mm diameter. Conch at 15 mm dm thickly discoidal, subinvolute (ww/dm ~0.48; uw/dm ~0.22). Whorl profile at 15 mm dm weakly compressed (ww/wh ~0.95); coiling rate low (WER ~1.70). Venter rounded, umbilical margin raised and narrowly rounded,

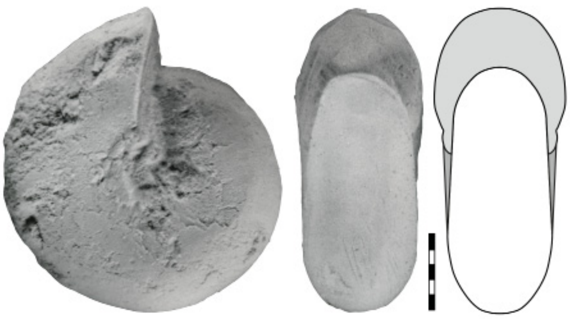

Fig. 89. *Gattenpleura concava* (Vöhringer, 1960), holotype GPIT-PV-63926 Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 4. Scale bar units = 1 mm.

accompanied by a dorsolateral spiral groove. Growth lines very fine, narrow-standing, with convex course. With shallow constrictions on the shell surface; with weak internal shell thickenings. Suture line with narrowly lanceolate external lobe and V-shaped adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 5 fig. 2) and Korn (1994: text-fig. 65d); re-illustrated here in Fig. 89; GPIT-PV-63926.

Paratype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; GPIT-PV-63920.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; MB.C.31175 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; MB.C.31176 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31177 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 28; Weyer & Korn 2000 Coll.; MB.C.5260.1.

Description

Holotype GPIT-PV-63926 is a moderately well-preserved specimen with 19 mm conch diameter (Fig. 89). The conch is thinly discoidal and involute (ww/dm ~0.42; uw/dm ~0.10) with a moderate coiling rate (WER = 1.75). The whorl profile is characteristic with a slightly raised umbilical margin, which is accompanied on the flank by a shallow spiral groove; the venter is broadly rounded. The shell ornament consists of delicate growth lines with convex course.

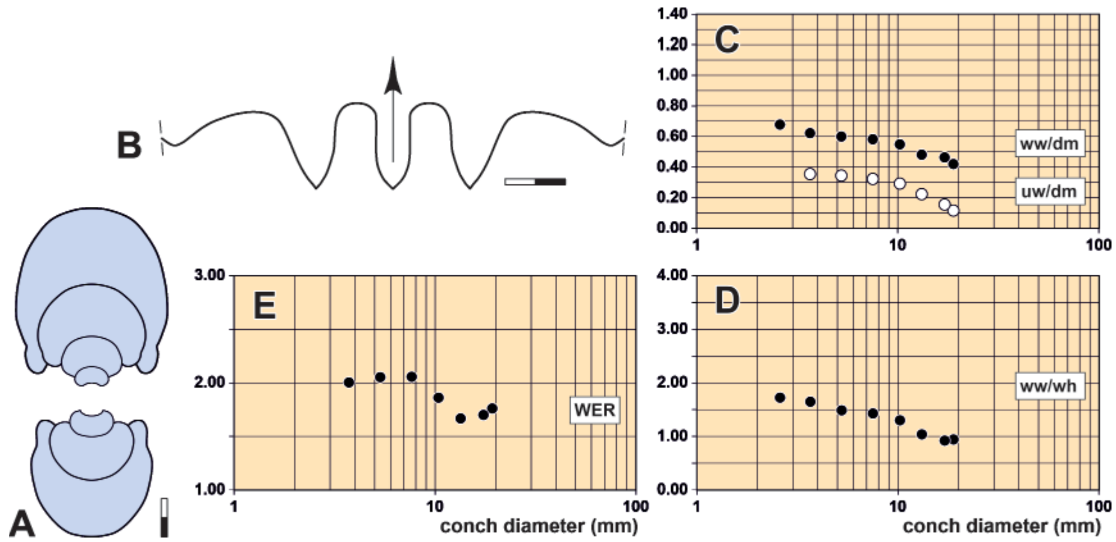

Fig. 90. *Gattenpleura concava* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63920 from bed 2. **B**. Suture line of paratype GPIT-PV-63920 from bed 2, at dm = 14.5 mm, ww = 7.5 mm, wh = 6.6 mm. **C–E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER). Scale bar units = 1 mm.

Table 87. Conch measurements, ratios and rates of *Gattenpleura concava* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63926	19.2	8.0	8.5	2.0	4.7	0.42	0.94	0.10	1.75	0.45
GPIT-PV-63920	17.4	8.0	8.7	2.5	4.0	0.46	0.92	0.14	1.69	0.54

Table 88. Conch ontogeny of *Gattenpleura concava* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
5 mm	thinly pachyconic; subevolute (ww/dm ~0.62; uw/dm ~0.35)	moderately depressed; moderately embracing (ww/wh ~1.55; IZR ~0.25)	high (WER ~2.05)
10 mm	thickly discoidal; subinvolute (ww/dm ~0.55; uw/dm ~0.28)	weakly depressed; moderately embracing (ww/wh ~1.30; IZR ~0.35)	moderate (WER ~1.85)
20 mm	thinly discoidal; involute (ww/dm ~0.40; uw/dm ~0.10)	weakly compressed; very strongly embracing (ww/wh ~0.95; IZR ~0.45)	low (WER ~1.70)

The sectioned paratype GPIT-PV-63920 provides a view into the conch ontogeny between 2.5 and 18 mm diameter (Fig. 90A). In this interval, the whorl profile changes from originally crescent-shaped to circular to slightly compressed. The dorsolateral groove is formed at about 12 mm conch diameter. The suture line of the paratype has a lanceolate external lobe, inverted U-shaped ventrolateral saddle and a V-shaped adventive lobe with slightly convex flanks (Fig. 90B).

Remarks

Gattenpleura concava differs from the other species of the genus by the lack of radial folds.

Genus ***Weyerella*** Bockwinkel & Ebbighausen, 2006

Type species

Weyerella protecta Bockwinkel & Ebbighausen, 2006: 117; original designation.

Genus diagnosis

Genus of the Gattendorfiinae with a small, thinly discoidal to pachyconic conch with low coiling rate (WER = 1.50–1.75); inner whorls evolute, adult stage subinvolute or subevolute, sometimes strongly overlapping the umbilicus. Ornament with fine to coarse, convex or slightly biconvex, rursiradiate growth lines, shell surface often with constrictions. Suture line with deep, lanceolate or V-shaped external lobe that is as deep as the adventive lobe.

Genus composition

Central Europe (Vöhringer 1960): *Gattendorfia molaris* Vöhringer, 1960; *Gattendorfia reticulum* Vöhringer, 1960; *Weyerella lenis* sp. nov.

North Africa (Bockwinkel & Ebbighausen 2006): *Weyerella protecta* Bockwinkel & Ebbighausen, 2006; *Weyerella minor* Bockwinkel & Ebbighausen, 2006.

NW China (Sheng 1984; Liang & Wang 1991; Ruan 1995): *Gattendorfia parapplanata* Sheng, 1984; *Gattendorfia angularia* Liang & Wang, 1991; *Gattendorfia acricula* Ruan, 1995; *Gattendorfia artilobata*

Ruan, 1995; *Gattendorfia compressa* Ruan, 1995; *Gattendorfia hoboksarica* Ruan, 1995; *Gattendorfia lanceolata* Ruan, 1995; *Gattendorfia latalobata* Ruan, 1995; *Gattendorfia umbilicata* Ruan, 1995; *Gattendorfia cuneata* Ruan, 1995.

South China (Ruan 1981): *Gattendorfia discoides* Ruan, 1981; *Gattendorfia mimica* Ruan, 1981; *Gattendorfia popanoides* Ruan, 1981.

Remarks

Weyerella is easily distinguished from the genus *Gattendorfia* by its small conch, which has a maximum diameter of about 30 mm, whereas specimensof *Gattendorfia* can reach 80 mm or more. Another difference is the simpler ontogeny of the conch in *Weyerella*, where the distinct phases, for instance seen in *Gattendorfia schmidti* sp. nov., are not developed. In *Weyerella*, the ww/dm and ww/wh trajectories are nearly monophasic with an almost continuous decrease.

On the one hand, *Weyerella* may be seen as the phylogenetic descendant of *Gattenpleura* with *G. concava* that develops a dorsolateral groove but does not possess the radial ribs of the other *Gattenpleura* species, being the intermediate form. *Weyerella* can, on the other hand, be seen as the ancestor of *Paprothites*, which has a conch morphology similar to *Weyerella* but possesses well-developed ribs.

Weyerella molaris (Vöhringer, 1960)
Figs 8B, 10D, 91–93; Tables 89–90

Gattendorfia molaris Vöhringer, 1960: 158, pl. 5 fig. 1, text-fig. 33.

Gattendorfia molaris – Weyer 1976: 845, text-fig. 5. — Korn 1994: 74, text-figs 65e–g, 66i–j, 67e, 68d. — Korn & Weyer 2003: 96, pl. 1 figs 13–14, pl. 2 figs 18–19. — Sprey 2002: 53, text-fig. 18d.
Weyerella molaris – Korn 2006: text-fig. 3h.

non *Gattendorfia molaris* – Ruan 1981: 83, pl. 20 figs 1–26. — Sheng 1989: 116, pl. 34 figs 3–5.

Diagnosis

Species of *Weyerella* with a conch reaching 30 mm diameter. Conch at 15 mm dm thickly discoidal, subevolute (ww/dm ~0.50; uw/dm ~0.40). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.35); coiling rate low (WER ~1.70). Venter rounded, umbilical margin narrowly rounded. Growth lines fine, wide-standing, with convex course. With moderately deep constrictions on the shell surface;

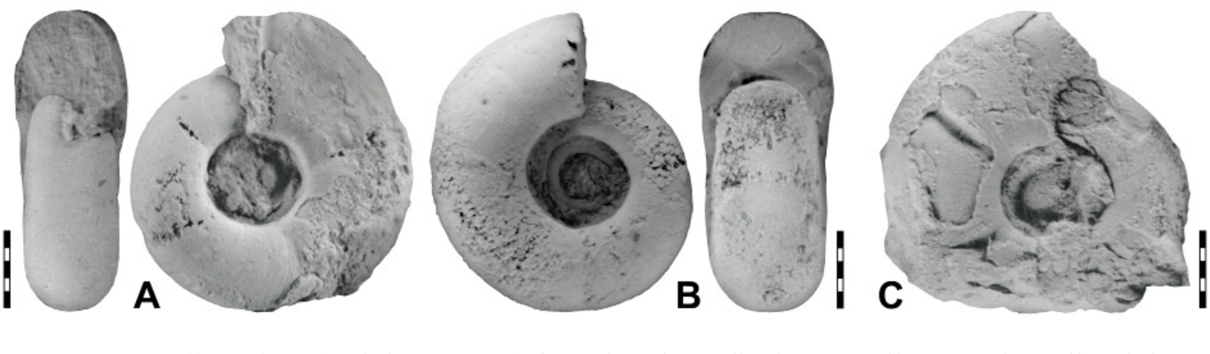

Fig. 91. *Weyerella molaris* (Vöhringer, 1960) from the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Holotype GPIT-PV-63930 from bed 3c. **B**. Paratype GPIT-PV-63928 from bed 2. **C**. Paratype GPIT-PV-63960 from bed 2. Scale bar units = 1 mm.

with moderately coarse internal shell thickenings. Suture line with narrowly lanceolate external lobe and lanceolate adventive lobe.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 5 fig. 1) and Korn (1994: text-fig. 65e); re-illustrated here in Fig. 91A; GPIT-PV-63930.

Paratypes

GERMANY • 6 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63928–GPIT-PV-63929, GPIT-PV-63931, GPIT-PV-63960–GPIT-PV-63961, GPIT-PV-64003.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schmidt 1921 Coll.; BGR X4643 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schindewolf 1925 Coll.; MB.C.4687 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; MB.C.31178.1–3 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31179.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; MB.C.31180.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; MB.C.31181.1–2 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; MB.C.31182.1–3 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; MB.C.31183.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, west of railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31184 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Weyer 1993–1994 Coll.; MB.C.31185 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31186.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31187.1–2 • 23 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.31188.1–23 • 41 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting;

Fig. 92. *Weyerella molaris* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, both Weyer 1993–1994 Coll. **A**. Specimen MB.C.31189.1 from bed 3d1b. **B**. Specimen MB.C.31190.1 from bed 3d2. Scale bar units = 1 mm.

Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31189.1–41 • 13 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31190.1–13 • 15 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31191.1–15 • 9 specimens; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Weyer 1993–1994 Coll.; MB.C.5240.8, MB.C.5240.21–28 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 28; Weyer & Korn 2000 Coll.; MB.C.5260.2 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval V; Paproth Coll.; MB.C.5284.

Description

Holotype GPIT-PV-63930 is a fairly well-preserved specimen almost completely covered with shell material; it has a conch diameter of almost 20 mm (Fig. 91A). It is thinly discoidal and subinvolute (ww/dm = 0.40; uw/dm = 0.29) with a low coiling rate (WER = 1.70). The whorl profile is almost circular.

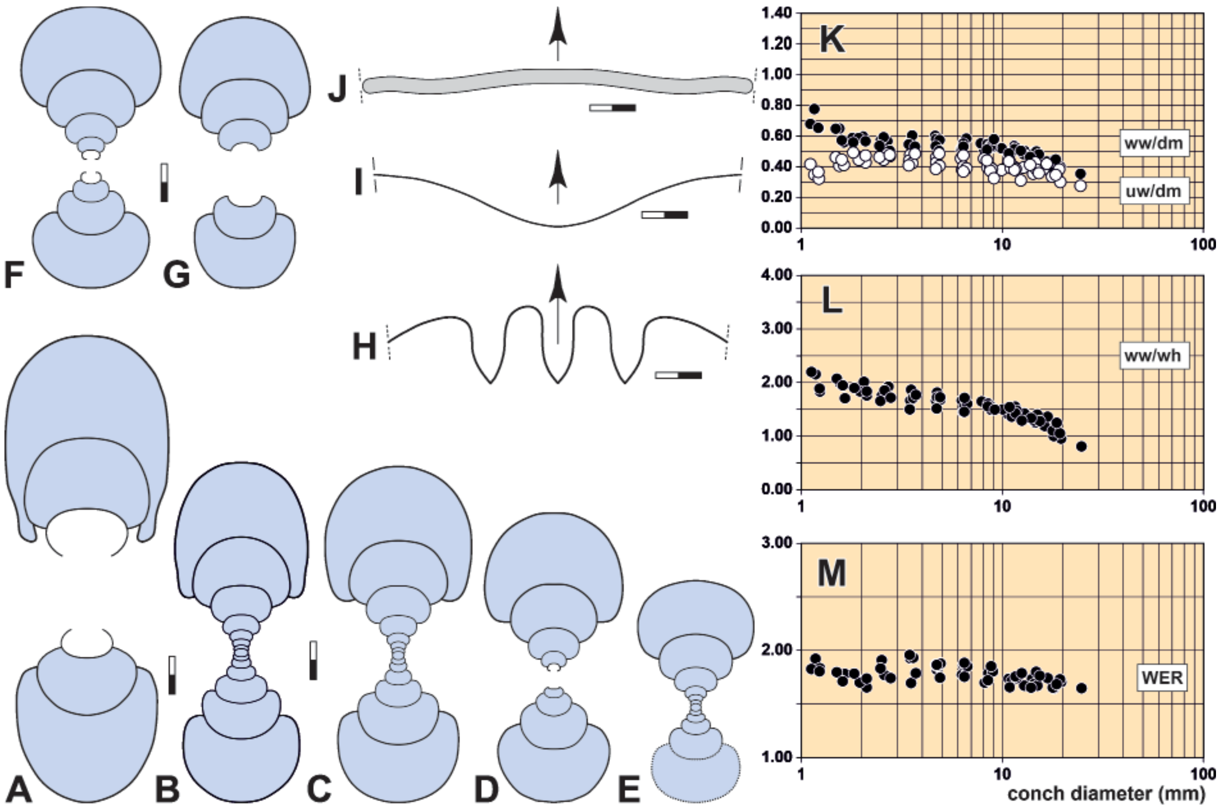

Fig. 93. *Weyerella molaris* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen BGR X4643 (Schmidt 1921 Coll.). **B**. Cross section of paratype GPIT-PV-63961 (Vöhringer Coll.) from bed 2. **C**. Cross section of specimen MB.C.31179.1 (Vöhringer Coll.) from bed 2. **D**. Cross section of specimen MB.C.31181.1 (Vöhringer Coll.) from bed 3c. **E**. Cross section of specimen MB.C.31182.1 (Vöhringer Coll.) from bed 3d. **F**. Cross section of specimen MB.C.31181.2 (Vöhringer Coll.) from bed 3c. **G**. Cross section of specimen MB.C.31179.2 (Vöhringer Coll.) from bed 2. **H**. Suture line of paratype GPIT-PV-63961 (Vöhringer Coll.) from bed 2, at ww = 7.4 mm, wh = 7.4 mm. **I**. Growth line course of holotype GPIT-PV-63930 (Vöhringer Coll.) from bed 3c, at ww = 7.0 mm, wh = 7.6 mm. **J**. Internal shell thickening course of paratype GPIT-PV-63960 (Vöhringer Coll.) from bed 2, at wh = 8.2 mm. **K–M**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

It can be clearly seen that during the last whorl there is increasing overlap upon the preceding whorl; therefore, the uw/dm ratio decreases considerably within a short growth interval. The ornament consists of fine growth lines, with a convex arch on the flank and extend in backward direction, to form a deep ventral sinus (Fig. 93I). In addition, very weak constrictions can be seen on the shell surface; they are restricted to the middle of the flank.

Paratype GPIT-PV-63928 (Fig. 91B) has almost the same size (19 mm conch diameter), but differs from the holotype in the shape of wider umbilicus (uw/dm = 0.34). It differs from the holotype probably owing to a longer pre-adult ontogenetic stage. While the holotype has just reached the stage in which the umbilical width is being reduced by increasing overlap the uw/dm ratio is reduced when compared with paratype GPIT-PV-63928. Both specimens are very similar in their strongly convex course of the growth lines and the presence of shell constrictions.

Paratype GPIT-PV-63960 with about 22 mm conch diameter also shows a strong umbilical overlap upon the preceding whorl (Fig. 91C). The specimen allows an insight into the course of internal shell thickening in the adult stage. This course is almost linear and slightly biconvex, in contrast to the growth lines, which run with a convex curve (Fig. 93J).

Many additional, well-preserved specimens are available. Two of them (MB.C.31189.1, MB.C.31190.1) are illustrated here (Fig. 92); they supplement the material from the type series and show largely the same morphological characters.

The suture line of paratype GPIT-PV-63961 shows a lanceolate external lobe and an almost identically shaped, approximately symmetrical adventive lobe. Both are separated by a nearly symmetrical, inverted U-shaped ventrolateral saddle (Fig. 93H).

A series of sectioned specimens (Fig. 93A–G) shows the variation of the species in terms of the different pace in the ontogenetic development of their conch morphology. In specimen BGR X4643 (Fig. 93A) a stronger overlap of the umbilicus with a conch diameter of 19 mm is not yet recognisable; however, half a volution later, at 22 mm in diameter, the overlap is very prominent and a shallow dorsolateral depression can be recognised.

Paratype GPIT-PV-63961 (Fig. 93B) and specimen MB.C.31179.1 (Fig. 93C) already show an incipient flattening of the whorl profile in the dorsolateral area at a conch diameter of 18 mm and a beginning of a stronger overlap upon the umbilicus. In contrast to this, in the specimens MB.C.31181.1 (Fig. 93D) and MB.C.31181.2 (Fig. 93F), such a tendency is not yet recognisable at all at a conch diameter of 15 mm.

Remarks

Weyerella molaris differs from *W. reticulum* in the absence of spiral lines. *Weyerella lenis* has a much more slender conch (ww/dm ~0.32 at 15 mm conch diameter in contrast to *W. molaris* with 0.50).

Species with similar conch morphology of the genus described from Guizhou have either a broader conch (*W. discoides* with ww/dm ~0.60) or a more slender conch (*W. popanoides* and *W. mimica* with ww/dm ~0.40) than *W. molaris* (ww/dm ~0.50). The material described by Ruan (1981) as *W. molaris* differs by the narrower umbilicus (uw/dm ~0.30) from the type material (uw/dm ~0.40) at 15 mm conch diameter. Therefore, it cannot be placed in this species.

Weyerella protecta from the Anti-Atlas is similar, but shows a narrowing of the umbilicus starting at a larger diameter. At 20 mm conch diameter, the uw/dm ratio is about 0.30 in *W. molaris*, but still about 0.38 in *W. protecta*.

Gattenpleura concava has similar juvenile whorls, but closes the umbilicus in the adult stage and possesses a conspicuous dorsolateral groove, which in *W. molaris* is only very incipiently developed.

Table 89. Conch measurements, ratios and rates of *Weyerella molaris* (Vöhringer, 1960) from Oberrödinghausen, Hasselbachtal and Oese.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
BGR X4643	24.64	8.59	10.87	6.62	5.40	0.35	0.79	0.27	1.64	0.50
GPIT-PV-63930	19.52	7.72	8.23	5.72	4.54	0.40	0.94	0.29	1.70	0.45
GPIT-PV-63928	18.54	8.21	6.65	6.31	4.23	0.44	1.23	0.34	1.68	0.36
GPIT-PV-63961	17.94	7.03	7.12	6.05	3.93	0.39	0.99	0.34	1.64	0.45
MB.C.31179.1	17.74	7.72	7.10	5.84	3.91	0.44	1.09	0.33	1.65	0.45
MB.C.31189.1	16.71	7.16	5.30	6.93	4.03	0.43	1.35	0.41	1.74	0.24
MB.C.5260.2	16.39	7.44	6.00	5.68	3.37	0.45	1.24	0.35	1.59	0.44
MB.C.31181.1	15.28	7.30	5.75	5.38	3.76	0.48	1.27	0.35	1.76	0.35
MB.C.31181.2	14.86	7.36	5.28	5.60	3.34	0.50	1.39	0.38	1.66	0.37
MB.C.31179.2	14.29	6.88	5.39	4.98	3.27	0.48	1.28	0.35	1.68	0.39
MB.C.5240.8	13.46	6.49	4.94	4.92	–	0.48	1.31	0.37	–	–
MB.C.31190.1	12.79	6.12	4.32	4.98	2.88	0.48	1.42	0.39	1.67	0.33
MB.C.31182.1	11.71	6.11	4.16	4.46	2.83	0.52	1.47	0.38	1.74	0.32

Table 90. Conch ontogeny of *Weyerella molaris* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; subevolute to evolute (ww/dm ~0.55; uw/dm = 0.40–0.50)	moderately depressed; moderately embracing (ww/wh ~1.85; IZR ~0.25)	low (WER ~1.70)
5 mm	thickly discoidal; subevolute to evolute (ww/dm ~0.55; uw/dm = 0.40–0.50)	moderately depressed; moderately embracing (ww/wh ~1.65; IZR ~0.20)	moderate (WER ~1.80)
10 mm	thickly discoidal; subevolute (ww/dm ~0.55; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.40; IZR ~0.30)	low (WER ~1.65)
20 mm	thinly discoidal; subevolute (ww/dm ~0.40; uw/dm ~0.30)	weakly depressed; strongly embracing (ww/wh ~1.05; IZR ~0.40)	low (WER ~1.70)

Weyerella reticulum (Vöhringer, 1960)
Figs 8C, 94–95; Tables 91–92

Gattendorfia reticulum Vöhringer, 1960: 156, pl. 5 fig. 3, text-fig. 31.

Gattendorfia reticulum – Korn 1992b: 17, pl. 2 figs 34–35; 1994: 74, text-figs 65h, 67g, 68b. — Schönlaub *et al*. 1992: pl. 5 figs 34–35. — Korn & Weyer 2003: 100, pl. 2 fig. 5.

Diagnosis

Species of *Weyerella* with a conch reaching 25 mm diameter. Conch at 15 mm dm thickly discoidal, subevolute (ww/dm ~0.45; uw/dm ~0.42). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.30); coiling rate low (WER ~1.65). Venter broadly rounded, umbilical margin narrowly rounded. Growth lines coarse, wide-standing, with convex course; ventral sinus very deep. The combination of growth lines with spiral lines cause a reticulate ornament. Without constrictions on the shell surface; without internal shell thickenings. Suture line with narrowly lanceolate, pouched external lobe and very narrow, lanceolate adventive lobe.

Table 91. Conch measurements, ratios and rates of the holotype of *Weyerella reticulum* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63974	14.9	6.8	5.1	6.4	3.2	0.46	1.33	0.43	1.62	0.37
GPIT-PV-63991	5.55	2.92	1.73	2.52	1.32	0.53	1.69	0.45	1.72	0.24

Material examined

Holotype
GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 6; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 5 fig. 3) and Korn (1994: text-fig. 65h); re-illustrated here in Fig. 94; GPIT-PV-63974.

Paratypes
GERMANY • 4 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63975–GPIT-PV-63976, GPIT-PV-63979, GPIT-PV-63991.

Additional material
GERMANY • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 62A; Weyer 1993–1994 Coll.; MB.C.5242.1.

Description
Holotype GPIT-PV-63974 has almost 15 mm conch diameter and is well-preserved and covered with shell remains (Fig. 94). The conch is discoidal and subevolute (ww/dm = 0.46; uw/dm = 0.43) with weakly depressed, continuously rounded whorl profile. The shell surface shows a combination of coarse growth lines, which are directed backwards already on the umbilical wall and flank and form a deep and broad ventral sinus, and spiral lines, which are less prominent than the growth lines. Shell constrictions are not present.

The suture line of paratype GPIT-PV-63975 is characterised by very narrow lobes (Fig. 95B). The external lobe is lanceolate and weakly pouched; next to it follows the weakly asymmetrical ventrolateral saddle and then the symmetrical, lanceolate adventive lobe, which has almost the same shape as the external lobe.

The sectioned paratype GPIT-PV-63991 shows only the whorl up to 5.5 mm conch diameter (Fig. 95A). The whorl profile is always crescent-shaped with a slowly decreasing ww/wh ratio from about 2.00 at 2 mm conch diameter to about 1.70 at 5.5 mm dm (Fig. 95E).

Fig. 94. *Weyerella reticulum* (Vöhringer, 1960), holotype GPIT-PV-63974 Vöhringer Coll.) from the Oberrödinghausen railway cutting, bed 6. Scale bar units = 1 mm.

Table 92. Conch ontogeny of *Weyerella reticulum* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; evolute (ww/dm ~0.62; uw/dm ~0.45)	moderately depressed; moderately embracing (ww/wh ~2.00; IZR ~0.20)	moderate (WER ~1.80)
5 mm	thickly discoidal; evolute (ww/dm ~0.55; uw/dm ~0.45)	moderately depressed; moderately embracing (ww/wh ~1.75; IZR ~0.20)	moderate (WER ~1.75)
15 mm	thinly discoidal; subevolute (ww/dm ~0.45; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.35; IZR ~0.35)	low (WER ~1.65)

Remarks

Weyerella reticulum is easily distinguished from the other species of the genus by its reticulate ornament.

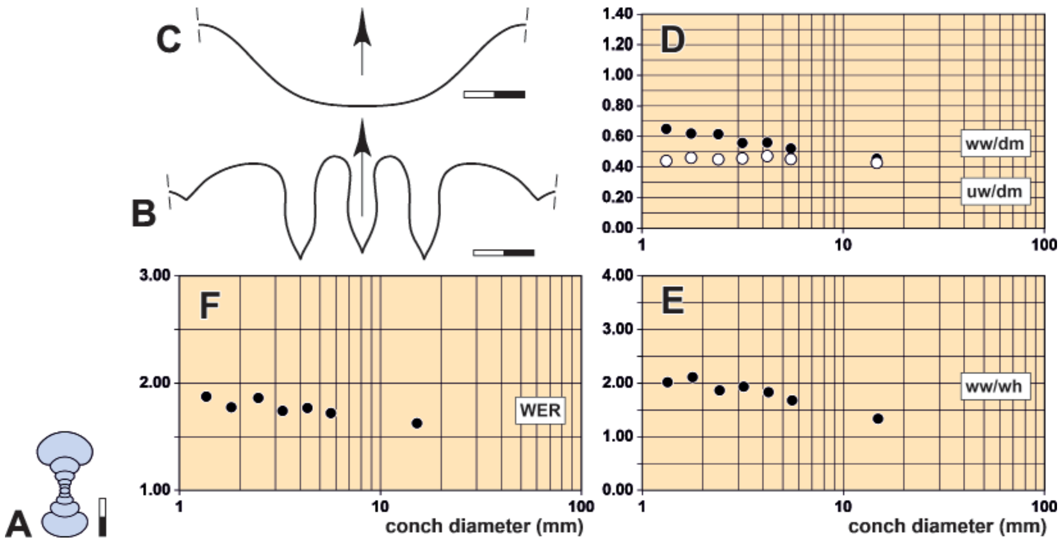

Fig. 95. *Weyerella reticulum* (Vöhringer, 1960) from the Oberrödinghausen railway cutting; all Vöhringer Coll. **A**. Cross section of paratype GPIT-PV-63991 from bed 5. **B**. Suture line of paratype GPIT-PV-63975 from bed 5, at dm = 11.5 mm, ww = 6.5 mm, wh = 4.0 mm. **C**. Growth line course of holotype GPIT-PV-63974 from bed 6, at dm = 14.2 mm, ww = 7.2 mm, ww = 5.4 mm. **D–F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER). Scale bar units = 1 mm.

Weyerella lenis sp. nov.

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Fig. 96; Tables 93–94

Diagnosis

Species of *Weyerella* with a conch reaching 25 mm diameter. Conch at 15 mm dm extremely discoidal, subevolute (ww/dm ~0.32; uw/dm ~0.35). Whorl profile at 15 mm dm weakly compressed (ww/wh ~0.85); coiling rate very low (WER ~1.45). Venter continuously rounded, umbilical margin narrowly rounded. Shell nearly smooth; without constrictions on the shell surface.

Etymology

From the Latin '*lenis*' = 'gentle', referring to the very weak ornament.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2a; Weyer 1993–1994 Coll.; illustrated in Fig. 96A; MB.C.31192.

Paratype

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63929.

Description

Holotype MB.C.31192 is an incomplete specimen with approximately 15 mm conch diameter (Fig. 96A). It is thinly discoidal and subevolute (ww/dm = 0.34; uw/dm = 0.36); the whorl profile is weakly compressed (ww/dm = 0.91) with slightly flattened, convergent flanks and a continuously rounded venter. The coiling rate is low (WER = 1.44). The shell surface appears to be completely smooth with the exception of a few barely discernible radial folds that extend backwards on the flank.

Paratype GPIT-PV-63929 had already been sectioned by Vöhringer, but not illustrated. It allows the study of all whorls up to a conch diameter of 9 mm (Fig. 96B). The whorl profile is kidney-shaped up to 5 mm conch diameter, thereafter it becomes C-shaped with increasing enclosure of the preceding whorl. The aperture is low in all stages; the coiling rate is always close to 1.50.

Remarks

Weyerella lenis sp. nov. differs from all the other species of the genus *Weyerella* in the combination of the very slender conch, the low coiling rate (WER ~1.50) and the smooth shell.

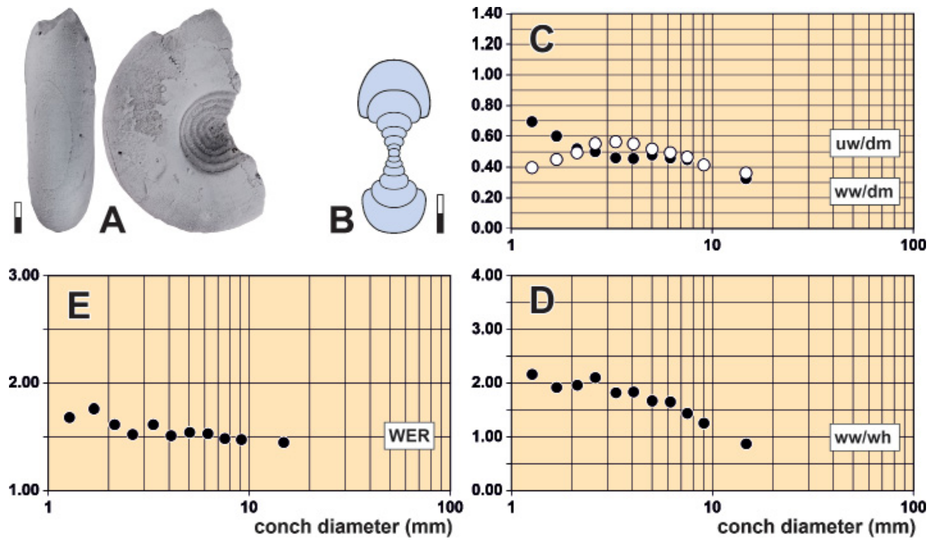

Fig. 96. *Weyerella lenis* sp. nov. from the Oberrödinghausen railway cutting. **A**. Holotype MB.C.31192 (Weyer 1993–1994 Coll.) from bed 2a. **B**. Cross section of paratype GPIT-PV-63929 (Vöhringer Coll.) from bed 2. **C**–**E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of the holotype and the paratype. Scale bar units = 1 mm.

Table 93. Conch measurements, ratios and rates of *Weyerella lenis* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31192	14.83	4.72	5.51	5.28	2.48	0.32	0.86	0.36	1.44	0.55
GPIT-PV-63929	9.12	3.79	3.04	3.73	1.59	0.42	1.25	0.41	1.47	0.48

Table 94. Conch ontogeny of *Weyerella lenis* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly discoidal; evolute (ww/dm ~0.50; uw/dm ~0.48)	moderately depressed; moderately embracing (ww/wh ~2.00; IZR ~0.20)	low (WER ~1.60)
5 mm	thickly discoidal; evolute (ww/dm ~0.55; uw/dm ~0.50)	moderately depressed; strongly embracing (ww/wh ~1.65; IZR ~0.35)	low (WER ~1.55)
15 mm	thinly discoidal; subevolute (ww/dm ~0.32; uw/dm ~0.35)	weakly compressed; very strongly embracing (ww/wh ~0.85; IZR ~0.55)	very low (WER ~1.45)

Genus ***Hasselbachia*** Korn & Weyer, 2003

Type species

Imitoceras multisulcatum Vöhringer, 1960: 141; original designation.

Genus diagnosis

Genus of the Gattendorfiinae with a discoidal to pachyconic conch with low coiling rate (WER = 1.50–1.70); inner whorls subevolute or evolute, umbilicus in the adult stage not completely closed. Ornament usually with coarse, convex or slightly biconvex growth lines. Suture line with deep, V-shaped external lobe (as deep as adventive lobe).

Genus composition

Central Europe (Vöhringer 1960): *Imitoceras multisulcatum* Vöhringer, 1960; *Imitoceras gracile* Vöhringer, 1960; *Hasselbachia erronea* sp. nov.

North Africa (Ebbighausen *et al.* 2004; Ebbighausen & Bockwinkel 2007): *Hasselbachia gourara* Ebbighausen, Bockwinkel, Korn & Weyer, 2004; *Hasselbachia arca* Ebbighausen & Bockwinkel, 2007.

Remarks

Several characters allow a clear separation from the superficially similar species of other genera, such as *Paragattendorfia* and *Stockumites*. The low aperture and hence slowly expanding whorls (WER ~1.50 in the adult stage) is in contrast to *Stockumites*, in which this value usually ranges between 1.70 and 1.90. Species of *Paragattendorfia* have similarly low coiling rates (WER ~1.45), but in *Hasselbachia*, the umbilicus is wide only in the inner whorls, followed by an incomplete adult closure by a significant overlap of the flanks upon the umbilicus. In *Paragattendorfia*, the uw/dm ratio is rather constant throughout ontogeny. *Hasselbachia* is remarkable because it combines characters, which are present in other genera: the low WER as in *Mimimitoceras*, the continuous opening of the umbilicus in the inner whorls as in *Paragattendorfia* and closure of the umbilicus is more similar to *Stockumites*.

Kullmann (2009) regarded *Hasselbachia* as probable synonym of the subgenus *Acutimitoceras* (*Stockumites*), but the clear distinguishable characters (e.g., the very low coiling rate in *Hasselbachia*) make such a decision obsolete. Apart from the coiling rate, the different shape of the inner whorls justify the independence of the genus and can be used as an indication for a phylogenetic placement of *Hasselbachia* in an evolutionary lineage within the subfamily Gattendorfiinae.

Hasselbachia multisulcata (Vöhringer, 1960)
Figs 8D, 97, 98A–D, 99; Tables 95–96

Imitoceras multisulcatum Vöhringer, 1960: 141, pl. 4 fig. 5, text-fig. 19.

Imitoceras multisulcatum – Weyer 1976: 841, text-fig. 4.
Acutimitoceras multisulcatum – Korn 1994: 47, text-figs 49g, l, 50j–k, 51c, 55b.
Hasselbachia multisulcata – Korn & Weyer 2003: 96, pl. 1 figs 7–8, text-fig. 14e–f. — Korn 2006: text-fig. 3e.
Acutimitoceras (*Stockumites*) *multisulcatum* – Sprey 2002: 52, pl. 4 fig. 5, text-fig. 17f.
Imitoceras (*Imitoceras*) *multisulcatum* – Ruan 1981: 80, pl. 18 figs 5–7, pl. 19 figs 1–13.

Diagnosis

Species of *Hasselbachia* with a globular and subevolute conch at 5 mm dm (ww/dm = 0.85–0.95; uw/dm = 0.40–0.45) and a thinly pachyconic and subinvolute conch at 15 mm dm (ww/dm = 0.60–0.65; uw/dm = 0.15–0.25). Whorl cross section at 15 mm dm weakly depressed (ww/wh = 1.25–1.50); coiling rate very low (WER ~1.45). Flanks strongly convergent. Shell ornament with coarse lamellar growth lines with convex course. Shell and internal mould with numerous short constrictions on the flank.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 4 fig. 5), Korn (1994: text-fig. 58b) and Korn (2006: text-fig. 3e); re-illustrated here in Fig. 97B; GPIT-PV-63911.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63938 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Vöhringer Coll.; GPIT-PV-63949, GPIT-PV-64017 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; GPIT-PV-63913, GPIT-PV-63915.

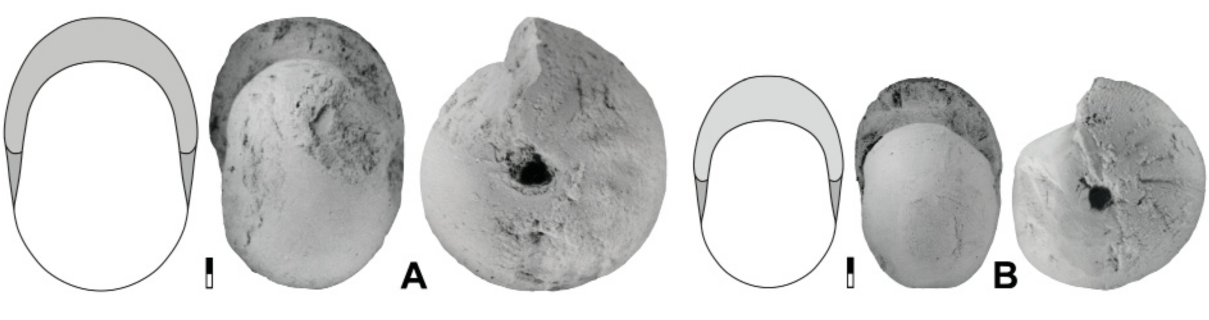

Fig. 97. *Hasselbachia multisulcata* (Vöhringer, 1960) from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Paratype GPIT-PV-63913 from bed 4. **B**. Holotype GPIT-PV-63911 from bed 3e. Scale bar units = 1 mm.

Additional material

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31193.1–2 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31194.1–3 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31195.1–5 • 4 specimens; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Weyer 1993–1994 Coll.; MB.C.5240.1–MB.C.5240.4.

Description

The two type specimens GPIT-PV-63911 and GPIT-PV-63913 (Fig. 97) are moderately well-preserved. Therefore, several specimens from new collections are described in more detail below. Holotype GPIT-PV-63911 has a conch diameter of 15 mm and is thinly pachyconic and involute (ww/dm = 0.69; uw/dm = 0.11). The shell shows growth lines that extend with a slightly convex curve across the flank and form a very broad, shallow ventral sinus (Fig. 99G).

The four rather well-preserved specimens MB.C.31195.1 (22 mm dm), MB.C.31195.2 (16.5 mm dm), MB.C.31194.1 (16 mm dm) and MB.C.31195.3 (15 mm dm) allow the study of conch shape and ornament (Fig. 98A–D). All of them are very similar in their conch proportions; they are thinly pachyconic (ww/dm = 0.60–0.63) and involute (uw/dm = 0.10–0.15). All show rapid closure of the umbilicus by overlap of the last whorl, meaning that the absolute umbilical diameter is reduced. The whorl profile has a semilunate shape with little space on the lateral sides; the flanks converge rather rapidly towards the broadly rounded venter.

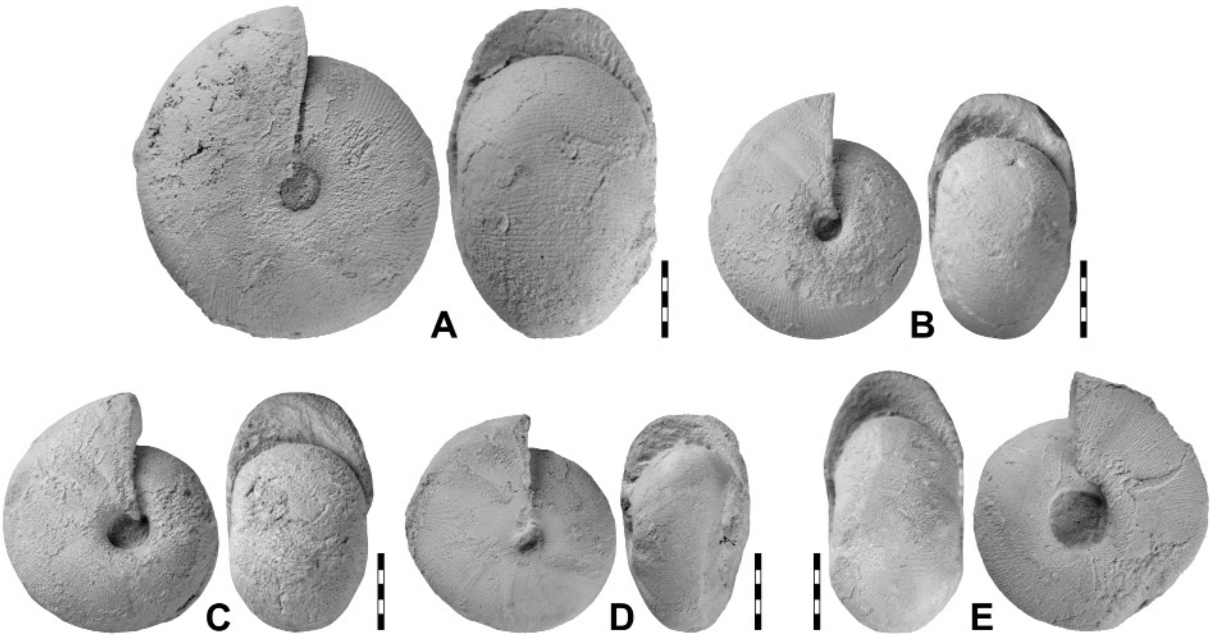

Fig. 98. *Hasselbachia* from the Oberrödinghausen railway cutting, all Weyer 1993–1994 Coll. **A**. *Hasselbachia multisulcata* (Vöhringer, 1960), specimen MB.C.31195.1 from bed 3e. **B**. *Hasselbachia multisulcata* (Vöhringer, 1960), specimen MB.C.31195.2 from bed 3e. **C**. *Hasselbachia multisulcata* (Vöhringer, 1960), specimen MB.C.31194.1 from bed 3d2. **D**. *Hasselbachia multisulcata* (Vöhringer, 1960), specimen MB.C.31195.3 from bed 3e. **E**. *Hasselbachia gracilis* (Vöhringer, 1960), specimen MB.C.31196.1 from bed 3d1b. Scale bar units = 1 mm.

The shell ornament is best preserved in specimen MB.C.31195.1 (Fig. 98A). It shows lamellar growth lines extending convexly with a broad arch across the flanks and form a shallow sinus across the venter. Like the other two specimens, it possesses only very weak and short constrictions in the midflank area.

Vöhringer produced three cross sections but published only one of them. These three are GPIT-PV-64017 (8.5 mm dm), GPIT-PV-63938 (13 mm dm) and GPIT-PV-63949 (14.5 mm dm) (Fig. 99A–C). None of them has the innermost whorls preserved, but these can be seen in specimen MB.C.5240.2 from Hasselbachtal (Fig. 99D). The conch shape and its proportions change markedly during ontogeny with a triphasic ww/dm trajectory and a biphasic uw/dm trajectory. The coiling rate decreases in the early juvenile stage to WER = 1.60 at 2.5 mm conch diameter, then slowly decreases to 1.50 and remains stable at this value until 17 mm diameter. The whorl profile is strongly depressed in the juvenile stage up to a conch diameter of 9 mm (ww/wh higher than 2.50); up to this size, the umbilicus is opening continuously. Thereafter, the whorls begin to embrace the umbilicus, which can best be observed in the specimens from the Hasselbachtal section (Fig. 99D–E).

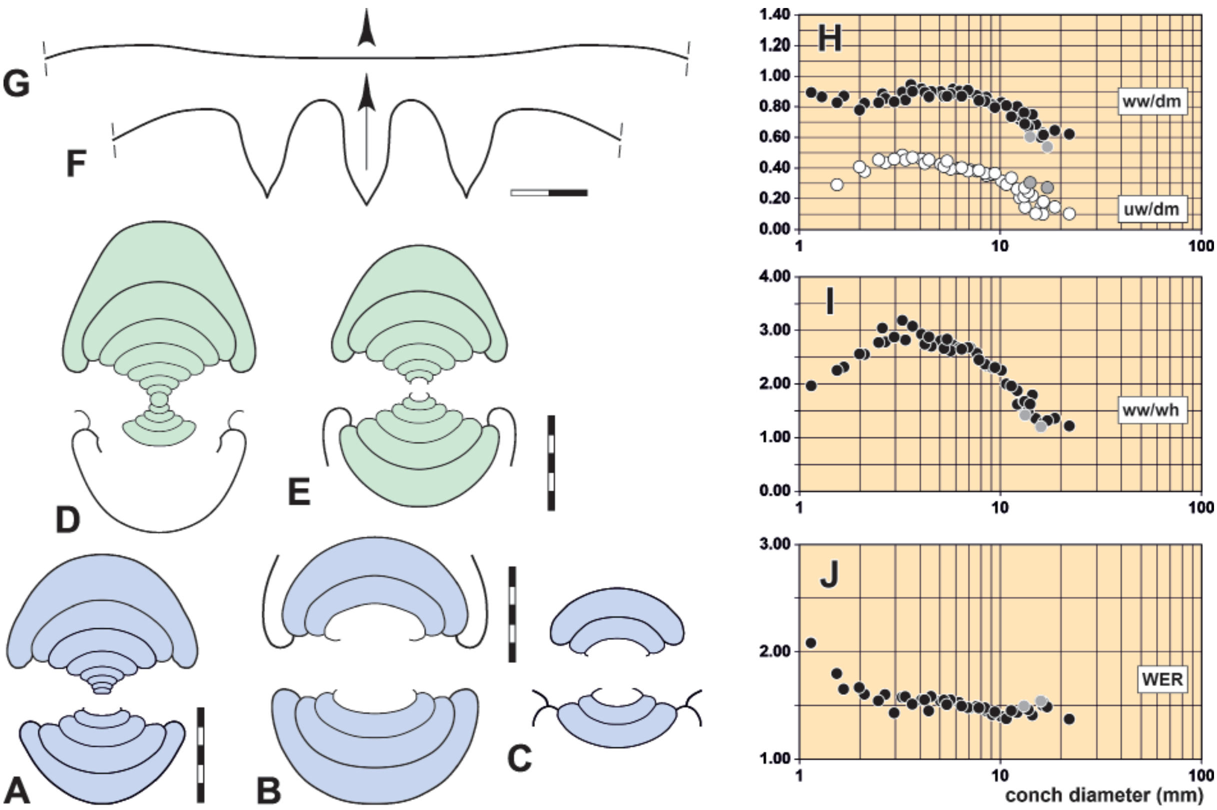

Fig. 99. *Hasselbachia multisulcata* (Vöhringer, 1960) from the Oberrödinghausen railway cutting (A-C, F, G) and the Hasselbachtal section (D, E; after Korn & Weyer 2003). **A**. Cross section of paratype GPIT-PV-63938 (Vöhringer Coll.) from bed 3e. **B**. Cross section of paratype GPIT-PV-63949 (Vöhringer Coll.) from bed 3d. **C**. Cross section of paratype GPIT-PV-64017 (Vöhringer Coll.) from bed 3e. **D**. Cross section of specimen MB.C.5240.2 (Weyer 1993–1994 Coll.) from bed 57. **E**. Cross section of specimen MB.C.5240.3 (Weyer 1993–1994 Coll.) from bed 57. **F**. Suture line of paratype GPIT-PV-64017 (Vöhringer Coll.) from bed 3e, at dm = 8.8 mm, ww = 7.7 mm, wh = 4.3 mm. **G**. Growth line course of holotype GPIT-PV-63911 (Vöhringer Coll.) from bed 3e, at 13.2 mm dm, 10.0 mm ww, 7.0 mm wh. **H–J**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens (holotype of *Hasselbachia gracilis* as grey dots). Scale bar units = 1 mm.

Table 95. Conch measurements, ratios and rates of *Hasselbachia multisulcata* (Vöhringer, 1960) from Oberrödinghausen and Hasselbachtal.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31195.1	22.1	13.8	11.3	2.3	3.3	0.62	1.22	0.11	1.38	0.71
MB.C.31195.2	16.3	10.3	8.2	1.7	3.0	0.63	1.25	0.10	1.51	0.63
MB.C.31194.1	16.0	9.6	8.0	2.4	3.1	0.60	1.21	0.15	1.55	0.61
GPIT-PV-63911	15.1	10.4	7.6	1.6	–	0.69	1.36	0.11	–	–
GPIT-PV-63938	14.5	10.9	6.1	3.2	2.3	0.75	1.80	0.22	1.42	0.62
MB.C.5240.3	13.8	9.2	6.1	3.4	2.4	0.67	1.51	0.25	1.47	0.61
GPIT-PV-63949	13.2	10.0	6.0	2.8	2.4	0.76	1.68	0.22	1.50	0.60
GPIT-PV-64017	8.4	7.0	3.0	3.1	1.5	0.84	2.37	0.37	1.48	0.49

Table 96. Conch ontogeny of *Hasselbachia multisulcata* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subevolute (ww/dm ~0.80; uw/dm ~0.40)	strongly depressed; strongly embracing (ww/wh ~2.50; IZR ~0.40)	low (WER ~1.60)
4 mm	thinly globular; subevolute (ww/dm ~0.90; uw/dm ~0.45)	very strongly depressed; strongly embracing (ww/wh ~2.75; IZR ~0.40)	low (WER ~1.55)
12 mm	thickly pachyconic; subevolute (ww/dm ~0.75; uw/dm ~0.35)	moderately depressed; very strongly embracing (ww/wh ~1.90; IZR ~0.60)	very low (WER ~1.45)
20 mm	thickly discoidal; involute (ww/dm ~0.55; uw/dm ~0.10)	weakly depressed; very strongly embracing (ww/wh ~1.40; IZR ~0.65)	very low (WER ~1.40)

The suture line of paratype GPIT-PV-64017 has a lanceolate external lobe accompanied by a slightly asymmetrical, rounded ventrolateral saddle. The adventive lobe is V-shaped with slightly outwardly curved flanks (Fig. 99F).

Remarks

Hasselbachia multisulcata differs from *H. gracilis* by the wider conch in combination with a narrower umbilicus. The uw/dm ratio, at 17 mm conch diameter, is about 0.27 in *H. gracilis*, but only about 0.13 in *H. multisulcata*.

Hasselbachia gracilis (Vöhringer, 1960)

Figs 8E, 98E, 100; Table 97

Imitoceras gracile Vöhringer, 1960: 143, pl. 4 fig. 6, text-fig. 20.

Acutimitoceras gracile – Korn 1994: 47, text-figs 49f, 55a.
Acutimitoceras (*Stockumites*) *gracile* – Becker 1996: 36.
Hasselbachia gracilis – Korn & Weyer 2003: 96, pl. 1 figs 9–10, 15–16.

Diagnosis

Species of *Hasselbachia* with a thickly discoidal and subinvolute conch at 15 mm dm (ww/dm ~0.55; uw/dm ~0.25); whorl cross section depressed (ww/wh ~1.50); coiling rate very low (WER ~1.50). Flanks strongly convergent. Fine lamellar growth lines with convex course. Shell and internal mould with short constrictions.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 4 fig. 6), and Korn (1994: text-fig. 58b), re-illustrated here in Fig. 100A; GPIT-PV-63917.

Paratype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63919.

Additional material

GERMANY • 4 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31196.1–4 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31197.1–2 • 2 specimens; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 53; Weyer 1993–1994 Coll.; MB.C.5238.1, MB.C.5238.2 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Weyer 1993–1994 Coll.; MB.C.5240.5.

Description

Holotype GPIT-PV-63917 is an incomplete specimen with 17 mm conch diameter (Fig. 100A). It is thickly discoidal and subinvolute (ww/dm = 0.54; uw/dm = 0.27) with a low coiling rate (WER = 1.49). The shell bears five shallow radial notches on the flank of the last half whorl. The growth lines are lamellar and very weakly convex across the flanks; they form a very shallow ventral sinus (Fig. 100B).

The moderately well-preserved specimen MB.C.31196.1 (Fig. 98E) with 17 mm dm has a thickly discoidal subinvolute conch (ww/dm = 0.54; uw/dm = 0.27) and a semilunate whorl section with very low aperture (WER = 1.49). The specimen is covered with shell remains, which show fine lamellar growth lines that extend backwardly directed across flanks and venter. The shell has some very shallow constrictions on the midflank.

Remarks

Hasselbachia gracilis differs from *H. multisulcata* by the more slender conch in combination with a wider umbilicus. The uw/dm ratio, at 17 mm conch diameter, is about 0.13 in *H. multisulcata*, but only about 0.27 in *H. gracilis*.

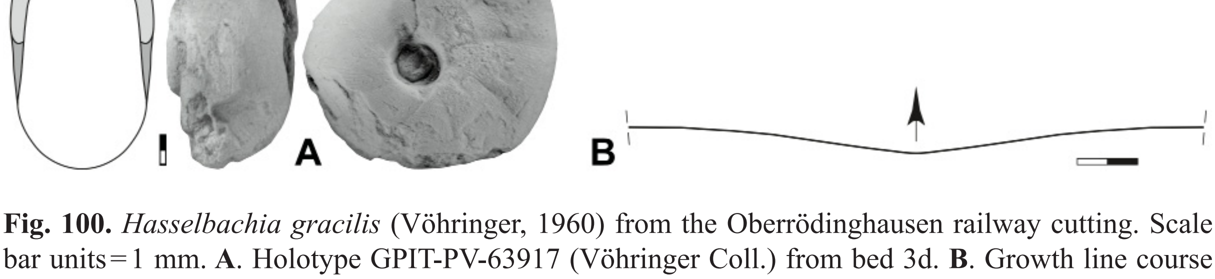

Fig. 100. *Hasselbachia gracilis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. Scale bar units = 1 mm. **A**. Holotype GPIT-PV-63917 (Vöhringer Coll.) from bed 3d. **B**. Growth line course of holotype GPIT-PV-63917, at dm = 16.6 mm, ww ca. 9.0 mm, wh = 8.3 mm. Scale bar units = 1 mm.

Table 97. Conch measurements, ratios and rates of *Hasselbachia gracilis* (Vöhringer, 1960) from Oberrödinghausen and Hasselbachtal.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63917	17.2	9.3	7.1	4.7	3.1	0.54	1.32	0.27	1.49	0.56
MB.C.5240.5	15.7	9.0	6.8	3.0	–	0.57	1.31	0.19	–	–

Hasselbachia erronea sp. nov.
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Figs 101–102; Tables 98–99

Acutimitoceras sphaeroidale – Vöhringer 1960: 143, text-fig. 21. — Korn 1992b: 17, pl. 2 figs 30–31. — Schönlaub *et al*. 1992: pl. 5 figs 30–31. — Korn 1994: text-figs 50f, 51b.

Diagnosis

Species of *Hasselbachia* with a thickly pachyconic and involute conch at 15 mm dm (ww/dm ~0.75; uw/dm ~0.10); whorl cross section moderately depressed (ww/wh ~1.65); coiling rate very low (WER ~1.60). Flanks moderately strongly converging. Fine lamellar growth lines with convex course. Shell and internal mould with constrictions extending across the venter.

Etymology

From the Latin '*erronea*', referring to the previous misunderstanding of the material.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; illustrated in Fig. 101; MB.C.31198.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-63932, GPIT-PV-63927 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval III; Paproth Coll.; MB.C.5286 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval IV; Paproth Coll.; MB.C.5283.1.

Fig. 101. *Hasselbachia erronea* sp. nov., holotype, MB.C.31198 (Weyer 1993–1994 Coll.) from the Oberrödinghausen railway cutting, bed 3e. Scale bar units = 1 mm.

Description

Holotype MB.C.31198 (Fig. 101) has 16 mm conch diameter and is thickly pachyconic with a very narrow umbilicus (ww/dm = 0.75; uw/dm = 0.09). The specimen possesses broadly rounded flanks that merge with a continuous curve into the evenly rounded venter. The umbilical margin is rather narrow. The shell bears an ornament with fine, widely spaced growth lines, which extend almost straight across flanks and venter, forming only a low lateral projection (Fig. 102B). Parallel to the growth lines extend very faint shell constrictions, spaced about 120 degrees apart.

The sectioned paratype GPIT-PV-63927 allows the study of conch ontogeny up to a diameter of 15 mm (Fig. 102A). It shows the transition from the juvenile stage with a kidney-shaped whorl profile to a C-shaped whorl profile at about 7 mm conch diameter. It can be observed that the absolute width of the umbilicus does not change above about 7 mm conch diameter. Accordingly, the uw/dm ratio is reduced from ~0.30 to ~0.15 between 7 and 15 mm conch diameter. The suture line of the specimen has a lanceolate, narrow external lobe with weakly convergent flanks. It is followed on the flank by a rather narrow, tightly rounded ventrolateral saddle and a narrow, V-shaped adventive lobe (Fig. 102C).

Remarks

Hasselbachia erronea sp. nov. is described here as a new species on the basis of the paratypes of "*Imitoceras sphaeroidale* Vöhringer, 1960". These three paratypes clearly differ from the holotype of that species in their much more slender conch and the presence of shell constrictions and cannot be included in the same genus.

Hasselbachia erronea sp. nov. differs from the species *H. gracilis and H. multisulcata* by the constrictions that extend across the venter in the new species.

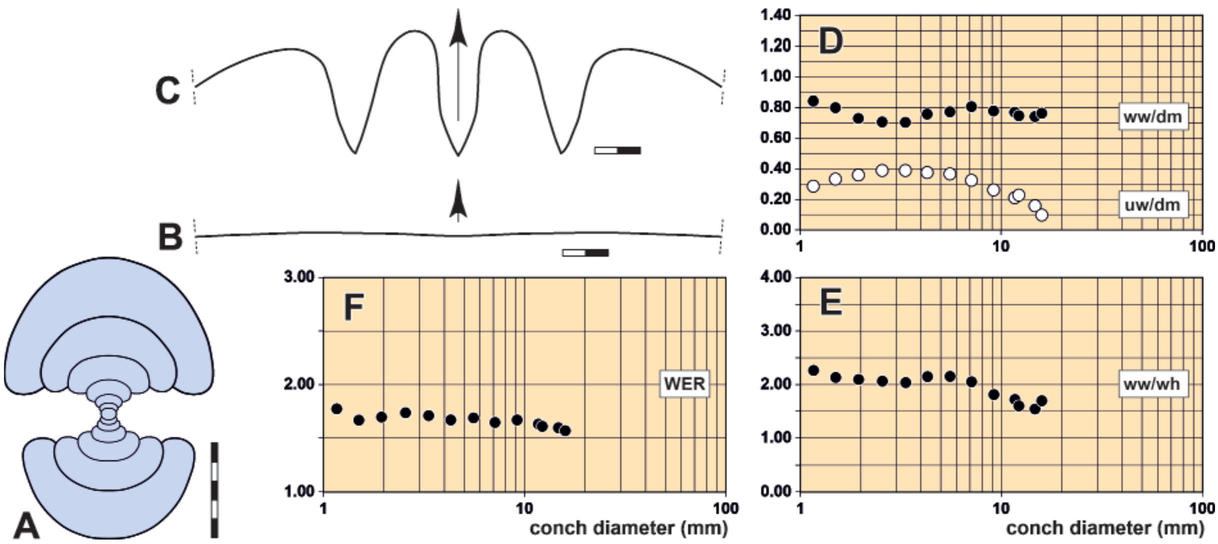

Fig. 102. *Hasselbachia erronea* sp. nov., from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63927 (Vöhringer Coll.) from bed 5. **B**. Growth line and constriction course of holotype MB.C.31198 (Weyer 1993–1994 Coll.) from bed 3e, at dm = 16.0 mm, ww = 12.2 mm, wh = 7.3 mm. **C**. Suture line of paratype GPIT-PV-63927 from bed 5, at dm = 16.0 mm, ww = 12.0 mm, wh = 7.6 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 98. Conch measurements, ratios and rates of *Hasselbachia erronea* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31198	16.0	12.2	7.3	1.5	3.2	0.76	1.68	0.09	1.57	0.56
GPIT-PV-63927	14.8	11.0	7.2	2.3	3.1	0.74	1.53	0.16	1.59	0.57
GPIT-PV-63932	12.3	9.2	5.8	2.8	2.6	0.75	1.59	0.23	1.61	0.55

Table 99. Conch ontogeny of *Hasselbachia erronea* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thinly pachyconic; subevolute (ww/dm ~0.72; uw/dm ~0.35)	strongly depressed; strongly embracing (ww/wh ~2.10; IZR ~0.35)	low (WER ~1.70)
4 mm	thickly pachyconic; subevolute (ww/dm ~0.75; uw/dm ~0.38)	strongly depressed; strongly embracing (ww/wh ~2.15; IZR ~0.35)	low (WER ~1.65)
12 mm	thickly pachyconic; subinvolute (ww/dm ~0.75; uw/dm ~0.20)	moderately depressed; very strongly embracing (ww/wh ~1.70; IZR ~0.55)	low (WER ~1.65)
16 mm	thickly pachyconic; involute (ww/dm ~0.75; uw/dm ~0.10)	moderately depressed; very strongly embracing (ww/wh ~1.60; IZR ~0.55)	low (WER ~1.60)

Subfamily **Pseudarietitinae** Bartzsch & Weyer, 1987

[nom. transl. Korn (1994: 75), pro Pseudarietitini Bartzsch & Weyer, 1987]

Subfamily composition

A total of 17 species of the Pseudarietitinae have been described so far; they belong to the following genera: *Pseudarietites* Frech, 1902 (7 species); *Paralytoceras* Frech, 1902 (3 species); *Paprothites* Bartzsch & Weyer, 1987 (7 species); *Rodingites* gen. nov. (2 species),

Two of the species are somewhat problematic, "*Pseudarietites serratus*" has some affinities to *Paralytoceras* and "*Protocanites carinatus* Vöhringer, 1960" is difficult to interpret as only one specimen is available. The conch shape similar to "*Pseudarietites planissimus*" suggests an attribution to this genus rather than to *Eocanites*. For the latter two species, the new genus *Rodingites* is introduced here.

Morphology

The pseudarietitin ammonoids are separated from the other Early Tournaisian ammonoids by two main characters, (1) the subevolute to evolute conch (which, however, also characterises some gattendorfiins and the early prolecanitid ammonoids) and (2) the rather coarse and often sharp ribs (which are not present in the gattendorfiins and prolecanitids). An additional character of the advanced pseudarietitins (*Pseudarietites*, *Rodingites* gen. nov., *Paralytoceras*) is the raised or even attached ventral keel, which may be simple or serrate.

Ontogeny

The conch ontogeny of the species is rather simple with a more or less monophasic trajectory of the ww/dm ratio, which is characterised by a continuous decrease. Different phases are only separable in some cases, such as *Pseudarietites subtilis* (see below), but they are weakly developed when compared with species of other prionoceratid subfamilies. The ventral keel of many of the genera is developed only rather late in ontogeny, at a conch diameter of about 8 mm.

Phylogeny

The origin of the subfamily Pseudarietitinae can be seen in the Gattendorfiinae, particularly in the genus *Weyerella*, which possibly gave rise to the morphologically simplest pseudarietin genus *Paprothites*. Species of both genera share a thickly discoidal, subevolute conch; the two genera differ mainly in the presence of ribs in *Paprothites*. These ribs, however, can be rather variable in *Paprothites*; *P. raricostatus* and *P. beckeri* sp. nov., for instance, possess very faint ribs and in this character are rather close to *Weyerella*.

Within the Pseudarietitinae, an evolution from the non-keeled *Paprothites* to the other two genera with keeled forms is obvious; it can also be observed in the stratigraphic succession with non-keeled *Paprothites* below the first occurrence of keeled *Pseudarietites*. The formation of the keel starts with the presence of incipient paired ventral grooves (which can be seen in *Paprothites ruzhencevi*), which in the genus *Pseudarietites* are then much more pronounced and allow a midventral keel to be developed. The keel is simple in the typical species of *Pseudarietites* (e.g., *P. silesiacus* and *P. westfalicus*) but serrated in the advanced *P. serratus*.

Stratigraphic occurrence

The genera of the subfamily Pseudarietitinae do not occur at the base of the Hangenberg Limestone or its time equivalents. In the Oberrödinghausen railway cutting, the first occurrence of *Paprothites dorsoplanus* is in bed 4 (according to Vöhringer 1960) and the first occurrence of *Pseudarietites westfalicus* is in bed 3c; the highest diversity of the subfamily occurs in beds 3c and 3b. These two species were selected by Vöhringer (1960) as index fossil for the middle two subzones of his *Gattendorfia* Stufe.

It has to be noted that the stratigraphic succession of the species of the subfamily does not perfectly reflect the proposed phylogenetic succession. The proposed phylogenetically simplest form *Paprothites raricostatus* was found only above the obviously more derived *P. dorsoplanus*. Furthermore, *Paralytoceras* sp. was collected in bed 3d, which means that the genus occurs slightly below the stratigraphic range of *Pseudarietites*.

Geographic occurrence

The Pseudarietitinae is a subfamily that is largely known from only three regions worldwide, Lower Silesia with the single locality Dzikowiec (e.g., Tietze 1870; Frech 1902; Weyer 1965; Dzik 1997), the Rhenish Mountains with a number of localities such as Hasselbachtal, Oese, Oberrödinghausen and Drewer (e.g., Schmidt 1924; Vöhringer 1960; Korn 1994; Korn *et al.* 1994; Korn & Weyer 2003) as well as Guizhou with the localities Wangyou (Sun & Shen 1965; Ruan 1981) and Dapoushang (Sheng 1989). There exists only one illustrated report of *Pseudarietites* from Thuringia (Bartzsch & Weyer 1982, 1986) and one report on *Paprothites* from Pomerania (Korejwo 1979). Other regions with considerably diverse Early Tournaisian ammonoid records are the Montagne Noire of France (Korn 1993; Korn & Feist 2007), the Carnic Alps of Austria and Italy (Korn 1992b; Schönlaub *et al.* 1992), the Anti-Atlas of Morocco (Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007) and the Gourara region of Algeria (Ebbighausen *et al.* 2004), however these regions did not provide material of the Pseudarietitinae.

The four genera occur, in the three regions, in different frequencies. Only *Paprothites* and *Pseudarietites* occur rather regularly in the middle part of the Hangenberg Limestone of the northern Rhenish Mountains. By contrast, specimens of *Rodingites* gen. nov. and *Paralytoceras* belong to the rarest Early Tournaisian ammonoids and are known from only few places (Lower Silesia, Rhenish Mountains, Guizhou). In all sites they occur in extremely low numbers. In the Rhenish Mountains, for instance, *Rodingites* is known by only one specimen of each of the two species. The genus is also very rare at Dzikowiec (Weyer 1965; Dzik 1997).

Only two specimens of *Paralytoceras crispum* are known from the type locality at Dzikowiec in Lower Silesia and only two fragmentary specimens are preserved from the Oberrödinghausen railway cutting. One of these was shown by Weyer (1965, pl. 6, fig. 4) and the second was found in the unpublished parts of the Vöhringer collection. During intensive field collections by DW in 1993 and 1994, only a few further specimens of *Paralytoceras* species was collected.

Palaeogeography

The distribution patterns of the species of the subfamily are not fully investigated. According to current knowledge, the Central European occurrences in the Rhenish Mountains and Lower Silesia are rather similar and largely composed of the same species but they differ markedly from the assemblages known from Guizhou. The reports on the species *Pseudarietites serratus* and *Paralytoceras crispum* from Guizhou (Ruan 1981) cannot be confirmed. The specimen of "*P. serratus*" is strongly corroded and does not clearly show a serrate keel and the specimen of "*P. crispum*" is a poorly preserved fragment difficult to identify.

Genus ***Paprothites*** Bartzsch & Weyer, 1987

Type species

Pseudarietites westfalicus var. *dorsoplana* Schmidt, 1924: 52; original designation.

Genus diagnosis

Genus of the subfamily Pseudarietitinae without ventral keel. Sculpture with simple ribs.

Genus composition

Central Europe (Schmidt 1924; Vöhringer 1960; Korn & Weyer 2003): *Pseudarietites westfalicus* var. *dorsoplana* Schmidt, 1924; *Pseudarietites raricostatus* Vöhringer, 1960; *Paprothites ruzhencevi* Korn & Weyer, 2003; *Paprothites beckeri* sp. nov.; *Paprothites kullmanni* sp. nov.

South China (Ruan 1981; Sheng 1989): *Pseudarietites ellipticus* Ruan, 1981; *Pseudarietites platyventrus* Ruan, 1981; *Pseudarietites subquadratus* Ruan, 1981; *Pseudarietites daposhangensis* Sheng, 1989.

Remarks

Paprothites is easily separable from *Weyerella* in the presence of ribs and from the members of the Pseudarietitinae by the lack of the ventral keel.

Paprothites dorsoplanus (Schmidt, 1924)
Figs 10F, 103–105; Tables 100–101

Pseudarietites westfalicus var. *dorsoplana* Schmidt, 1924: 152, pl. 8 fig. 13.

Pseudarietites dorsoplanus dorsoplanus – Vöhringer 1960: 161, pl. 6 fig. 10, text-fig. 39. — Korejwo 1979: pl. 12 fig. 2.
Paprothites dorsoplanus – Korn 1994: 75, text-figs 70a–b, 71c, 72a; 2006: text-fig. 4e. — Korn & Weyer 2003: 100, pl. 2 figs 22–23. — Sprey 2002: 53, text-fig. 18h. — Kullmann 2009: text-fig. 5.4.

non *Paprothites dorsoplanus* – Dzik 1997: 109, text-fig. 29c.

Diagnosis

Species of *Paprothites* with a conch reaching 30 mm diameter. Conch at 15 mm dm thinly discoidal, subevolute (ww/dm ~0.40; uw/dm ~0.40). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.30);

coiling rate moderate (WER ~1.80). Venter rounded, umbilical margin rounded. On the flank 25 sharp ribs with weakly concave course.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schmidt Coll.; illustrated by Schmidt (1924: pl. 8, fig. 13) and Korn (2006: text-fig. 4e); re-illustrated here in Fig. 103A; BGRB X5715.

Additional material

GERMANY • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63967, GPIT-PV-63969, GPIT-PV-63971 • 38 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.31199.1–38 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1a; Weyer 1993–1994 Coll.; MB.C.31200.1–5 • 11 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31201.1–11 • 12 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31202.1–12 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone; Korn 1977 Coll.; MB.C.31203 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 3d; Korn & Weyer 2000 Coll.; MB.C.31204 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 51; Weyer 1993–1994 Coll.; MB.C.5237.3 • 4 specimens; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 53; Weyer 1993–1994 Coll.; MB.C.5238.3–6 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Weyer 1993–1994 Coll.; MB.C.5240.9 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 25; Weyer & Korn 2000 Coll.; MB.C.5261.1 • 3 specimens; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 22; Weyer & Korn 2000 Coll.; MB.C.5262.1, MB.C.5262.6–MB.C.5262.7.

Description

Holotype BGRB X5715 is a well-preserved specimen with 13 mm conch diameter (Fig. 103A). It is representative for the morphology of the species, in which morphological variation ranges only within narrow limits. The specimen is thinly discoidal and subevolute (ww/dm = 0.44; uw/dm = 0.39) with a weakly depressed crescent-shaped whorl profile (ww/wh = 1.30) and a moderately high aperture (WER = 1.75). Its sculpture shows 24 protracted ribs on one volution; these are coarsest on the inner

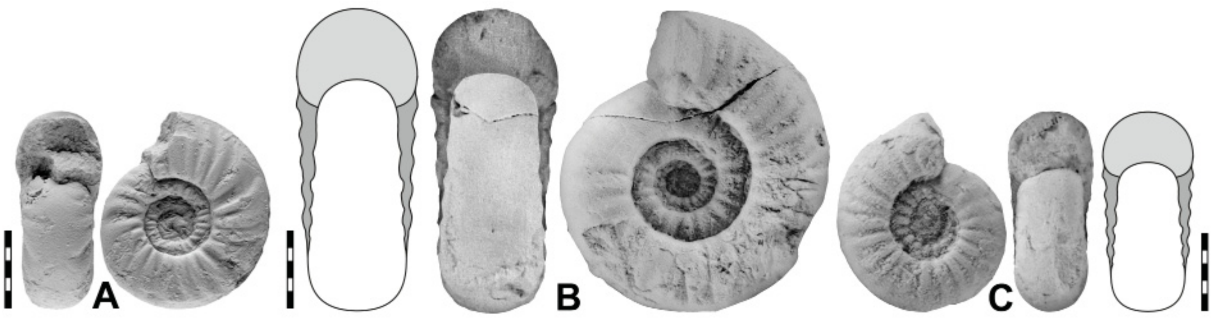

Fig. 103. *Paprothites dorsoplanus* (Schmidt, 1924) from the Oberrödinghausen railway cutting. **A**. Holotype BGRB X5715 (Schmidt Coll.) from an unknown bed. **B**. Specimen GPIT-PV-63967 (Vöhringer Coll.) from bed 3d. **C**. Specimen GPIT-PV-63969 (Vöhringer Coll.) from bed 3d. Scale bar units = 1 mm.

flank and fade out in the ventrolateral area. The interspaces between the ribs are occasionally deepened to constrictions, which wedge out on the outer flank near the venter.

A series of four well-preserved specimens (Fig. 104) between 9 and 22.5 mm conch diameter are suitable to complement the species description. They show slight variation in the strength and number of the ribs; while the smaller specimens MB.C.31201.4 (9 mm dm; Fig. 104D) and MB.C.31201.3 (10 mm dm; Fig. 104C) have rather weak ribs, these are coarser, particularly on the umbilical margin, in specimen MB.C.31201.2 (16 mm dm; Fig. 104B) and also in the largest available specimen MB.C.31201.1 (22.5 mm dm; Fig. 104A). In the latter specimen, the ribs extend with linear course and radial direction across the inner and middle flank; they turn forward on the outer flank where the fade out. Specimens MB.C.31201.3 and MB.C.31201.2 show incipient ventrolateral furrows. For the demonstration of the low variation in conch geometry and sculpture, another eight specimens are shown (Fig. 104E–L).

Paprothites dorsoplanus has a rather simple conch ontogeny, which can be described using the cross section of specimen GPIT-PV-63971 with 8 mm conch diameter (Fig. 105A) and some other specimens (Fig. 105C–E). The ww/dm trajectory is monophasic with a continuous decrease from 0.90 at 1 mm dm to 0.45 at 20 mm dm. The uw/dm trajectory is weakly triphasic and oscillating between 0.30 and 0.45 and the WER is stable at a value around 1.70 between 1.5 and 20 mm diameter. Throughout ontogeny, the whorl profile is crescent-shaped and depressed with an ontogenetic trend to a more strongly compressed shape.

Remarks

Paprothites dorsoplanus is easily distinguishable from the co-occurring *P. raricostatus* and *P. beckeri* sp. nov. by the much coarser ribs. On the other side, *P. ruzhencevi* and *P. kullmanni* sp. nov. have coarser and sharper ribs than *P. dorsoplanus*. Furthermore, the ribs are much more strongly bent forward across the flanks in *P. ruzhencevi*.

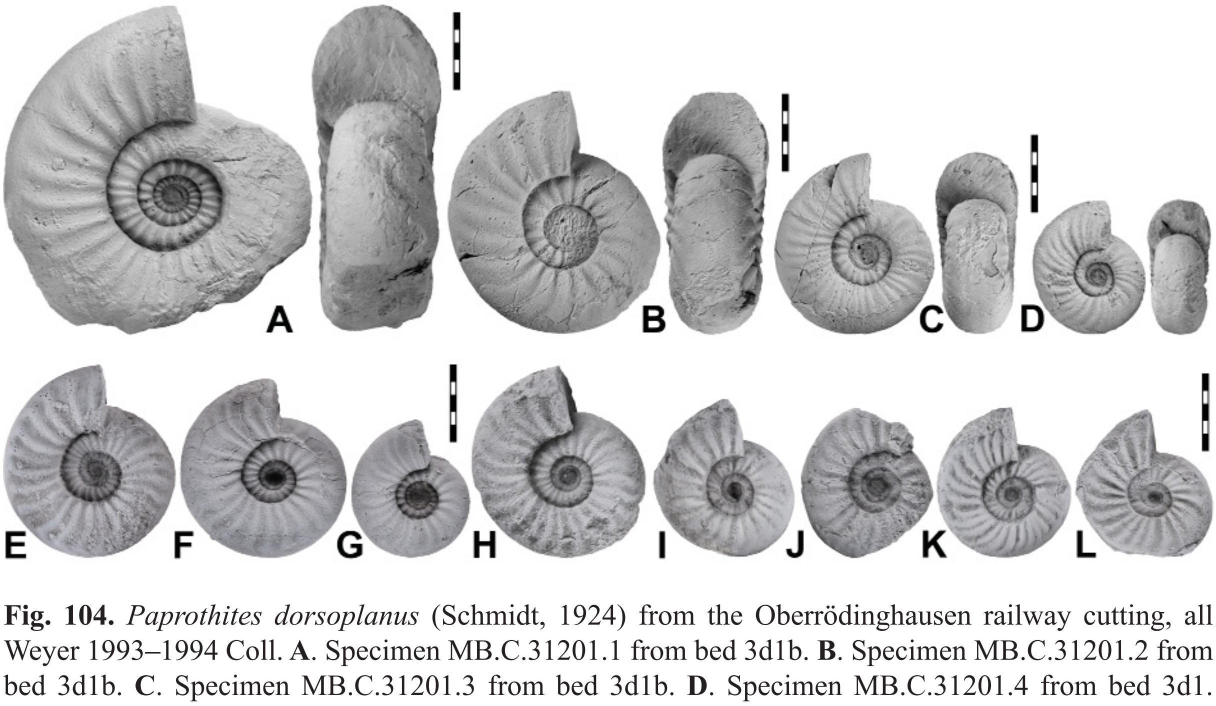

Fig. 104. *Paprothites dorsoplanus* (Schmidt, 1924) from the Oberrödinghausen railway cutting, all Weyer 1993–1994 Coll. **A**. Specimen MB.C.31201.1 from bed 3d1b. **B**. Specimen MB.C.31201.2 from bed 3d1b. **C**. Specimen MB.C.31201.3 from bed 3d1b. **D**. Specimen MB.C.31201.4 from bed 3d1. **E**. Specimen MB.C.31201.5 from bed 3d1. **F**. Specimen MB.C.31201.6 from bed 3d1. **G**. Specimen MB.C.31201.7 from bed 3d1. **H**. Specimen MB.C.31199.1 from bed 3d1. **I**. Specimen MB.C.31199.2 from bed 3d1. **J**. Specimen MB.C.31199.3 from bed 3d1. **K**. Specimen MB.C.31199.4 from bed 3d1. **L**. Specimen MB.C.31199.5 from bed 3d1. Scale bar units = 1 mm.

Table 100. Conch measurements, ratios and rates of *Paprothites dorsoplanus* (Schmidt, 1924) from Oberrödinghausen and Oese.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31201.1	22.60	8.44	7.62	8.64	5.50	0.37	1.11	0.38	1.75	0.15
GPIT-PV-63967	19.95	8.32	6.41	8.77	4.70	0.42	1.30	0.44	1.71	0.27
MB.C.31201.2	16.06	7.05	5.63	6.20	4.13	0.44	1.25	0.39	1.81	0.27
GPIT-PV-63969	13.19	5.63	4.23	5.54	3.18	0.43	1.33	0.42	1.74	0.25
BGRB X5715	13.04	5.73	4.38	5.11	3.20	0.44	1.31	0.39	1.76	0.27
MB.C.31201.3	12.08	5.46	4.12	4.67	3.03	0.45	1.33	0.39	1.78	0.26
MB.C.5261.1	11.47	5.35	4.24	4.40	3.20	0.47	1.26	0.38	1.92	0.20
MB.C.31201.4	8.87	4.18	3.24	3.17	2.14	0.47	1.29	0.36	1.74	0.34

Table 101. Conch ontogeny of *Paprothites dorsoplanus* (Schmidt, 1924) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subevolute (ww/dm ~0.75; uw/dm ~0.35)	strongly depressed; strongly embracing (ww/wh ~2.20; IZR ~0.30)	low (WER ~1.70)
5 mm	thickly discoidal; subevolute (ww/dm ~0.55; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.55; IZR ~0.35)	low (WER ~1.70)
10 mm	thinly discoidal; subevolute (ww/dm ~0.42; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.40; IZR ~0.35)	low (WER ~1.70)
20 mm	thinly discoidal; subevolute (ww/dm ~0.40; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.30; IZR ~0.35)	low (WER ~1.70)

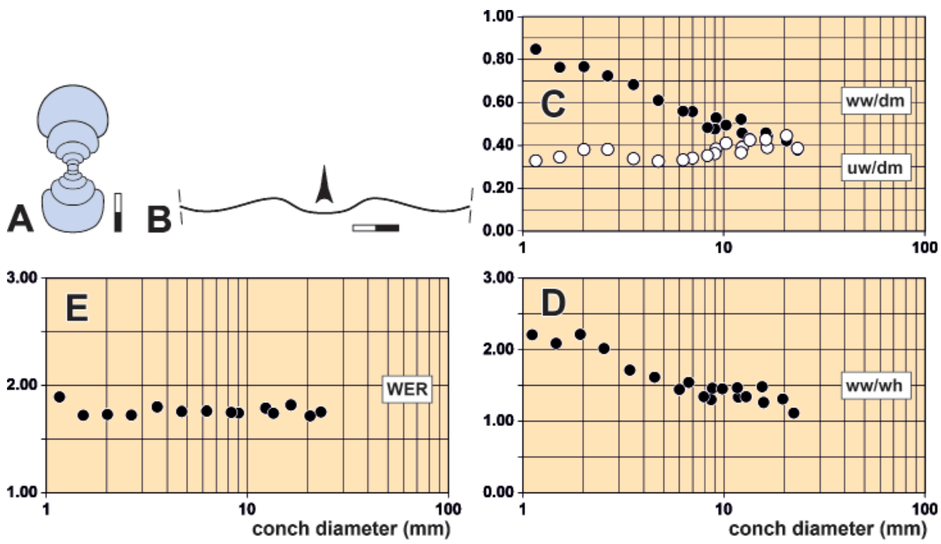

Fig. 105. *Paprothites dorsoplanus* (Schmidt, 1924) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen GPIT-PV-63971 (Vöhringer Coll.) from bed 3d. **B**. Growth line course of specimen GPIT-PV-63967 (Vöhringer Coll.) from bed 3d, at ww = 6.4 mm, wh = 5.2 mm. **C–E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Paprothites raricostatus (Vöhringer, 1960)
Fig. 106A–B; Table 102

Pseudarietites dorsoplanus raricostatus Vöhringer, 1960: 162, pl. 6 fig. 9.

Paprothites raricostatus – Korn 1994: 77, text-fig. 70c; 2006: text-fig. 4f.

Diagnosis

Species of *Paprothites* with a conch reaching 30 mm diameter. Conch at 15 mm dm thinly discoidal, subevolute (ww/dm ~0.40; uw/dm ~0.35). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.20); coiling rate low (WER ~1.70). Venter rounded, umbilical margin rounded. On the inner flank 20 shallow, rounded ribs with nearly linear course.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 9), Korn (1994: text-fig. 70c) and Korn (2006: text-fig. 4f); re-illustrated herein Fig. 106A; GPIT-PV-63973.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.31205 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1a; Weyer 1993–1994 Coll.; MB.C.31206 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31207.

Description

Holotype GPIT-PV-63973 is a specimen with 14 mm conch diameter (Fig. 106A); it is thinly discoidal and subevolute (ww/dm = 0.41; uw/dm = 0.37) with a weakly depressed, broadly rounded whorl profile (ww/wh = 1.19) and a low coiling rate (WER = 1.71). It has a sculpture with weak radial plications on the inner flank.

Specimen MB.C.31207 is a well-preserved specimen with 18.5 mm conch diameter (Fig. 106B). It is thinly discoidal and subevolute (ww/dm = 0.35; uw/dm = 0.40) with a very weakly depressed whorl profile (ww/wh = 1.05). Umbilical margin, flanks and venter are broadly rounded. The last whorl

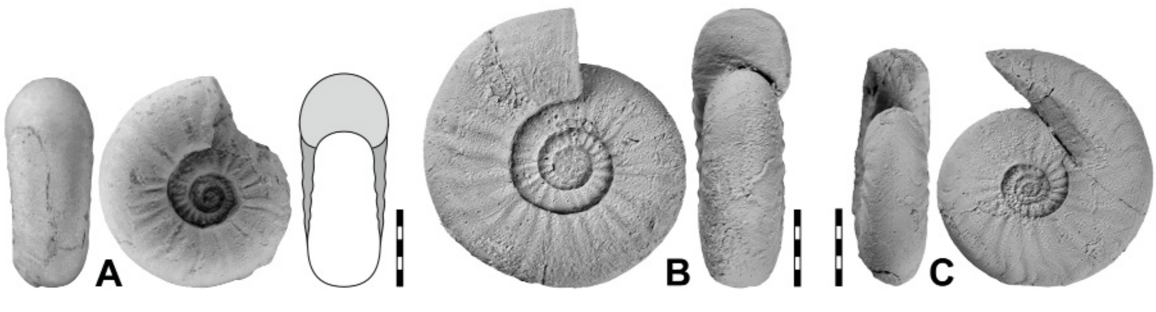

Fig. 106. *Paprothites* from the Oberrödinghausen railway cutting. **A**. *Paprothites raricostatus* (Vöhringer, 1960), holotype GPIT-PV-63973 (Vöhringer Coll.) from bed 3d. **B**. *Paprothites raricostatus* (Vöhringer, 1960), specimen MB.C.31207 (Weyer 1993–1994 Coll.) from bed 3d1b. **C**. *Paprothites beckeri* sp. nov., holotype MB.C.31208 (Weyer 1993–1994 Coll.) from bed 3d1. Scale bar units = 1 mm.

Table 102. Conch measurements, ratios and rates of *Paprothites raricostatus* (Vöhringer, 1960).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31207	18.57	6.57	6.24	7.44	4.23	0.35	1.05	0.40	1.68	0.32
GPIT-PV-63973	14.05	5.81	4.87	5.18	3.29	0.41	1.19	0.37	1.71	0.32

possesses about 24 very low plications, which extend slightly forward and disappear already in the outer flank area.

Remarks

Paprothites raricostatus has conch proportions like *P. dorsoplanus*, but is clearly separated by the much weaker sculpture. While *P. dorsoplanus* has rather sharp riblets, in *P. raricostatus* there are only very faint plications at 15–20 mm conch diameter. *P. beckeri* has a much narrower umbilicus (uw/dm = 0.30) than *P. raricostatus* (uw/dm = 0.40).

Paprothites beckeri sp. nov.

urn:lsid:zoobank.org:act:91E3B90F-6B65-4875-815A-568CFFEC7E20

Fig. 106C; Table 103

Diagnosis

Species of *Paprothites* with a conch reaching 30 mm diameter. Conch at 15 mm dm extremely discoidal, subevolute (ww/dm ~0.35; uw/dm ~0.30). Whorl profile at 15 mm dm weakly compressed (ww/wh ~0.90); coiling rate moderate (WER ~1.80). Venter rounded, umbilical margin rounded. On the inner flank 15 very shallow, rounded ribs with nearly linear course.

Etymology

Named after R. Thomas Becker in appreciation of his studies on the Devonian–Carboniferous boundary.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; illustrated in Fig. 106C; MB.C.31208.

Description

Holotype MB.C.31208 with 16 mm dm is thinly discoidal with a moderately wide umbilicus (ww/dm = 0.34; uw/dm = 0.31). Its whorl profile is compressed (ww/wh = 0.87), the flanks are nearly parallel and the venter is rounded. The last volution shows only very weak radial plications, which have a concave course on the flanks. In the outer flank area, they are paralleled by faint and short constrictions. As can be seen in the umbilical opening, the penultimate volution bears coarser ribs, which amount about 18 per volution (106C).

Remarks

Paprothites beckeri sp. nov. has, with a uw/dm ratio of only 0.30, a much more narrowly umbilicate conch than all the other species of the genus. Furthermore, it has much weaker ribs, even when compared with *P. raricostatus*.

Table 103. Conch measurements, ratios and rates of *Paprothites beckeri* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31208	15.72	–	–	–	3.89	–	–	–	1.77	–
MB.C.31208	14.75	4.95	5.70	4.54	–	0.34	0.87	0.31	–	–

Paprothites ruzhencevi Korn & Weyer, 2003
Figs 107–108; Table 104

Paprothites ruzhencevi Korn & Weyer, 2003: 100, pl. 1 figs 21–24.

Paprothites ruzhencevi – Korn 2006: text-fig.4b–c.

Diagnosis

Species of *Paprothites* with a conch reaching 40 mm diameter. Conch at 15 mm dm thinly discoidal, evolute (ww/dm ~0.40; uw/dm ~0.50). Whorl profile at 15 mm dm moderately depressed (ww/wh ~1.60); coiling rate low (WER ~1.55). Venter rounded, umbilical margin rounded. On the flank 25 very sharp ribs with concave course. Venter in the adult stage with incipient grooves.

Material examined

Holotype
GERMANY • Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Trostheide Coll.; illustrated by Korn & Weyer (2003: pl. 1, figs 21–24) and Korn (2006: text-fig. 4b–c), re-illustrated here in Fig. 107; MB.C.5240.6.

Paratypes
GERMANY • 4 specimens; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 57; Weyer 1993–1994 Coll.; MB.C.5240.11–14.

Additional material
GERMANY • 40 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31209.1–40.

Fig. 107. *Paprothites ruzhencevi* Korn & Weyer, 2003, holotype MB.C.5240.6 (Trostheide Coll.) from Hasselbachtal, bed 57. Scale bar units = 1 mm.

Table 104. Conch measurements, ratios and rates of *Paprothites ruzhencevi* Korn & Weyer, 2003.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31209.1	22.25	8.38	5.78	11.12	4.80	0.38	1.45	0.50	1.63	0.17
MB.C.31209.2	22.18	9.78	5.88	11.40	–	0.44	1.66	0.51	–	–

Description

Two well-preserved adult specimens from Oberrödinghausen are illustrated here, MB.C.31209.1 (22 mm dm; Fig. 108A) and MB.C.31209.2 (ca. 26 mm dm; Fig. 108B), both 22 mm in diameter. In both, at 22 mm dm, the umbilicus has exactly half of the width of the conch diameter, but the specimens differ in the shape of their whorl profile. The ww/wh ratio is 1.45 in specimen MB.C.31209.1 but 1.65 in specimen MB.C.31209.2. Both specimens show coarse ribbing. In specimen MB.C.31209.1, there are 28 ribs on the last volution, about 25 in the penultimate volution and also 25 in the volution before. The ribs are sharp and extend with a concave arch across the flank. Both specimens show two barely visible longitudinal grooves on the venter.

Remarks

Paprothites ruzhencevi differs from *P. dorsoplanus* and *P. raricostatus* in the shape and course of the ribs, which are rounded and extend almost straight across the flanks in the latter two species. Both species have a much narrower umbilicus (uw/dm = 0.35–0.40) than *P. ruzhencevi* (uw/dm ~0.50). *Paprothites ruzhencevi* differs from *P. kullmanni* sp. nov. in the more strongly depressed whorl profile (ww/wh ~1.50 or more in *P. ruzhencevi* but only ~1.25 in *P. kullmanni*) and in the lack of a midventral groove.

Fig. 108. *Paprothites ruzhencevi* Korn & Weyer, 2003 from the Oberrödinghausen railway cutting, both Weyer 1993–1994 Coll. **A**. Specimen MB.C.31209.1 from bed 3d1b. **B**. Specimen MB.C.31209.2 from bed 3d1b. Scale bar units = 1 mm.

Paprothites kullmanni sp. nov.
urn:lsid:zoobank.org:act:E347E068-0C6F-4263-BE30-7540C182E55C
Fig. 109; Table 105

Diagnosis

Species of *Paprothites* with a conch reaching 30 mm diameter. Conch at 25 mm dm extremely discoidal, evolute (ww/dm ~0.33; uw/dm ~0.50). Whorl profile at 25 mm dm weakly depressed (ww/wh ~1.25); coiling rate low (WER ~1.60). Flanks and venter flattened, umbilical margin rounded. Sculpture on the flank with 40 sharp ribs with concave course on the flanks.

Etymology

Named after Jürgen Kullmann (1931–2018) in appreciation of his studies on Carboniferous ammonoids.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oese, old quarry; Hangenberg Limestone; Kullmann 1968 Coll.; illustrated in Fig. 109A; MB.C.5270.

Paratypes

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; MB.C.31210.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3e; Weyer 1993–1994 Coll.; MB.C.31211.

Description

Holotype MB.C.5270 (Fig. 109A) is a specimen with 26 mm conch diameter, which allows the study of the conch geometry, the ornament and parts of the suture line. The conch is extremely discoidal with a wide umbilicus (ww/dm = 0.33; uw/dm = 0.52) and a low coiling rate (WER = 1.60). The whorl profile is weakly depressed (ww/wh = 1.23) and shows flattened, weakly convergent flanks, which are separated from the also flattened venter by a tightly rounded ventrolateral shoulder. On the penultimate half whorl, the venter shows a shallow longitudinal groove that is not located on the centre of the venter, but asymmetrically on the right side.

The sculpture consists of sharp ribs confined to the flanks, which are highest on the middle of the flank and emerge as small nodes in the ventrolateral area. There are 24 of these ribs on the last half whorl; the penultimate half whorl has 16 ribs. They run across the flank with a concave arc directed forward. The suture line shows a lanceolate, narrow and deep external lobe.

Paratype MB.C.31211 (109B) is a fragment of a specimen of about 25 mm conch diameter. It shows a modification of the sculpture in that the ribs extend beyond the venter and form chevron-shaped sinuses. In the other aspects it largely agrees with the holotype.

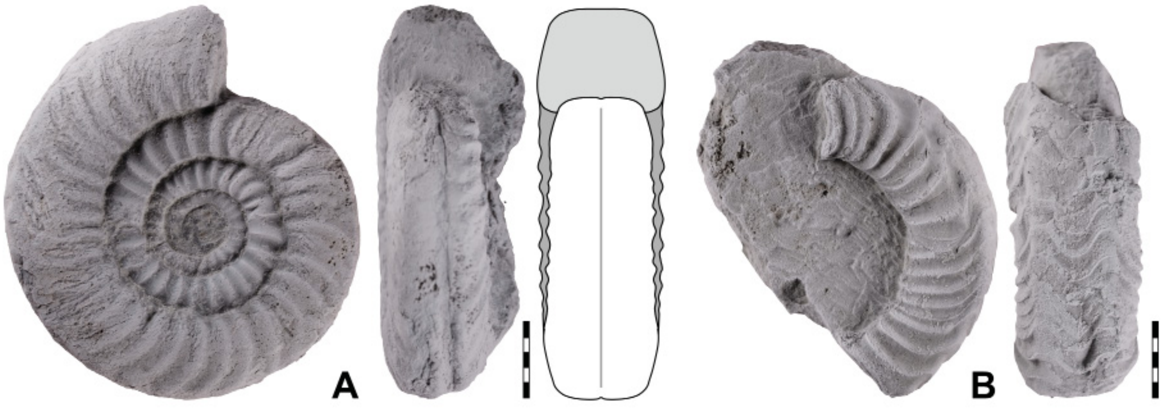

Fig. 109. *Paprothites kullmanni* sp. nov. **A**. Holotype MB.C.5270 (Kullmann 1968 Coll.) from Oese. **B**. Paratype MB.C.31211 (Weyer 1993–1994 Coll.) from the Oberrödinghausen railway cutting, bed 3e. Scale bar units = 1 mm.

Table 105. Conch measurements, ratios and rates of the holotype of *Paprothites kullmanni* sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.5270	26.12	8.52	6.92	13.53	5.49	0.33	1.23	0.52	1.60	1.00
MB.C.5270	21.85	7.42	6.04	11.61	–	0.34	1.23	0.53	–	–

Remarks

Paprothites kullmanni sp. nov. differs from *P. dorsoplanus*, *P. raricostatus* and *P. beckeri* sp. nov. by the very sharp ribs. *Paprothites ruzhencevi* has sharp ribs, but shows a rounded whorl profile without the distinct ventrolateral shoulder present in *P. kullmanni*; furthermore, *P. ruzhencevi* has a more depressed whorl profile (ww/wh ~1.50 or more) than *P. kullmanni* (w/wh ~1.25).

Genus ***Pseudarietites*** Frech, 1902

Type species

Pseudarietites silesiacus Frech, 1902: 63; by monotypy.

Genus diagnosis

Genus of the subfamily Pseudarietitinae with a circular or depressed whorl profile with raised ventral keel paralleled by two longitudinal grooves. Sculpture with simple ribs.

Genus composition

Central Europe (Frech 1902; Schmidt 1924; Vöhringer 1960): *Pseudarietites silesiacus* Frech, 1902; *Pseudarietites westfalicus* Schmidt, 1924; *Pseudarietites subtilis* Vöhringer, 1960; *Pseudarietites serratus* Vöhringer, 1960.

South China (Ruan 1981): *Pseudarietites rotatilis* Ruan, 1981.

Remarks

Pseudarietites differs from *Paprothites* in the presence of ventral furrows and a raised keel. *Paralytoceras*, unlike *Pseudarietites*, has a combination of sharp ribs and spiral lines. *Rodingites* gen. nov. has a more strongly compressed whorl profile with acute venter and a very prominent attached keel.

Pseudarietites westfalicus Schmidt, 1924
Figs 8E, 110–112; Tables 106–107

Pseudarietites westfalicus Schmidt, 1924: 152, pl. 8 fig. 12.

Pseudarietites westfalicus – Schmidt 1925: 536, pl. 19 fig. 7. — Korn 1994: 78, text-figs 70d–e, 71d, 72b; 2006: text-fig. 4d. — Kullmann 2009: text-fig. 5.2b–c.
Pseudarietites westfalicus westfalicus – Vöhringer 1960: 163, pl. 6 fig. 11, text-fig. 40. — Weyer 1965: 448.

Diagnosis

Species of *Pseudarietites* with a conch reaching 40 mm diameter. Conch at 15 mm dm thinly discoidal, subevolute (ww/dm ~0.40; uw/dm ~0.42). Whorl profile at 15 mm dm weakly depressed (ww/wh ~1.25); coiling rate low (WER ~1.70). Venter broadly rounded with distinct keel between two distinct grooves, umbilical margin rounded. On the flank 25 sharp ribs with concave course.

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schmidt Coll.; illustrated by Schmidt (1924: pl. 8, fig. 12) and Korn (2006: text-fig. 4d); re-illustrated here in Fig. 110; BGRB X5716.

Additional material

GERMANY • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schindewolf 1925 Coll.; MB.C.31212.1–3 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63978, GPIT-PV-63980 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-63982 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Korn 1991 Coll.; MB.C.31213 • 22 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31214.1–22 • 8 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31215.1–8 • 7 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c1; Weyer 1993–1994 Coll.; MB.C.31216.1–7 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c2; Weyer 1993–1994 Coll.; MB.C.31217 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 3b; Korn & Weyer 2000 Coll.; MB.C.31218 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 49; Weyer 1993–1994 Coll.; MB.C.5236.1 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 30; Weyer & Korn 2000 Coll.; MB.C.5258.2 • 1 specimen; Rhenish Mountains, Oese, old quarry; Hangenberg Limestone, bed 28; Weyer & Korn 2000 Coll.; MB.C.5260.4 • 1 specimen; Rhenish Mountains, Oese, old quarry; bed interval VI; Paproth Coll.; MB.C.5282.

Description

Holotype BGRB X5716 is a specimen with nearly 15 mm conch diameter and allows the examination of two whorls (Fig. 110). It is thinly discoidal and subevolute (ww/dm = 0.42; uw/dm = 0.45) with a weakly depressed whorl profile (ww/wh = 1.28). The venter possesses two shallow longitudinal grooves with a rounded keel rising between them. On the last volution there are about 24 sharp ribs; these ribs form sharp nodes around the umbilicus and become weaker towards the flank. In the area of the outer flank they bend slightly forward and form a low projection before they diminish. Faint growth lines follow the course of the ribs; they form a low ventrolateral projection and a deep, broadly rounded ventral sinus. The penultimate whorl possesses 24 ribs.

The smaller, well-preserved specimen MB.C.31214.1 has a conch diameter of 14.5 mm and is also thinly discoidal and subevolute (ww/dm = 0.39; uw/dm = 0.43). In the sculpture it closely resembles the

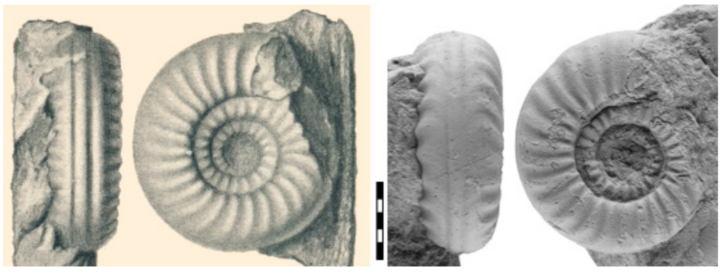

Fig. 110. *Pseudarietites westfalicus* Schmidt, 1924 from the Oberrödinghausen railway cutting, holotype BGRB X5716 (Schmidt Coll.), bed unknown. Reproduction of the figure by Schmidt (1924: pl. 8 fig. 12) and photographs. Scale bar units = 1 mm.

Table 106. Conch measurements, ratios and rates of *Pseudarietites westfalicus* Schmidt, 1924 from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63978	27.4	9.3	9.8	12.4	6.2	0.34	0.95	0.45	1.67	0.37
GPIT-PV-63980	26.9	8.6	7.8	12.4	6.4	0.32	1.09	0.46	1.73	0.18
GPIT-PV-63982	16.9	6.2	5.0	7.8	3.9	0.37	1.24	0.46	1.70	0.22
BGRB X5716	14.7	6.2	4.8	6.5	–	0.42	1.28	0.44	–	–
MB.C.31214.1	14.4	5.6	4.8	6.1	3.3	0.39	1.18	0.43	1.69	0.31

Table 107. Conch ontogeny of *Pseudarietites westfalicus* Schmidt, 1924 from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
5 mm	thinly pachyconic; subevolute (ww/dm ~0.65; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.75; IZR ~0.30)	moderate (WER ~1.75)
10 mm	thinly discoidal; subevolute (ww/dm ~0.44; uw/dm ~0.40)	weakly depressed; moderately embracing (ww/wh ~1.40; IZR ~0.25)	moderate (WER ~1.75)
20 mm	thinly discoidal; subevolute (ww/dm ~0.35; uw/dm ~0.40)	weakly depressed; strongly embracing (ww/wh ~1.10; IZR ~0.35)	low (WER ~1.70)

holotype; it has 26 ribs on the last and 24 ribs on the penultimate whorl (Fig. 112A). The ventral grooves are slightly deeper than in the holotype.

The incomplete ontogeny preserved in the sectioned specimen GPIT-PV-63982 shows a whorl profile that is, between 4 and 7.5 mm conch diameter, depressed crescent-shaped with a ww/wh ratio being reduced from 1.70 to 1.50. A raised ventral keel is present at 9.8 mm dm.

Larger specimens (e.g., specimens GPIT-PV-63978 and GPIT-PV-63980) show that the whorl profile becomes circular at 27 mm dm (Fig. 111A–B).

The growth trajectories are essentially consistent with those from the other representatives of the subfamily. Almost all trajectories are close to monophasic in the interval between 4 and 27 mm conch diameter with only minor changes of the conch ratios (Fig. 112C–E).

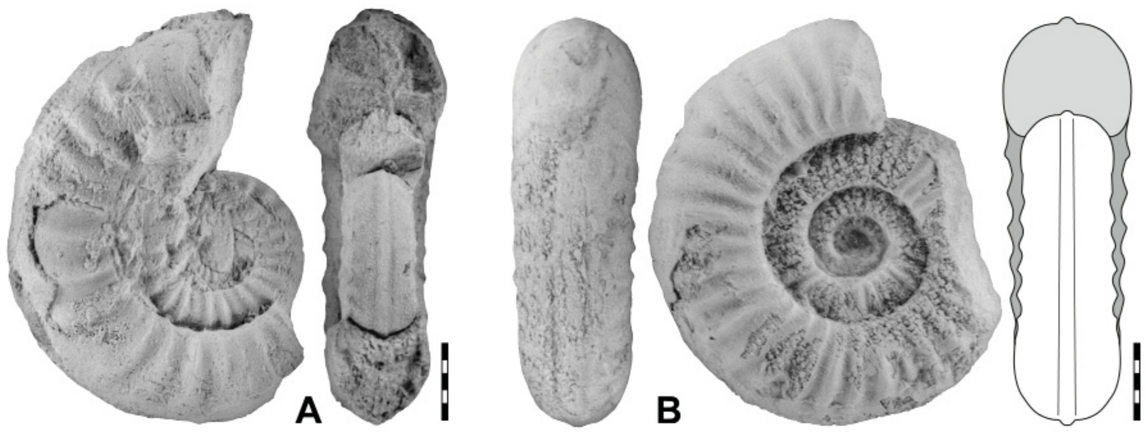

Fig. 111. *Pseudarietites westfalicus* Schmidt, 1924 from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Specimen GPIT-PV-63978 from bed 3b. **B**. Specimen GPIT-PV-63980 from bed 3b. Scale bar units = 1 mm.

Remarks

Pseudarietites westfalicus differs from the very similar *P. silesiacus* in the lower number of ribs (25 in *P. westfalicus* but 30 in *P. silesiacus*). *Pseudarietites westfalicus* can be separated from *P. subtilis* by the much wider umbilicus (uw/dm = 0.45 in *P. westfalicus* at 20 mm dm but about 0.35 in *P. subtilis*).

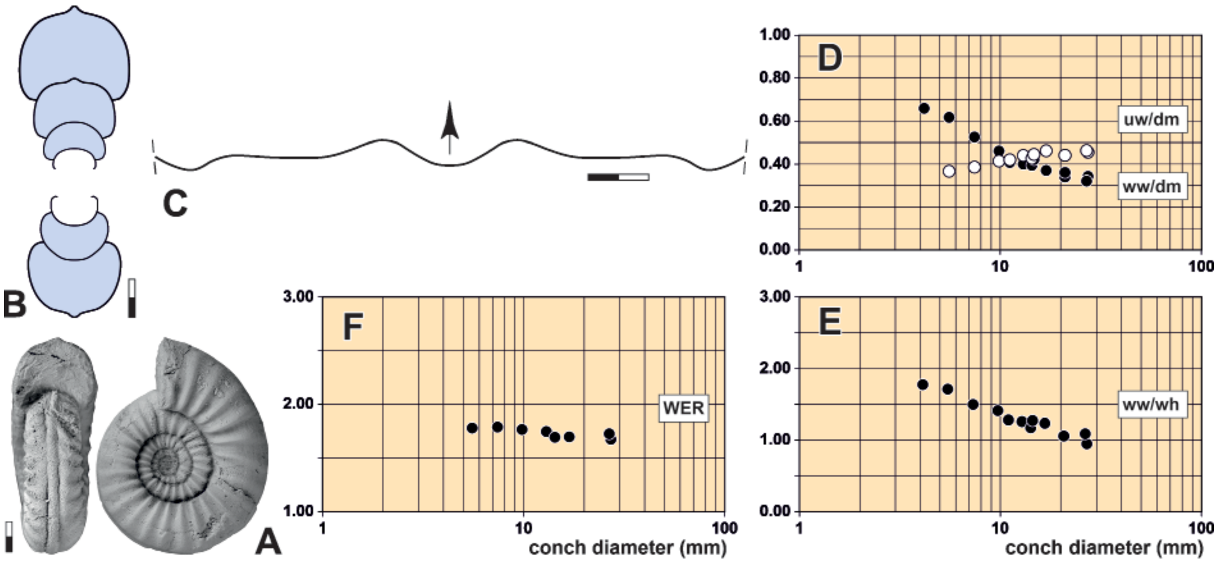

Fig. 112. *Pseudarietites westfalicus* Schmidt, 1924 from the Oberrödinghausen railway cutting. **A**. Specimen MB.C.31214.1 (Weyer 1993–1994 Coll.) from bed 3a. **B**. Cross section of specimen GPIT-PV-63982 (Vöhringer Coll.) from bed 3c. **C**. Growth line course of specimen GPIT-PV-63980 (Vöhringer Coll.) from bed 3b, at dm = 24.5 mm, ww = 8.2 mm, wh = 8.2 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Pseudarietites subtilis Vöhringer, 1960
Figs 113–114; Tables 108–109

Pseudarietites westfalicus subtilis Vöhringer, 1960: 164, pl. 6 fig. 12.

Pseudarietites westfalicus subtilis – Bartzsch & Weyer 1982: 20, text-fig. 5; 1986: pl. 2 fig. 1.
Pseudarietites subtilis – Korn 1994: 78, text-figs 70g–h, 71e, 72c.

Diagnosis

Species of *Pseudarietites* with a conch reaching 40 mm diameter. Conch at 15 mm dm thinly discoidal, subevolute (ww/dm ~0.40; uw/dm ~0.33). Whorl profile at 15 mm dm nearly circular (ww/wh ~1.00); coiling rate moderate (WER ~1.90). Venter broadly rounded with distinct keel between two distinct grooves, umbilical margin rounded. On the flank 30 sharp ribs with nearly linear course.

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 12) and Korn (1994: text-fig. 70g); re-illustrated here in Fig. 113A; GPIT-PV-63984.

Paratypes
GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-63986, GPIT-PV-63959.

Additional material
GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31219 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c1; Weyer 1993–1994 Coll.; MB.C.31220.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, west of railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31221.

Description

Holotype GPIT-PV-63984 is a fairly well-preserved but somewhat damaged specimen with 26 mm conch diameter (Fig. 113A). It is extremely discoidal and subevolute (ww/dm = 0.33; uw/dm = 0.39) and it seems that the umbilicus shows a little bit of opening during the last volution. The ww/wh ratio is nearly equal and the coiling rate is low (WER = 1.69). The sculpture consists of about 18 almost straight ribs on the flank of the penultimate last whorl. The ribs weaken out towards the aperture; the last half volution bear about 30 ribs, which are slightly forward directed but almost straight. Fine growth lines follow the course of the ribs on the flanks and form a rather narrow, shallow sinus on the venter (Fig. 114C). The venter has barely visible longitudinal grooves and a rounded keel between them.

Paratype GPIT-PV-63986 has 18 mm conch diameter (Fig. 113B) and corresponds, in conch shape and sculpture, to the penultimate whorl of the holotype. It shows ribs that are very sharp on the inner flank.

Specimen MB.C.31221 (Fig. 114A) is incomplete, but displays the characteristics of the species. It has a conch diameter of 17 mm and is thinly discoidal with a moderately wide umbilicus (ww/dm = 0.37; uw/dm = 0.36). It possesses more than 30 sharp ribs on the last volution; these ribs extend forward over the midflank area and diminish without an extra projection on the outer flank. The venter possesses two longitudinal grooves and a raised keel.

Paratype GPIT-PV-63959 was sectioned by Vöhringer; it allows the description of the ontogeny of the conch up to a diameter of 22 mm (Fig. 114B). The shape of the whorl profile goes through three ontogenetic stages. In the first stage, up to 3 mm dm, it is broadly crescent-shaped and depressed, followed by the second stage, up to 6 mm dm, in which the profile is rather circular. In the third stage, the ventral keel develops and the profile becomes compressed (ww/wh = 0.92 at 22 mm dm).

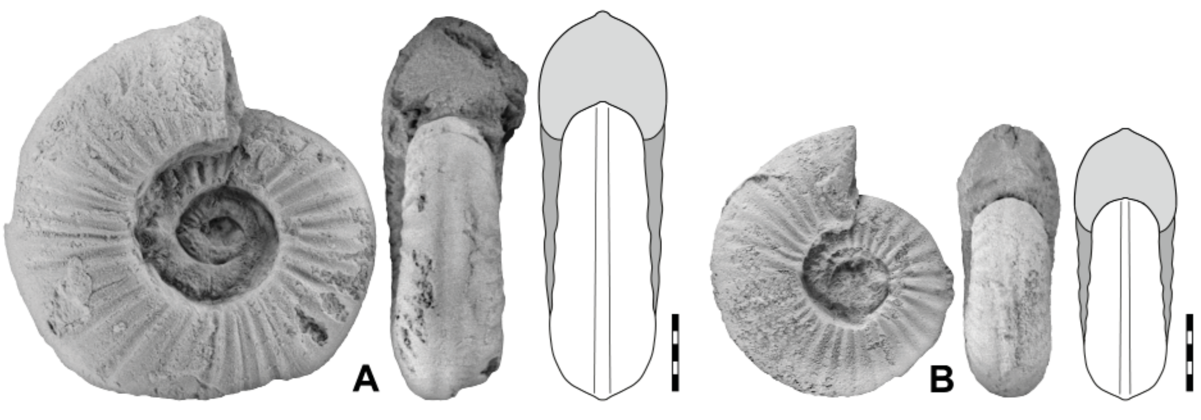

Fig. 113. *Pseudarietites subtilis* Vöhringer, 1960 from the Oberrödinghausen railway cutting, both Vöhringer Coll. **A**. Holotype GPIT-PV-63984 from bed 3c. **B**. Paratype GPIT-PV-63986 from bed 3c. Scale bar units = 1 mm.

Table 108. Conch measurements, ratios and rates of *Pseudarietites subtilis* Vöhringer, 1960 from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63984	25.8	8.6	8.8	10.2	6.0	0.33	0.99	0.39	1.69	0.32
GPIT-PV-63959	22.3	7.8	8.5	7.6	6.1	0.35	0.92	0.34	1.88	0.29
GPIT-PV-63986	17.9	6.6	6.8	6.2	4.6	0.37	0.98	0.34	1.81	0.32
MB.C.31221	17.0	6.3	5.9	6.1	–	0.37	1.08	0.36	–	–
MB.C.31220.2	10.4	3.8	4.2	2.9	–	0.37	0.91	0.28	–	–

Table 109. Conch ontogeny of *Pseudarietites subtilis* Vöhringer, 1960 from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
2 mm	thickly pachyconic; subevolute (ww/dm ~0.80; uw/dm ~0.40)	strongly depressed; strongly embracing (ww/wh ~2.30; IZR ~0.30)	low (WER ~1.70)
5 mm	thinly pachyconic; subevolute (ww/dm ~0.60; uw/dm ~0.35)	moderately depressed; strongly embracing (ww/wh ~1.75; IZR ~0.30)	moderate (WER ~1.90)
10 mm	thinly discoidal; subevolute (ww/dm ~0.45; uw/dm ~0.35)	weakly depressed; moderately embracing (ww/wh ~1.40; IZR ~0.25)	high (WER ~2.05)
20 mm	thinly discoidal; subevolute (ww/dm ~0.35; uw/dm ~0.35)	weakly depressed; moderately embracing (ww/wh ~1.10; IZR ~0.25)	moderate (WER ~1.90)

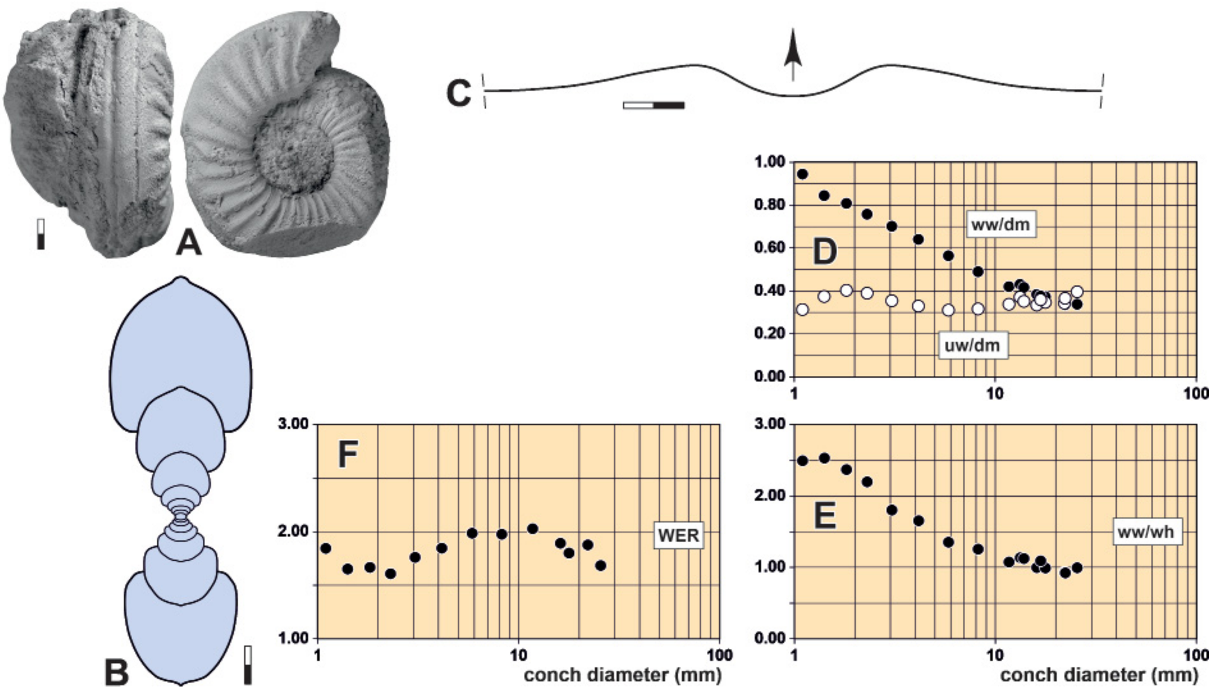

Fig. 114. *Pseudarietites subtilis* Vöhringer, 1960 from the Oberrödinghausen railway cutting. **A**. Specimen MB.C.31221 (Korn 1977 Coll.), bed unknown. **B**. Cross section of paratype GPIT-PV-63959 (Vöhringer Coll.) from bed 3c. **C**. Growth line course of holotype GPIT-PV-63984 (Vöhringer Coll.) from bed 3c, at dm = 26.5 mm, ww = 8.1 mm, wh = 8.6 mm. **D–F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

The sectioned paratype GPIT-PV-63959 shows that the ww/dm ratio has a monophasic ontogenetic trajectory with a continuous linear decrease from 1.00 at 0.8 mm dm to 0.35 at 22 mm. The ontogeny of the uw/dm ratio is triphasic; it increases in early ontogeny to 0.40 at 2 mm dm, then decreases to 0.30 at 8 mm dm and finally increases slightly to 0.34 at 22 mm dm. The ontogeny of the coiling rate is also triphasic; after an initial decrease of the WER to about 1.60 at 2.5 mm dm, it increases to a maximum value of 2.05 at 12 mm dm, followed by a decline in adulthood to 1.90 (Fig. 114D–F).

Remarks

Pseudarietites subtilis differs from *P. westfalicus* in the much narrower umbilicus (uw/dm = 0.35 in *P. subtilis* at 20 mm dm but about 0.45 in *P. westfalicus*).

Pseudarietites serratus Vöhringer, 1960
Fig. 115C

Pseudarietites serratus Vöhringer, 1960: 166, pl. 6 fig. 8.

Paralytoceras serratum – Korn 1994: 79, text-fig. 70i.

non *Pseudarietites serratus* – Ruan 1981: 88, pl. 22 figs 1–3. — Sheng 1989: 117, pl. 34 fig. 8.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 8) and Korn (1994: text-fig. 70i); re-illustrated here in Fig. 115C; GPIT-PV-63964.

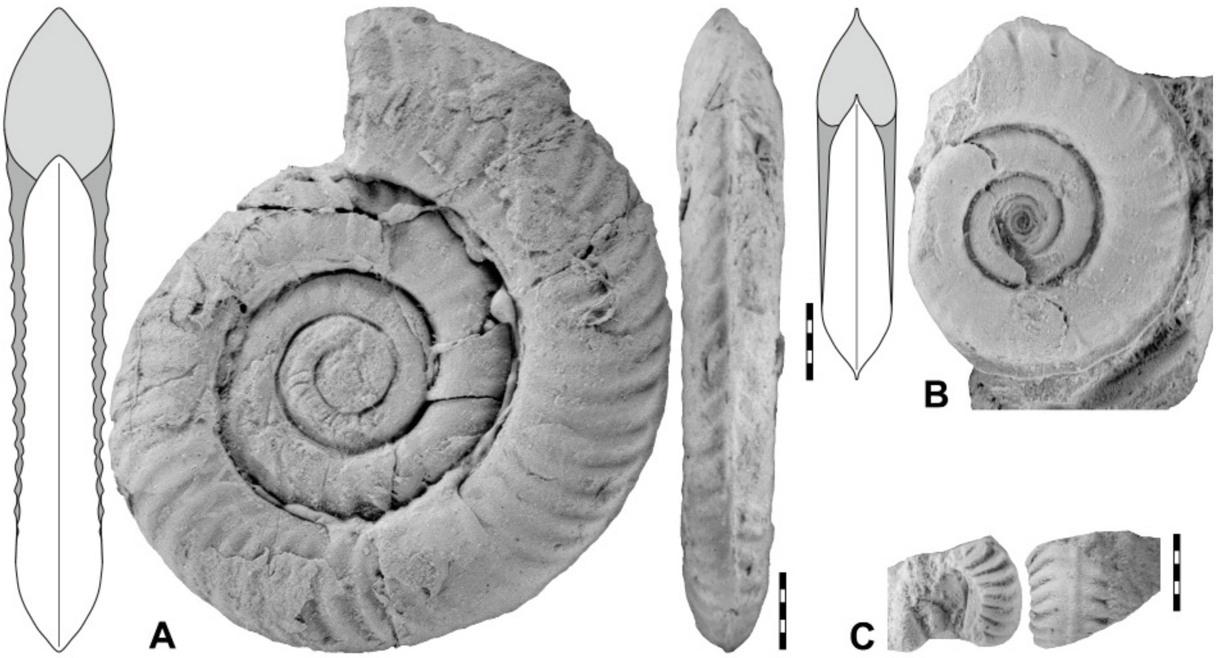

Fig. 115. Pseudarietitinae from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. *Rodingites planissimus* (Vöhringer, 1960), holotype GPIT-PV-63962 from bed 3a. **B**. *Rodingites carinatus* (Vöhringer, 1960), holotype GPIT-PV-64011 from bed 3b. **C**. *Pseudarietites serratus* Vöhringer, 1960, holotype GPIT-PV-63964 from bed 1. Scale bar units = 1 mm.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Weyer 1993–1994 Coll.; MB.C.31222.

Description

Holotype GPIT-PV-63964 is the larger of only two fragments available (Fig. 115C). It is part of a specimen only about 10 mm in diameter, consisting of only one whorl segment. The conch is apparently rather widely umbilicate and the whorl profile is crescent-shaped. There is a broad, weakly serrated keel on the middle of the venter. On the flank there are coarse, rounded ribs with a concave course; they already disappear on the outer venter at some distance from the keel.

Remarks

It is not completely clear that *Pseudarietites serratus* belongs to this genus; however, the form of the venter with two longitudinal grooves and the keel between the grooves speak for this attribution. The specimen illustrated by Korn (1988b) as "*Paralytoceras* cf. *serratum*" is poorly preserved and it is not clear if it belongs to this species. Because of the insufficient material, the species can only tentatively be attributed to *Pseudarietites*.

Pseudarietites serratus differs from the other species of the genus in the broad, crescent-shaped whorl section and the noded keel.

Genus ***Rodingites*** gen. nov.
urn:lsid:zoobank.org:act:37306BE3-F3E7-4834-BB63-B092BAA43545

Type species

Pseudarietites planissimus Vöhringer, 1960: 165.

Genus diagnosis

Genus of the subfamily Pseudarietitinae with a compressed whorl profile with acute venter and an attached ventral keel. Sculpture with simple ribs or folds.

Etymology

Named after the town of Oberrödinghausen.

Genus composition

Pseudarietites planissimus Vöhringer, 1960; *Protocanites carinatus* Vöhringer, 1960.

Remarks

The new genus is separated from *Pseudarietites* because of its widely umbilicate conch and the compressed whorl cross section with acute venter that bears an attached keel.

Rodingites planissimus (Vöhringer, 1960) gen. et comb. nov.
Fig. 115A; Table 110

Pseudarietites planissimus Vöhringer, 1960: 165, pl. 6 fig. 13, text-fig. 42.

Pseudarietites planissimus – Weyer 1965: 449, pl. 8 fig. 3. — Korn 1994: 78, text-figs 70j, 72d; 2006: text-fig. 4g. — Sprey 2002, pl. 4 fig. 4.

Table 110. Conch measurements, ratios and rates of the holotype of *Rodingites planissimus* (Vöhringer, 1960) gen. et comb. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63962	42.9	7.2	11.3	22.9	10.0	0.17	0.63	0.53	1.70	0.12
GPIT-PV-63962	32.9	5.7	8.4	16.9	–	0.17	0.67	0.51	–	–

Diagnosis

Species of *Rodingites* gen. nov. with a conch reaching 50 mm diameter. Conch at 40 mm dm extremely discoidal, evolute (ww/dm ~0.17; uw/dm ~0.50). Whorl profile at 40 mm dm weakly depressed (ww/wh ~0.65); coiling rate low (WER ~1.70). Venter acute with keel, umbilical margin rounded. Sculpture on the flank 50 sharp ribs with concave course.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 13), Korn (1994: text-fig. 70j), Sprey (2002: pl. 4 fig. 4) and Korn (2006: text-fig. 4g); re-illustrated here in Fig. 115A; GPIT-PV-63962.

Description

Holotype GPIT-PV-63962 is a rather complete specimen with 43 mm conch diameter and allows the study of the last two and a half whorls (Fig. 115A). It is a very evolute, extremely discoidal conch (ww/dm = 0.17; uw/dm = 0.53) with a galeate whorl profile. The venter is characterised by an attached keel. The last one and a half whorls bear rounded ribs, which start on the inner half of the flank, but only become very distinct in the ventrolateral area. These ribs start at a conch diameter of about 16 mm as ventrolateral nodes. The last half whorl possesses 25 of these ribs, the spacing of which becomes increasingly smaller. They have a concave course across the flank and are truncated by the ventral keel.

Remarks

Because of the extremely discoidal conch shape, the very wide umbilicus and the dense ribbing, *Rodingites planissimus* gen. et comb. nov. cannot be confused with any other ammonoid species from the early Tournaisian. The most similar species is *Rodingites carinatus* gen. et comb. nov., but it possesses no ribs, but only flat radial folds.

Rodingites carinatus **(**Vöhringer, 1960) gen. et comb. nov.

Fig. 115B; Table 111

Protocanites carinatus Vöhringer, 1960: 170, pl. 6 fig. 7, text-figs 47, 50.

Protocanites (*Eocanites*) *carinatus* – Weyer 1965: 458, pl. 8 figs 6–7.
Pseudarietites carinatus – Korn 1994: 77, text-figs 70f, 72e.

Diagnosis

Species of *Rodingites* gen. nov. with a conch reaching 30 mm diameter. Conch at 25 mm dm extremely discoidal, subevolute (ww/dm ~0.22; uw/dm ~0.44). Whorl profile at 25 mm dm weakly depressed (ww/wh ~0.70); coiling rate low (WER ~1.70). Venter acute with raised keel, umbilical margin rounded. Sculpture with very shallow, rounded folds with nearly linear course.

Table 111. Conch measurements, ratios and rates of the holotype of *Rodingites carinatus* (Vöhringer, 1960) gen. et comb. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-64011	24.1	5.2	7.4	10.8	5.8	0.22	0.71	0.45	1.74	0.21
GPIT-PV-64011	18.7	4.6	5.6	7.9	–	0.25	0.83	0.42	–	–

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 7) and Korn (1994: text-fig. 70f); re-illustrated here in Fig. 115B; GPIT-PV-64011.

Description

Holotype GPIT-PV-64011 is a specimen with 24 mm diameter embedded in a piece of limestone. The conch shows the last five whorls (Fig. 115B). The outer appearance is serpenticonic with a largely smooth shell surface. The conch is very slender and evolute (ww/dm = 0.22; uw/dm = 0.45) with a galeate whorl profile, which tapers sharply at the venter and has an attached, crest-like shell keel. On the last whorl, radial concave folds appear on the flank; they are most evident on the outer half of the flank. Some spiral lines are formed on the middle of the flank.

Remarks

Rodingites carinatus gen. et comb. nov. has the most prominent keel of all ammonoid species known so far from the early Tournaisian. The species is distinguished from *Rodingites planissimus* gen. et comb. nov. by the absence of the coarse ribs, which in *Rodingites carinatus* are only developed as very low folds.

Genus ***Paralytoceras*** Frech, 1902

Type species

Clymenia crispa Tietze, 1870: 135, by monotypy.

Genus diagnosis

Genus of the subfamily Pseudarietitinae with a circular or compressed whorl profile with raised ventral keel that is sometimes paralleled by two longitudinal grooves. Sculpture with collar-like ribs and spiral ornament.

Genus composition

Central Europe (Tietze 1870): *Clymenia crispa* Tietze, 1870.

South China (Ruan 1981): *Pseudarietites lenticulus* Ruan, 1981; *Pseudarietites tricarinatus* Ruan, 1981.

Remarks

Paralytoceras can clearly be separated from the other genera of the Pseudarietitinae by its sculpture, consisting in the middle ontogenetic stage of a succession of collar-like riblets that are often crenulated and cause a conspicuous spiral ornament. The genus could be related to *Pseudarietites*, as some of the *Paralytoceras* species show a very similar ventral shape with longitudinal grooves paralleling a raised ventral keel.

Specimens of *Paralytoceras* belong to the rarest Early Tournaisian ammonoids and are known from only few places worldwide (Lower Silesia, Rhenish Mountains, Guizhou). In all regions they occur in extremely low numbers; only two specimens of the type species are known from the type locality at

Dzikowiec in Lower Silesia. Only a few fragmentary specimens are preserved from the Oberrödinghausen railway cutting.

Paralytoceras crispum (Tietze, 1870)
Fig. 116A

Clymenia crispa Tietze, 1869: 36 [nomen nudum].

Clymenia crispa – Tietze 1870: 135, pl. 16 fig. 12.
Sporadoceras (*Paralytoceras*) *crispum* – Frech 1902: 83, pl. 3 fig. 14.
Paralytoceras crispum – Schindewolf 1923: 397, text-fig. 11e. — Weyer 1965: 452, pl. 6 figs 2–4, text-fig. 2. — Dzik 1997: 109, text-fig. 29h. — Kullmann 2009: text-fig. 5.3.
Pseudarietites crispus – Ruan 1981: 92, pl. 22 figs 20–21.

Diagnosis

Species of *Paralytoceras* with conch reaching 60 mm diameter. Conch at 35 mm dm extremely discoidal, subevolute (ww/dm ~0.30, uw/dm ~0.40). Whorl profile at 35mm dm weakly compressed (ww/wh ~0.80); coiling rate moderate (WER ~1.95). Venter narrowly rounded with separate keel, umbilical margin rounded. Ornament with about 100 sharp, crenulated riblets with concave course on half a volution.

Material examined

Holotype

POLAND • Silesia, Dzikowiec (Ebersdorf); *Gattendorfia* Limestone; Tietze Coll.; illustrated by Tietze (1870: pl. 16 fig. 12), Frech (1902: pl. 3 fig. 14), Weyer (1965: pl. 6 fig. 2), Dzik (1997: text-fig. 29h) and Kullmann (2009: text-fig. 5.3); MB.C.4692.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schmidt 1921 Coll.; BGR X1280 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; MB.C.31223 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c1; Weyer 1993–1994 Coll.; MB.C.31224.

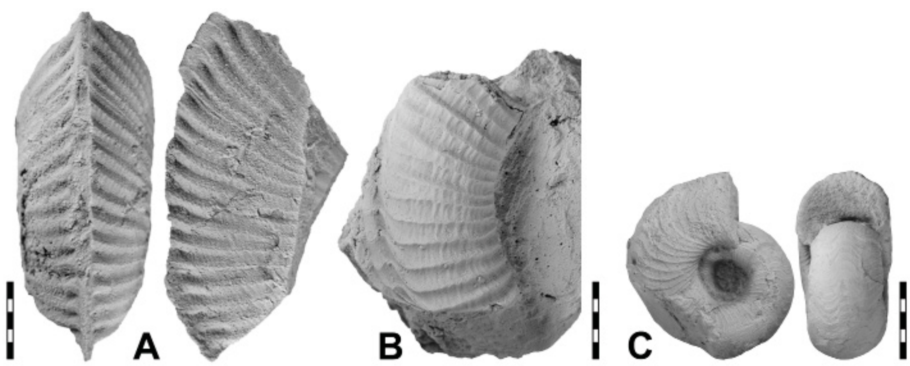

Fig. 116. *Paralytoceras* from the Oberrödinghausen railway cutting. **A**. *Paralytoceras crispum* (Tietze, 1870), specimen MB.C.31223 (Vöhringer Coll.) from bed 2. **B**. *Paralytoceras* sp. 1, specimen MB.C.31225 (Weyer 1993–1994 Coll.) from bed 3d1. **C**. *Paralytoceras* (?) sp. 2, specimen MB.C.31227 (Weyer 1993–1994 Coll.) from bed 3d1b. Scale bar units = 1 mm.

Description

Specimen MB.C.31223 was found in the unpublished parts of the Vöhringer collection; this so far unrecognised specimen is figured here (Fig. 116A). It is a fragment of a specimen with an original whorl height of about 14 mm. Its whorl profile is depressed with sinuous flanks slowly approaching the acute venter. The specimen shows sharp riblets, which originate from densely spaced collar-like structures. They extend in a shallow curve in forward direction across the flanks and end at the raised ventral keel. Near the venter, the riblets have a width of 0.6 mm, similar or identical with the width of the interspaces between the riblets. The entire flank bears spiral lines; these are much weaker than the riblets and occur between as well as on top of the riblets.

Remarks

Paralytoceras crispum differs from the other species of the genus in the wider umbilicus.

Paralytoceras sp. 1
Fig. 116B

Material examined

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; illustrated in Fig. 116B; MB.C.31225 • 1 specimen; Rhenish Mountains, Oberrödinghausen, road cutting; Hangenberg Limestone, bed 3d; Korn & Weyer 2000 Coll.; MB.C.31226.

Description

The fragmentary specimen MB.C.31225 has about 8.5 mm whorl height and belongs to a subevolute ammonoid (Fig. 116B). The venter bears a prominent keel, which is raised out of the venter. The flank is covered by numerous collars standing in distances of 1.0 to 1.4 mm; these collars extend from the umbilical seam across flanks and venter. Between these collars, there occur very fine growth lines and coarser spiral elements, the latter cause a crenulation on the margins of the collars.

***Paralytoceras* (?)** sp. 2
Fig. 116C; Table 112

Material examined

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; illustrated in Fig. 116C; MB.C.31227.

Description

The single specimen (MB.C.31227) has 12.5 mm and is a thickly discoidal, subevolute conch with kidney-shaped whorl profile. Its ornament consists of coarse, sharp growth lines that extend with a wide sinus across the flanks and form a high, narrow ventrolateral projection and a rather narrow, deep ventral sinus (Fig. 116C).

Table 112. Conch measurements, ratios and rates of *Paralytoceras* (?) sp. 2.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31227	12.4	6.2	4.9	3.8	3.1	0.50	1.28	0.30	1.78	0.36
MB.C.31227	9.1	5.3	3.5	2.9	–	0.58	1.49	0.32	–	–

Order Prolecanitida Miller & Furnish, 1954
Suborder Prolecanitina Miller & Furnish, 1954

Superfamily **Prolecanitoidea** Hyatt, 1884

Diagnosis

Superfamily of the Prolecanitina with an unsubdivided adventive lobe.

Superfamily composition

Prolecanitidae Hyatt, 1884; Daraelitidae Tschernow, 1907.

Family **Prolecanitidae** Hyatt, 1884

Diagnosis

Family of the Prolecanitoidea with an unsubdivided external lobe.

Family composition

Prolecanitinae Hyatt, 1884; Eocanitinae Weyer, 1972 [synonym of Prolecanitinae Hyatt, 1884]; Protocanitinae Weyer, 1972.

Subfamily **Prolecanitinae** Hyatt, 1884

Diagnosis

Subfamily of the Prolecanitidae with a lanceolate or pouched external lobe.

Subfamily composition

Prolecanites Mojsisovics, 1882; *Paraprolecanites* Karpinsky, 1889 [synonym of *Prolecanites* Mojsisovics, 1882]; *Metacanites* Schindewolf, 1922; *Rhipaeocanites* Ruzhencev, 1949 [synonym of *Prolecanites* Mojsisovics, 1882]; *Dombarocanites* Ruzhencev, 1949; *Eocanites* Librovitch, 1957; *Michiganites* Ruzhencev, 1962; *Katacanites* Kullmann, 1963; *Asioclymenia* Sun & Shen, 1965 [synonym of *Eocanites* Librovitch, 1957]; *Becanites* Korn, 1997; *Kahlacanites* Ebbighausen, Bockwinkel, Korn & Weyer, 2004; *Nomismocanites* gen. nov.

Morphology

Most of the representatives of the Prolecanitinae share the "standard prolecanitid morphology", meaning that they have an evolute conch with a compressed oval whorl profile and a very small whorl overlap zone. Most of the species possess a weak ornament consisting only of fine growth lines. It appears that the highest morphological diversity in the shape of the conch appears at the beginning of their evolutionary history, the earliest prolecanitid genus *Eocanites* shows a rather wide range of whorl profiles including compressed oval, circular, subquadratic shapes with rounded, flat and concave venter. The ornament ranges from delicate to coarse with lateral folds and weak riblets.

Ontogeny

Most of the representatives of the subfamily Prolecanitinae have a simple conch ontogeny, simply because the juvenile conchs usually do not differ markedly from the adults. Like many other Palaeozoic ammonoids, the conch of the prolecanitids tend to be more slender during ontogeny.

Eocanites has, like most of the other early prolecanitid ammonoids, an ontogeny with nearly monophasic trajectories of the cardinal conch parameters. As seen in specimen GPIT-PV-63981 (*E. delicatus* sp. nov.), the ww/dm trajectory decreases from about 0.65 at 1.2 mm diameter to 0.28 at 12 mm diameter. The uw/dm trajectory shows an initial increase to 0.57 at 3 mm diameter and then stays at this value. The whorl expansion rate fluctuates between 1.60 and 1.70 in the growth interval between 2 and 12 mm diameter.

Phylogeny

It is up to now not clear from where the genus *Eocanites* and with this the entire order Prolecanitida derives. An origin from Devonian ammonoids of the order Agoniatitida, as proposed by Schindewolf (1929) because of the putative different suture ontogeny ("U type ontogeny") and accepted by Ruzhencev (1960) does not have to be discussed any longer. Already Vöhringer (1960) suggested an origin of the prolecanitid ammonoids from prionoceratids with wide umbilicus in the juvenile stage (such as *Stockumites intermedius*). Korn *et al.* (2003b) provides rather firm evidence that the suture ontogeny of the prolecanitids shows the A-mode and hence does not differ from the goniatitids, hence an origin from prionoceratids at the Devonian–Carboniferous boundary is most likely.

Eocanites appears suddenly with the rather distinct species *E. ruani* and this cannot be connected with any other ammonoid species so far. Among the genera with open umbilicus in a rather late growth interval, only *Gattendorfia* is known to occur at the same stratigraphic level. However, *G. subinvoluta* and *G. rhenana* sp. nov. possess inner whorls with a very characteristic trapezoidal profile, while these in *Eocanites* are circular or depressed oval. A tendency towards trapezoidal whorl profiles can also be seen in *Stockumites*, such as *S. hilarus* from the Devonian–Carboniferous boundary beds of the Anti-Atlas in Morocco (Korn *et al.* 2004, 2007). This may exclude a direct phylogenetic connection.

Stratigraphic occurrence

Representatives of the subfamily Prolecanitinae are known from near the base of the Carboniferous throughout to the Serpukhovian; particularly in the latest Viséan to early Serpukhovian strata of the South Urals they are diverse and very common (Ruzhencev & Bogoslovskaya 1971).

Eocanites is obviously restricted to the Hangenberg Limestone and its time equivalents in other regions. Detailed bed-by-bed collections are only available from the Rhenish Mountains and it is particularly the Oberrödinghausen railway cutting that yielded numerous specimens from a number of horizons. At this place, the genus has not been recorded from the lowermost limestone bed (bed 6) but enters with *E. ruani* in bed 5. Only somewhat higher, the other species occur successively, e.g., *E. nodosus* in bed 4, *E. brevis* and *E. spiratissimus* in bed 3d, *E. tener* in bed 3c, *E. supradevonicus* in bed 3b, *E. delicatus* sp. nov. in bed 2 and *E. planus* in bed 1.

Geographic occurrence

Many of the Early Tournaisian ammonoid occurrences contain specimens of *Eocanites* and hence the genus shows a wide geographic distribution. The genus is reported from Alberta (questionable; Schindewolf 1959), south Portugal (Korn 1997), the Montagne Noire (Becker & Weyer 2004; Korn & Feist 2007), the Rhenish Mountains (Schmidt 1924; Schindewolf 1926b; Vöhringer 1960; Korn 1994; Korn & Weyer 2003), the Thuringian Mountains (Bartzsch *et al.* 2003), Lower Silesia (Frech 1902; Dzik 1997) the Carnic Alps of Austria and Italy (Korn 1992b; Schönlaub *et al.* 1992), Guizhou (Sun & Shen 1965; Ruan & He 1974; Ruan 1981) and the Anti-Atlas of Morocco (Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007).

Genus ***Eocanites*** Librovitch, 1957

Diagnosis

Genus of the Prolecanitinae with the sutural formula E A L U I; lateral lobe small, cuneiform.

Genus composition

Eocanites is currently composed of 21 species, which have been described from various regions:

Central Europe (Schmidt 1925; Schindewolf 1926b; Vöhringer 1960; Bartzsch *et al.* 2003): *Gattendorfia nodosa* Schmidt, 1925; *Protocanites supradevonicus* Schindewolf, 1926; *Protocanites planus* Schindewolf, 1926; *Protocanites spiratissimus* Schindewolf, 1926; *Protocanites supradevonicus brevis* Vöhringer, 1960; *Protocanites planus tener* Vöhringer, 1960; *Eocanites ruani* Bartzsch, Korn & Weyer, 2003; *Eocanites delicatus* sp. nov.

North Africa (Bockwinkel & Ebbighausen 2006; Ebbighausen & Bockwinkel 2007): *Eocanites dkorni* Bockwinkel & Ebbighausen, 2006; *Eocanites rtbeckeri* Bockwinkel & Ebbighausen, 2006; *Eocanites simplex* Bockwinkel & Ebbighausen, 2006.

South China (Sun & Shen 1965; Ruan & He 1974; Ruan 1981): *Asioclymenia asiatica* Sun & Shen, 1965; *Eocanites briareus* Ruan, 1981; *Eocanites circinatus* Ruan, 1981; *Eocanites curvicostatus* Ruan, 1981; *Eocanites holcoventrus* Ruan, 1981; *Eocanites huishuiensis* Ruan, 1981; *Eocanites nanus* Ruan, 1981; *Eocanites retiolus* Ruan, 1981; *Eocanites robustus* Ruan, 1981; *Eocanites rursiradiatus* Ruan, 1981; *Eocanites stenosellatus* Ruan, 1981.

Remarks

Eocanites, along with *Protocanites*, is the genus of the entire order Prolecanitida with the simplest suture line consisting only of the elements E A L U I. In contrast to *Protocanites* with a V-shaped external lobe, *Eocanites* has a parallel-sided or slightly pouched external lobe.

Eocanites ruani Bartzsch, Korn & Weyer, 2003
Figs 117–118

Eocanites ruani Bartzsch, Korn & Weyer, 2003: 8, text-figs 1–2.
Gattendorfia nodosa Schmidt, 1925: 536, pl. 19 fig. 10, pl. 23 fig. 3.

Protocanites nodosus – Vöhringer 1960: 169, pl. 6 fig. 1b, text-fig. 44a.
Eocanites nodosus – Korn & Feist 2007: 108, text-fig. 6f.

non *Eocanites ruani* Becker & Weyer 2004: 8, text-fig. 17.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 50 mm diameter. Conch at 12 mm dm evolute (uw/dm ~0.50) with weakly depressed whorl profile (ww/wh ~1.05) and broadly rounded venter; conch at 30 mm dm evolute (uw/dm ~0.50) with weakly compressed whorl profile (ww/wh ~0.95) and flat or weakly concave venter. Ornament with moderately coarse, strongly rursiradiate, biconvex growth lines with deep ventral sinus. With low, rounded crescent-shaped ventrolateral ribs and nodes.

Material examined

Holotype

GERMANY • Thuringian Mountains, Saalfeld, Pfaffenberg SW quarry; Pfaffenberg Member of the Gleitsch Formation, bed 4; Bartzsch & Weyer 1974 Coll.; illustrated by Bartzsch *et al.* (2003: text-fig. 1.1) and Korn (2006: text-fig. 4i); MB.C.5360.1.

Paratypes

GERMANY • 10 specimens; Thuringian Mountains, Saalfeld, Pfaffenberg SW quarry; Pfaffenberg Member of the Gleitsch Formation, bed 4; Bartzsch & Weyer 1967–1976 Coll.; MB.C.5360.2–

MB.C.5360.9, MB.C.5361, MB.C.5362.1 • 1 specimen; Thuringian Mountains, Saalfeld, Pfaffenberg SW quarry; Pfaffenberg Member of the Gleitsch Formation, bed 4; Riedel Coll.; MB.C.5362.2.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4; Vöhringer Coll.; GPIT-PV-63970 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5; Vöhringer Coll.; GPIT-PV-64001 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 4a; Weyer 1993–1994 Coll.; MB.C.31228.1–3 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a1; Weyer 1993–1994 Coll.; MB.C.31229 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5a2; Weyer 1993–1994 Coll.; MB.C.31230.1–2 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 5b; Weyer 1993–1994 Coll.; MB.C.31231 • 1 specimen; Rhenish Mountains, Drewer; Hangenberg Limestone; Schmidt Coll.; GZG.INV.1690.

Description

Specimen MB.C.31229 is a small fragment, but it clearly shows the characteristic features of the species (Fig. 117B). At 9 mm whorl height, the profile has almost equal width and height, but the flanks converge to the flattened, slightly concave venter. The specimen shows crescent-shaped ribs on the outer flank; these ribs form blunt nodes on the ventrolateral shoulder.

The transition to the adult stage can also be followed in the sectioned specimen GPIT-PV-63970; the almost circular juvenile whorl profile has developed a concave venter at 8 mm whorl height (Fig. 118A). The ontogenetic trajectories of the cardinal conch parameters are rather simple, at least to a conch diameter of 9 mm (Fig. 118C-E).

The fragment of the larger specimen GPIT-PV-64001 represents the adult stage with flat venter and ribs on the flank, which turn into short nodes near the ventrolateral shoulder (Fig. 117A).

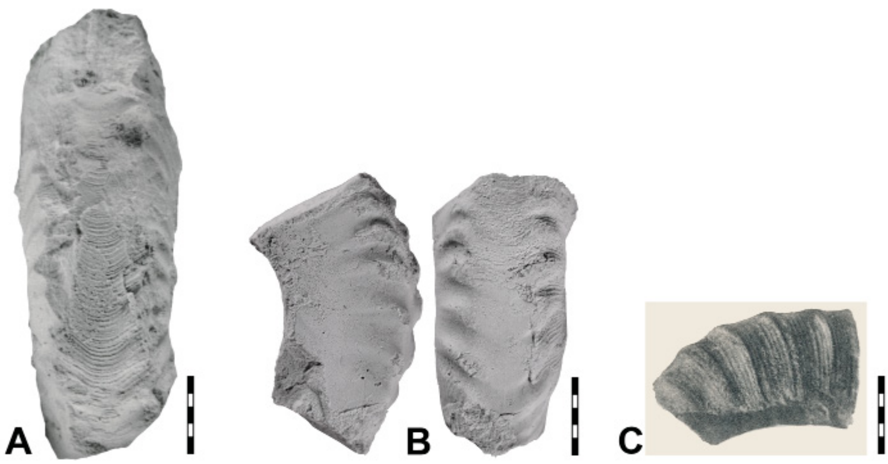

Fig. 117. *Eocanites ruani* (Bartzsch, Korn & Weyer, 2003) from the Oberrödinghausen railway cutting. **A**. Specimen GPIT-PV-64001 (Vöhringer Coll.) from bed 5. **B**. Specimen MB.C.31229 (Weyer 1993–1994 Coll.) from bed 5a1. **C**. Reproduction of the figure of "*Gattendorfia nodosa*" of Schmidt (1925: pl. 23 fig. 3). Scale bar units = 1 mm.

Remarks

Specimens of *Eocanites ruani* were considered by Schmidt (1925), Vöhringer (1960) and Korn (1994) as adult stages of *E. nodosus*. However, *E. nodosus* has a much finer ornament with coarse growth lines formed on the entire flank and venter; furthermore, ribs, nodes and a concave venter are not known from *E. nodosus*.

Eocanites ruani can be easily distinguished from almost all other Central European species of the genus by the concave venter and the characteristic crescent-shaped ribs on the outer half of the flank. *Eocanites ruani* is so far apparently the only representative of the genus from the lower part of the *Gattendorfia* stage.

Of the species of *Eocanites* described from Guizhou, *E. holcoventrus* and *E. robustus* have a concave venter, but both species have an almost square-shaped whorl profile. Furthermore, *E. holcoventrus* has no ribs and *E. robustus* has sigmoidally curved ribs on the flank.

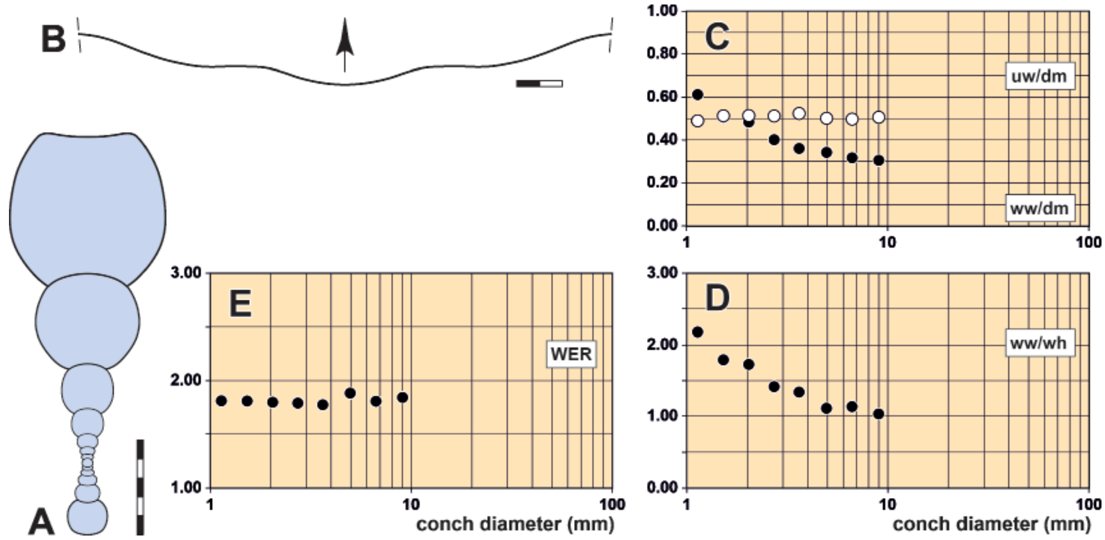

Fig. 118. *Eocanites ruani* (Bartzsch, Korn & Weyer, 2003) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen GPIT-PV-63970 (Vöhringer Coll.) from bed 4 (after Vöhringer 1960). **B**. Growth line course of specimen MB.C.31229 (Weyer 1993–1994 Coll.) from bed 5a1, at ww = 9.7 mm, wh = 9.3 mm. **C**–**E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Eocanites nodosus (Schmidt, 1925)
Figs 119–120; Tables 113–114

Gattendorfia nodosa Schmidt, 1925: 536, pl. 19 fig. 10, pl. 23 fig. 2.

Protocanites nodosus – Vöhringer 1960: 169, pl. 6 fig. 1a, text-fig. 44b.
Protocanites (*Eocanites*) *nodosus* – Weyer 1965: 457, pl. 7 fig. 4.
Eocanites nodosus – Weyer 1977: 173, pl. 1 fig. 4. — Korn 1994: 81, text-figs 73a–b, d, 74a, 75c; 2006, text-fig. 4h. — Dzik 1997: 108, text-fig. 29b. — Sprey 2002: pl. 4 fig. 6.

non *Gattendorfia nodosa* Schmidt, 1925: 536, pl. 19 fig. 10, pl. 23 fig. 3.
non *Protocanites nodosus* – Vöhringer 1960: 169, pl. 6 fig. 1b, text-fig. 44a.
non *Eocanites nodosus* – Korn 1997: 33, pl. 1 figs 4–5, text-fig. 18. — Korn & Feist 2007: 108, text-fig. 6f.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 35 mm diameter. Conch at 12 mm dm evolute (uw/dm ~0.50) with a weakly depressed whorl profile (ww/wh ~1.05) and a broadly rounded venter; conch at 30 mm dm evolute (uw/dm ~0.50) with weakly compressed whorl profile (ww/wh ~0.90) and broadly rounded venter. Ornament with coarse, strongly rursiradiate, biconvex, crenulated growth lines with deep ventral sinus. Ornament without ribs or nodes. Suture line with lanceolate external lobe and asymmetric, dorsally pouched adventive lobe.

Material examined

Lectotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone; Schmidt Coll.; designated by Vöhringer (1960); illustrated by Schmidt (1925: pl. 23 fig. 2), re-illustrated here in Fig. 119D; GZG.INV.1689.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-63968 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d; Vöhringer Coll.; GPIT-PV-63972 •

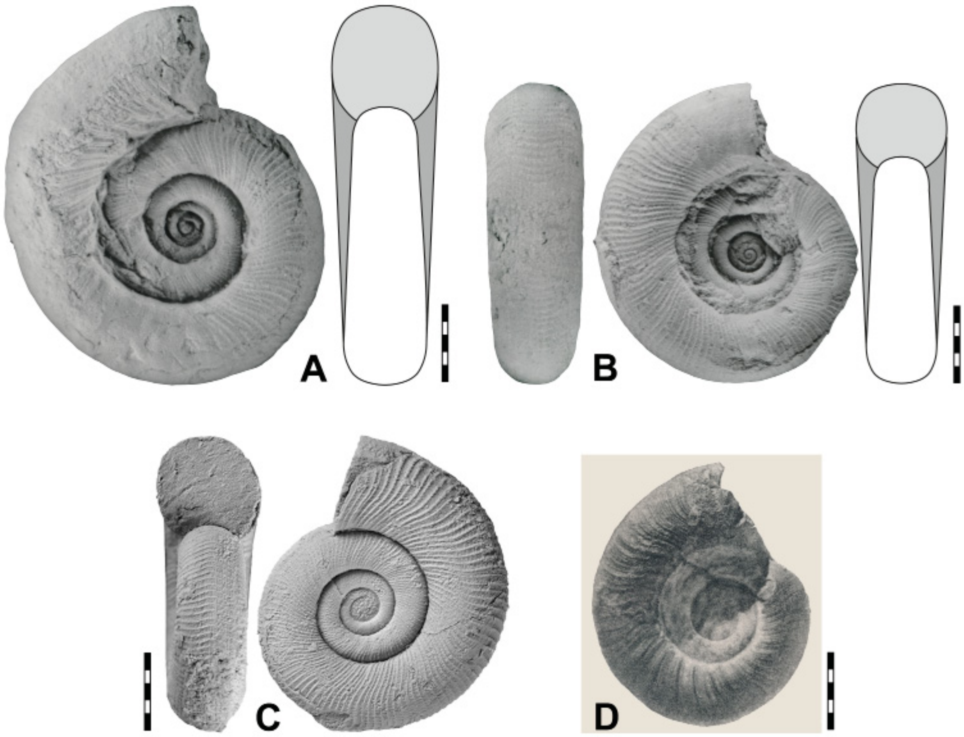

Fig. 119. *Eocanites nodosus* (Schmidt, 1925) from the Oberrödinghausen railway cutting. **A**. Specimen GPIT-PV-63968 (Vöhringer Coll.) from bed 3d. **B**. Specimen GPIT-PV-63972 (Vöhringer Coll.) from bed 3d. **C**. Specimen MB.C.31234.1 (Weyer 1993–1994 Coll.) from bed 3d1b. **D**. Reproduction of the figure of "*Gattendorfia nodosa*" of Schmidt (1925, pl. 23 fig. 2). Scale bar units = 1 mm.

1 specimen; Rhenish Mountains, Oberrödinghausen, west of railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31232 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.31233.1–2 • 15 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31234.1–15 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d2; Weyer 1993–1994 Coll.; OR- MB.C.31235.1–3 • 1 specimen; Rhenish Mountains, Hasselbachtal; Hangenberg Limestone, bed 71; Weyer 1993–1994 Coll.; MB.C.5244.2.

Description

Lectotype GZG.INV.1689 has a conch diameter of 17.5 mm and possesses coarse, crenulated growth lines, but no ribs (Fig. 119D). Although more than 20 specimens are available, none is larger than 25 mm. The largest specimen GPIT-PV-63968 is still chambered at 19 mm conch diameter (Fig. 119A); therefore the total size including body chamber can be estimated at about 35 mm.

The three specimens GPIT-PV-63968 (25 mm dm; Fig. 119A), GPIT-PV-63972 (20 mm dm; Fig. Fig. 119B) and MB.C.31234.1 (19 mm dm; Fig. 119C) show very similar dimensions and conch proportions like the lectotype. They are very discoidal and serpenticonic (ww/dm = 0.28–0.36; uw/dm = 0.46–0.48) with a more or less circular whorl profile (ww/wh = 0.93–1.14). All three show a rather coarse ornament with coarse growth lines directed backwards on the flank, between which finer spiral lines are formed. The growth lines themselves are not crossed by the spiral lines and therefore do not show granulation. The course of the growth lines is biconvex and rursiradiate.

The sectioned specimen MB.C.31234.2 allows the study of conch ontogeny up to 22 mm diameter (Fig. 120A). At all stages the whorl profile has a similar shape; it is widest at the broadly rounded umbilical margin and shows weakly converging flanks and a broadly rounded venter.

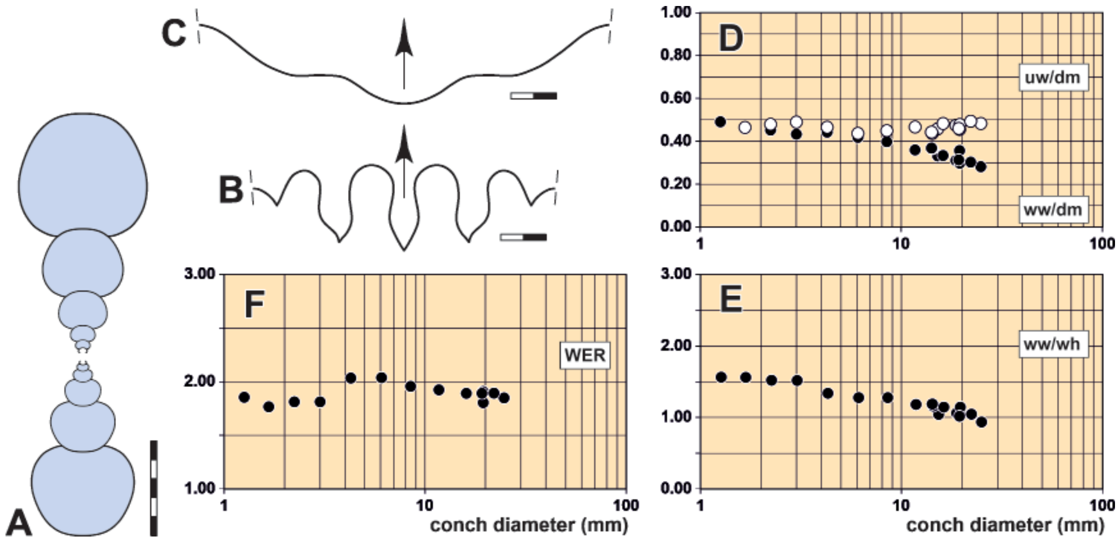

Fig. 120. *Eocanites nodosus* (Schmidt, 1925) from the Oberrödinghausen railway cutting. **A**. Cross section of specimen MB.C.31234.2 (Weyer 1993–1994 Coll.) from bed 3d1b. **B**. Suture line of specimen GPIT-PV-63968 from bed 3d, at dm = 18.6 mm, ww = 5.5 mm, wh = 5.5 mm. **C**. Growth line course of specimen GPIT-PV-63968 from bed 3d, at dm = 22.5 mm, ww = 6.4 mm, wh = 6.9 mm. **D**–**F**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 113. Conch measurements, ratios and rates of *Eocanites nodosus* (Schmidt, 1925) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63968	25.1	7.1	7.6	12.1	6.6	0.28	0.93	0.48	1.85	0.13
GPIT-PV-63972	19.7	5.9	5.7	9.4	5.0	0.30	1.03	0.48	1.80	0.11
MB.C.31234.1	19.6	7.0	6.2	9.0	5.4	0.36	1.14	0.46	1.91	0.12
MB.C.31234.3	19.4	6.1	6.1	9.0	5.3	0.31	1.01	0.46	1.89	0.12
GPIT-PV-63970	9.0	2.7	2.6	4.5	2.4	0.30	1.03	0.50	1.84	0.10

Table 114. Conch ontogeny of *Eocanites nodosus* (Schmidt, 1925) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
3 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.50)	moderately depressed; weakly embracing (ww/wh ~1.55; IZR ~0.10)	moderate (WER ~1.80)
10 mm	thinly discoidal; evolute (ww/dm ~0.40; uw/dm ~0.50)	weakly depressed; weakly embracing (ww/wh ~1.25; IZR ~0.10)	moderate (WER ~1.95)
20 mm	extremely discoidal; evolute (ww/dm ~0.30; uw/dm ~0.50)	weakly depressed; weakly embracing (ww/wh ~1.05; IZR ~0.10)	moderate (WER ~1.85)

The ontogenetic trajectories of the cardinal conch parameters are rather simple (Fig. 120D–F). The uw/dm ratio remains almost constant between 1 and 25 mm conch diameter at a value around 0.50 and the whorl expansion rate is stable at about 1.80. In contrast to this, the shape of the whorl profile changes continuously; the ww/wh ratio decreases from about 2.15 to 0.93. Correspondingly, the ww/dm ratio also decreases from ~0.60 to ~0.30.

The suture line of specimen GPIT-PV-63968 has a lanceolate, rather distinctly pouched external lobe, an inflated ventrolateral saddle and a distinctly asymmetric adventive lobe. This has a vertical, sigmoidal ventral flank and a very strongly sigmoidal dorsal flank (Fig. 120B). The lateral lobe is small and V-shaped.

Remarks

Schmidt (1925) as well as Vöhringer (1960) and Korn (1994) united two forms under the species *Eocanites nodosus*; they assumed that the ribbed adult stage with concave venter belongs to the subadult form with very coarse, crenulated growth lines. However, there is no evidence for this assumption, because the ribbed species *E. ruani* already has an almost rectangular profile and strong radial ribs at a whorl height of 10 mm, where specimens of *E. nodosus* do not possess ribs. The selection of the lectotype led to the somewhat peculiar situation that the species name *E. nodosus* is now used not for the nodose form (later described as *E. ruani*), but for the non-nodose form.

Eocanites brevis (Vöhringer, 1960)
Figs 121–122; Tables 115–116

Protocanites supradevonicus brevis Vöhringer, 1960: 172, pl. 6 fig. 5, text-fig. 46a.

Protocanites (*Eocanites*) *supradevonicus brevis* – Weyer 1965: 458, pl. 6 fig. 5.
Eocanites brevis – Korn 1994: 81, text-figs 73c, 75b. — Korn *et al*. 2003b: 1125, text-fig. 3a.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 50 mm diameter. Conch at 12 mm dm evolute (uw/dm ~0.50) with weakly compressed whorl profile (ww/wh ~0.90) and broadly rounded venter;

conch at 30 mm dm evolute (uw/dm ~0.50) with weakly compressed whorl profile (ww/wh ~0.85) and broadly rounded venter. Ornament with coarse, strongly rursiradiate, concavo-convex growth lines with moderately deep ventral sinus; without ribs.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 5) and Korn (1994, text-fig. 73c); re-illustrated here in Fig. 121A; GPIT-PV-63985.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Vöhringer Coll.; GPIT-PV-63983 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-63987.

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1990 Coll.; MB.C.31236 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31237.3–5 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c1; Weyer 1993–1994 Coll.; MB.C.31238 • 3 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.31239.1–3.

Description

Holotype GPIT-PV-63985 is a completely shell-covered specimen of 18 mm conch diameter (Fig. 121A). It is extremely discoidal and evolute (ww/dm ~0.22; uw/dm ~0.50) with a compressed oval whorl profile (ww/wh ~0.80). The ornament consists of rather coarse growth lines, which are directed backwards on the inner flank half and describe a radial course on the outer flank half; the ventral sinus is rather shallow and broadly rounded (Fig. 122B).

The cross section of paratype GPIT-PV-63987 allows the study of the conch ontogeny from the initial stage to a diameter of 27 mm (Fig. 122A). All stages larger than 2 mm dm are very similar in shape with almost static umbilical width and coiling rate (Fig. 122C, E); however, the whorl profile becomes continuously narrower (from ww/wh ~1.50 at 2 mm dm to ~0.85 at 27 mm dm; (Fig. 122D).

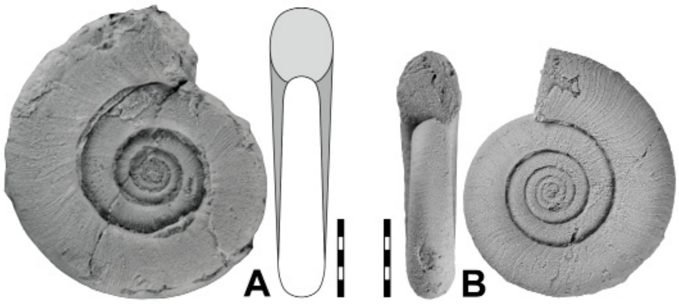

Fig. 121. *Eocanites brevis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63985 (Vöhringer Coll.) from bed 3c. **B**. Specimen MB.C.31238 (Weyer 1993–1994 Coll.) from bed 3c1. Scale bar units = 1 mm.

Table 115. Conch measurements, ratios and rates of *Eocanites brevis* (Vöhringer, 1960) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-63987	26.9	6.9	8.0	13.1	7.2	0.26	0.87	0.49	1.86	0.10
GPIT-PV-63985	17.9	4.0	4.8	8.9	4.5	0.22	0.82	0.50	1.79	0.06
GPIT-PV-63985	13.5	3.0	3.6	6.5	–	0.22	0.82	0.48	–	–
MB.C.31238	16.4	4.3	4.8	8.3	4.2	0.26	0.88	0.51	1.80	0.13
MB.C.31238	12.4	3.2	3.3	6.5	–	0.26	0.97	0.52	–	–

Table 116. Conch ontogeny of *Eocanites brevis* (Vöhringer, 1960) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
3 mm	thinly discoidal; evolute (ww/dm ~0.35; uw/dm ~0.50)	weakly depressed; weakly embracing (ww/wh ~1.20; IZR ~0.10)	moderate (WER ~1.90)
10 mm	extremely discoidal; evolute (ww/dm ~0.30; uw/dm ~0.50)	weakly compressed; weakly embracing (ww/wh ~0.95; IZR ~0.10)	moderate (WER ~1.90)
20 mm	extremely discoidal; evolute (ww/dm ~0.25; uw/dm ~0.50)	weakly compressed; weakly embracing (ww/wh ~0.85; IZR ~0.10)	moderate (WER ~1.90)

Remarks

Eocanites brevis resembles *E. nodosus*, but has considerably weaker growth lines and no spiral lines. *Eocanites brevis* is separated from *E. delicatus* sp. nov. by the compressed whorl profile (ww/wh ~0.80 in *E. brevis* but ~0.90 in *E. delicatus* at about 40 mm dm) and from *E. planus* by the wider umbilicus (uw/dm ~0.50 in contrast to less than 0.45 in *E. planus*).

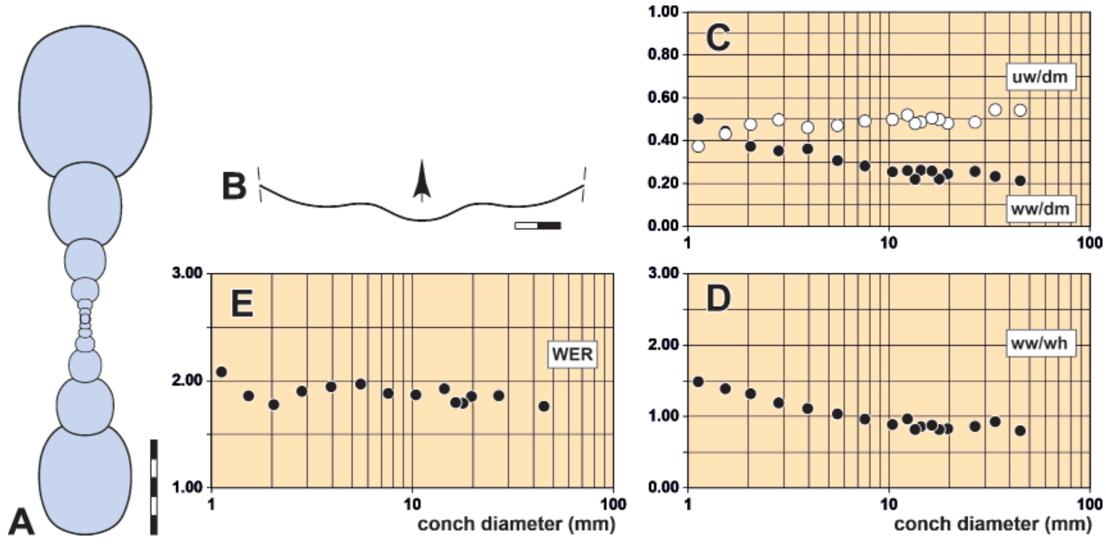

Fig. 122. *Eocanites brevis* (Vöhringer, 1960) from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-63987 (Vöhringer Coll.) from bed 3c. **B**. Growth line course of holotype GPIT-PV-63985 (Vöhringer Coll.) from bed 3c, at dm = 17.6 mm, ww = 4.2 mm, wh = 5.0 mm. **C–E**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Eocanites tener (Vöhringer, 1960)
Fig. 123A; Table 117

Protocanites planus tener Vöhringer, 1960: 176, pl. 6 fig. 4.

Protocanites (*Eocanites*) *planus tener* – Weyer 1965: 458, pl. 8 fig. 5.
Eocanites tener – Korn 1994: 83, text-fig. 73g.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 35 mm diameter. Conch at 12 mm dm evolute (uw/dm ~0.50) with weakly compressed whorl profile (ww/wh ~0.90) and broadly rounded venter; conch at 20 mm dm evolute (uw/dm ~0.50) with weakly compressed whorl profile (ww/wh ~0.90) and broadly rounded venter. Ornament with very fine, rursiradiate, concavo-convex growth lines with moderately deep ventral sinus. Without ribs.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 4) and Korn (1994: text-fig. 73g); re-illustrated here in Fig. 123A; GPIT-PV-64006.

Paratype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Vöhringer Coll.; GPIT-PV-63994.

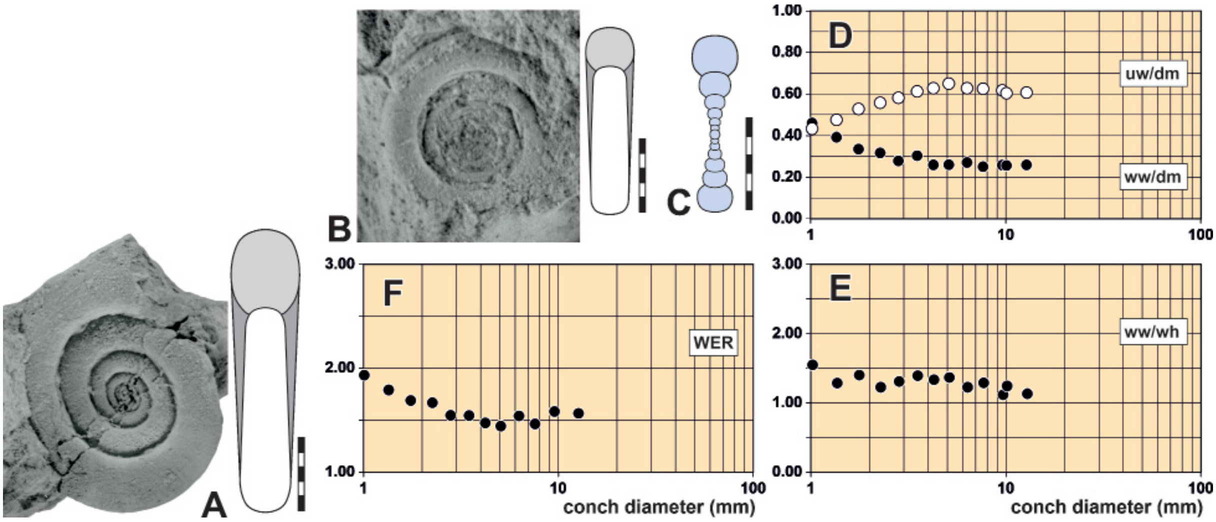

Fig. 123. *Eocanites* from the Oberrödinghausen railway cutting, all Vöhringer Coll. **A**. *Eocanites tener* (Vöhringer, 1960), holotype GPIT-PV-64006 from bed 3c **B**. *Eocanites spiratissimus* (Schindewolf, 1926), neotype GPIT-PV-64007 from bed 3c. **C**. *Eocanites spiratissimus* (Schindewolf, 1926), cross section of specimen GPIT-PV-64012 from bed 3c. **D**–**F**. *Eocanites spiratissimus* (Schindewolf, 1926), ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

Table 117. Conch measurements, ratios and rates of *Eocanites tener* (Vöhringer, 1960).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-64006	17.8	4.4	5.4	8.9	4.9	0.25	0.82	0.50	1.91	0.09
GPIT-PV-64006	12.9	3.2	3.5	6.7	–	0.25	0.92	0.52	–	–

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; MB.C.31240 • 7 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3a; Weyer 1993–1994 Coll.; MB.C.31241.1–7 • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; MB.C.31242 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c1; Weyer 1993–1994 Coll.; MB.C.31243.1–2 • 5 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1; Weyer 1993–1994 Coll.; MB.C.312441.1–5 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; MB.C.31245.1–2.

Description

Holotype GPIT-PV-64006 is a specimen with a diameter of 18 mm (Fig. 123A). It is extremely discoidal and evolute (ww/dm ~0.25; uw/dm ~0.50) with an oval whorl profile (ww/wh ~0.80). The shell appears to be almost smooth, but it bears very fine growth lines with concave course on the flank.

Remarks

Eocanites tener is separated from most other species of the genus by its almost smooth shell surface. Only *E. planus* also has an almost smooth shell, but has a narrower umbilicus (uw/dm is less than 0.45 in *E. planus*, but ~0.50 in *E. tener*).

Eocanites spiratissimus (Schindewolf, 1926)
Fig. 123B–F; Tables 118–119

Protocanites spiratissimus Schindewolf, 1926: 105.

Protocanites spiratissimus – Vöhringer 1960: 175, pl. 6 fig. 6, text-figs 45, 51.
Protocanites (*Eocanites*) *spiratissimus* – Weyer 1965: 458.
Eocanites spiratissimus – Korn 1994: 83, text-figs 73h.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 25 mm diameter. Conch at 12 mm dm very evolute (uw/dm ~0.60) with weakly depressed whorl profile (ww/wh ~1.10) and broadly rounded venter. Ornament with very fine, rursiradiate, concavo-convex growth lines with moderately deep ventral sinus. Without ribs.

Material examined

Neotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 3) and Korn (1994: text-fig. 73h); re-illustrated here in Fig. 123B; GPIT-PV-64007.

Table 118. Conch measurements, ratios and rates of *Eocanites spiratissimus* (Schindewolf, 1926) from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-64007	12.8	3.3	2.9	7.8	2.6	0.26	1.14	0.61	1.57	0.12
GPIT-PV-64012	9.6	2.4	2.2	5.9	2.0	0.26	1.12	0.62	1.58	0.10

Table 119. Conch ontogeny of *Eocanites spiratissimus* (Schindewolf, 1926) from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
3 mm	extremely discoidal; evolute (ww/dm ~0.25; uw/dm ~0.55)	weakly depressed; weakly embracing (ww/wh ~1.30; IZR ~0.10)	low (WER ~1.55)
10 mm	extremely discoidal; very evolute (ww/dm ~0.25; uw/dm ~0.60)	weakly depressed; weakly embracing (ww/wh ~1.29; IZR ~0.10)	low (WER ~1.60)

Additional material

GERMANY • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3c; Vöhringer Coll.; GPIT-PV-64012, GPIT-PV-64010.

Description

Neotype GPIT-PV-64007 is a specimen with only 13 mm diameter and is largely embedded in a small limestone block (Fig. 123B). The dimensions can only be partially estimated, but it is clear that the conch is very evolute (uw/dm ~0.60 and that the whorl profile is almost circular. The shell appears to be smooth and bears very fine, rursiradiate growth lines.

The sectioned specimen GPIT-PV-64012 allows the study of conch geometry up to 10 mm diameter (Fig. 123C). The umbilicus is extremely wide between 3 and 10 mm conch diameter (uw/dm exceeds the value of 0.60) and the whorl profile decreases continuously from uw/wh ~1.40 to ~1.25.

Remarks

A type specimen was not selected when Schindewolf (1926b) described the species *Eocanites spiratissimus*; obviously no later author has determined a lectotype. In his monograph, Vöhringer (1960) did not give any information on a type of the species either. For this reason, a neotype from the Vöhringer Collection from the type locality is proposed here. *Eocanites spiratissimus* differs from the other species of *Eocanites* in the very wide umbilicus at 10 mm conch diameter. The uw/dm ratio exceeds, at 10 mm conch diameter, a value of 0.60 in *E. spiratissimus*, but usually less than 0.55 in the other species.

Eocanites supradevonicus (Schindewolf, 1926)

Fig. 124; Table 120

Protocanites supradevonicus Schindewolf, 1926: 104, text-figs 3a, 4–5.

Protocanites supradevonicus supradevonicus – Bartzsch & Weyer 1982: 19, text-fig. 4/1.

non *Protocanites supradevonicus supradevonicus* – Vöhringer 1960: 171, pl. 6 fig. 2, text-figs 46b, 48.
non *Eocanites supradevonicus* – Korn 1994: 80, text-figs 66m, 73e, 74c, 75a; 2006: text-fig. 4J. — Kullmann 2000: text-fig. 4m. — Furnish *et al*. 2009: text-fig. 117.2.

Table 120. Conch measurements, ratios and rates of *Eocanites supradevonicus* (Schindewolf, 1926).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31246	45.2	9.7	12.0	24.6	11.2	0.21	0.81	0.54	1.76	0.07
MB.C.31246	33.9	8.0	8.5	18.5	–	0.23	0.93	0.55	–	–

Diagnosis

Species of the genus *Eocanites* with a conch reaching 50 mm diameter. Conch at 30 mm dm evolute (uw/dm ~0.55) with a weakly compressed whorl profile (ww/wh ~0.85) and a broadly rounded venter. Ornament with fine, weakly rursiradiate, concavo-convex growth lines with moderately deep ventral sinus. With low, rounded radial folds.

Material examined

Neotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3b; Weyer 1993–1994 Coll.; illustrated in Fig. 124; MB.C.31246.

Description

Neotype MB.C.31246 is a rather well-preserved, fully shell-covered specimen with 45 mm conch diameter (Fig. 124). It is extremely discoidal and evolute (ww/dm = 0.21; uw/dm = 0.54) with a compressed whorl profile (ww/wh = 0.81). The coiling rate is moderate (WER = 1.76). The whorl profile is widest in the dorsal flank region; from there the flanks slowly converge towards the broadly rounded venter. The well-preserved shell ornament has fine, sharp growth lines at different distances; they extend from the umbilicus slightly in backward direction. They form a lateral sinus on the middle of the flank and curve anteriorly to a ventrolateral projection and a rather shallow ventral sinus. In addition, there are very shallow radial folds (about eight per quarter whorl), which are most prominent on the inner and outer flanks; they are usually very weak on the middle of the flank and diminish before reaching the venter.

Fig. 124. *Eocanites supradevonicus* (Schindewolf, 1926) from the Oberrödinghausen railway cutting, neotype MB.C.31246 (Weyer 1993–1994 Coll.) from bed 3b. Scale bar units = 1 mm.

Remarks

Schindewolf (1926b) did not select a holotype when describing the species *Eocanites supradevonicus*; a type specimen was obviously not subsequently dedicated as a lectotype. Vöhringer (1960) did not give any information on a type of the species in his monograph either. He also did not discuss the possible differences in conch shape and ornament between his specimens and the original description given by Schindewolf (1926b). To stabilise the species, a neotype from the Weyer collection from the type locality is proposed here.

The specimen already illustrated by Vöhringer (1960) as *Eocanites supradevonicus* obviously has a much weaker ornamentation than the specimen of the poor illustration given by Schindewolf (1926b), which is very evolute and shows an ornament composed of very low radial folds and growth lines.

Eocanites supradevonicus differs from most of the other Central European species of the genus by its very wide umbilicus (uw/dm ~0.55), which in many of the other species only reaches a width of 0.50 in the adult stage. Furthermore, *E. supradevonicus* differs from most species by its weak folds on the flank.

Eocanites delicatus sp. nov.

urn:lsid:zoobank.org:act:84F708EA-F37B-4DF4-8503-B777178537CA
Figs 125–126; Tables 121–122

Protocanites Lyoni – Schmidt 1924: 153, pl. 8 figs 14–18. — Schmidt, 1925: 537, pl. 19 fig. 11.
Protocanites supradevonicus supradevonicus – Vöhringer 1960: 171, pl. 6 fig. 2, text-figs 46b, 48.
Eocanites supradevonicus – Korn 1994: 80, text-figs 66m, 73e, 74c, 75a; 2006: text-fig. 4j. — Kullmann 2000: text-fig. 4m. — Sprey 2002: 53, text-fig. 18g. — Furnish *et al*. 2009: text-fig. 117.2.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 60 mm diameter. Conch at 12 mm dm evolute (uw/dm ~0.55) with weakly depressed whorl profile (ww/wh ~1.10) and broadly rounded venter; conch at 30 mm dm evolute (uw/dm ~0.50) with nearly circular whorl profile (ww/wh ~1.00) and broadly rounded venter. Ornament with fine, rursiradiate, concavo-convex growth lines with moderately deep ventral sinus. With low, rounded folds on the flank. Suture line with weakly pouched external lobe and lanceolate, weakly pouched adventive lobe.

Etymology

From the Latin '*delicatus*', referring to the delicate shell ornament.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 2), Korn (1994: text-fig. 73e) and Korn (2006: text-fig. 4j); re-illustrated here in Fig. 125A.; GPIT-PV-63997.

Paratypes

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; GPIT-PV-64008 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2; Vöhringer Coll.; GPIT-PV-63981, GPIT-PV-63999 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1977 Coll.; MB.C.31247.1–2 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Korn 1990 Coll.; MB.C.31248.1–2 •

1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2b; Korn 1991 Coll.; MB.C.31249 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Weyer 1993–1994 Coll.; MB.C.31250.1–2 • 10 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2a; Weyer 1993–1994 Coll.; MB.C.31251.1–10 • 2 specimens; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 2b; Weyer 1993–1994 Coll.; MB.C.31252.1–2.

Description

Holotype GPIT-PV-63997 is a well-preserved specimen with 42 mm conch diameter embedded in rock matrix (Fig. 125A). The conch is extremely discoidal with a wide umbilicus (ww/dm ~0.25; uw/dm ~0.50) and a compressed oval whorl profile (ww/wh ~0.85); the coiling rate is low (WER ~1.70). The shell bears fine, regularly spaced growth lines that are directed backwards on the flank. A very weak radial folding is also visible on the flank.

Paratype MB.C.31247.1 is a specimen with 31 mm diameter (Fig. 125B); it is thinly discoidal and evolute with a nearly circular whorl profile (ww/dm ~0.28; uw/dm ~0.50; ww/wh ~0.96). The ornament consists of fine growth lines running backwardly directed across the flanks and form a rounded ventral sinus.

Eocanites delicatus sp. nov. has, like most of the other early prolecanitid ammonoids, a rather simple conch ontogeny with nearly monophasic trajectories of the cardinal conch parameters. As seen in specimens GPIT-PV-64008 (Fig. 126A) and GPIT-PV-63981 (Fig. 126B), the uw/dm trajectory decreases from about 0.65 at 1.2 mm diameter to 0.28 at 12 mm diameter. The uw/dm trajectory shows an initial increase to 0.57 at 3 mm diameter and then stays at this value. The whorl expansion rate fluctuates between 1.60 and 1.70 in the growth interval between 2 and 12 mm diameter (Fig. 126E–G).

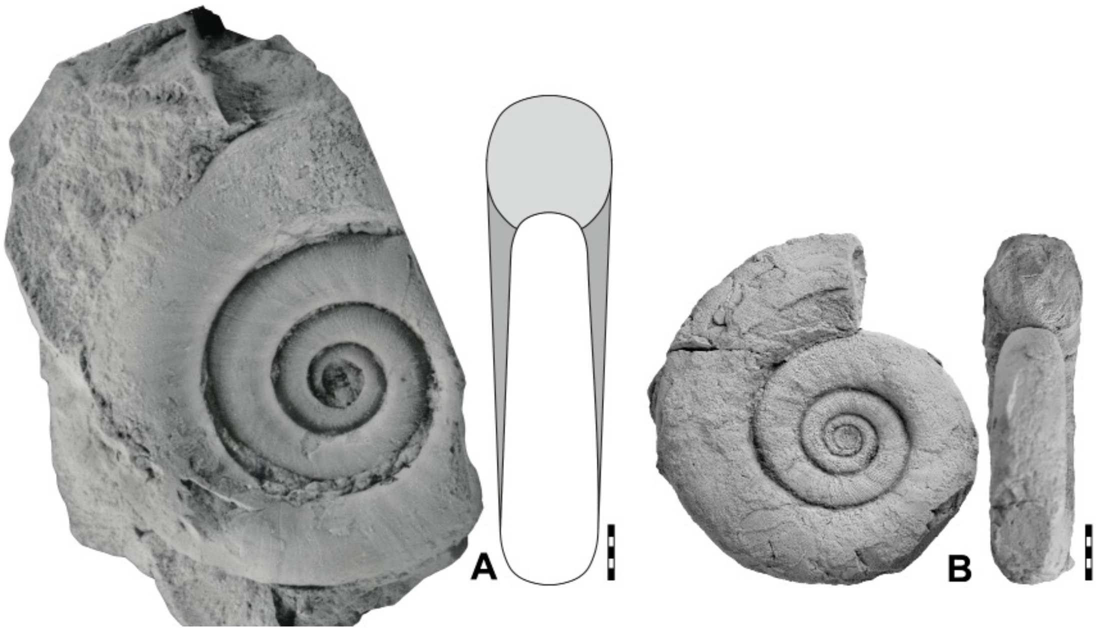

Fig. 125. *Eocanites delicatus* sp. nov. from the Oberrödinghausen railway cutting. **A**. Holotype GPIT-PV-63997 (Vöhringer Coll.) from bed 1. **B**. Paratype MB.C.31247.1 (Korn 1977 Coll.) from an unknown bed. Scale bar units = 1 mm.

Table 121. Conch measurements, ratios and rates of *Eocanites delicatus* sp. nov. from Oberrödinghausen.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-64008	47.0	11.7	13.9	22.9	12.5	0.25	0.84	0.49	1.86	0.09
GPIT-PV-63997	42.3	9.7	11.5	21.8	9.8	0.23	0.84	0.52	1.69	0.15
GPIT-PV-63997	31.6	7.2	8.3	15.9	–	0.23	0.88	0.50	–	–
GPIT-PV-63981	11.5	3.1	2.9	6.4	2.6	0.27	1.07	0.56	1.67	0.09
MB.C.31247.1	31.1	8.6	9.0	15.5	8.1	0.28	0.96	0.50	1.82	0.10

Table 122. Conch ontogeny of *Eocanites delicatus* sp. nov. from Oberrödinghausen.

dm	conch shape	whorl cross section shape	whorl expansion
3 mm	thinly discoidal; evolute (ww/dm ~0.35; uw/dm ~0.55)	moderately depressed; weakly embracing (ww/wh ~1.55; IZR ~0.10)	low (WER ~1.60)
10 mm	extremely discoidal; evolute (ww/dm ~0.30; uw/dm ~0.55)	weakly depressed; weakly embracing (ww/wh ~1.05; IZR ~0.10)	low (WER ~1.60)
30 mm	extremely discoidal; evolute (ww/dm ~0.25; uw/dm ~0.50)	weakly compressed; weakly embracing (ww/wh ~0.95; IZR ~0.10)	moderate (WER ~1.80)

Remarks

The holotype that was illustrated by Vöhringer (1960) under the name *Eocanites supradevonicus* has a much weaker ornament than the specimen of the poor illustration given by Schindewolf (1926b) and is thus not included in that species.

Eocanites delicatus sp. nov. can be distinguished from *E. supradevonicus* by several characteristics. Firstly, the conch of *E. delicatus* is slightly less widely umbilicate (uw/dm ~0.50 in contrast to

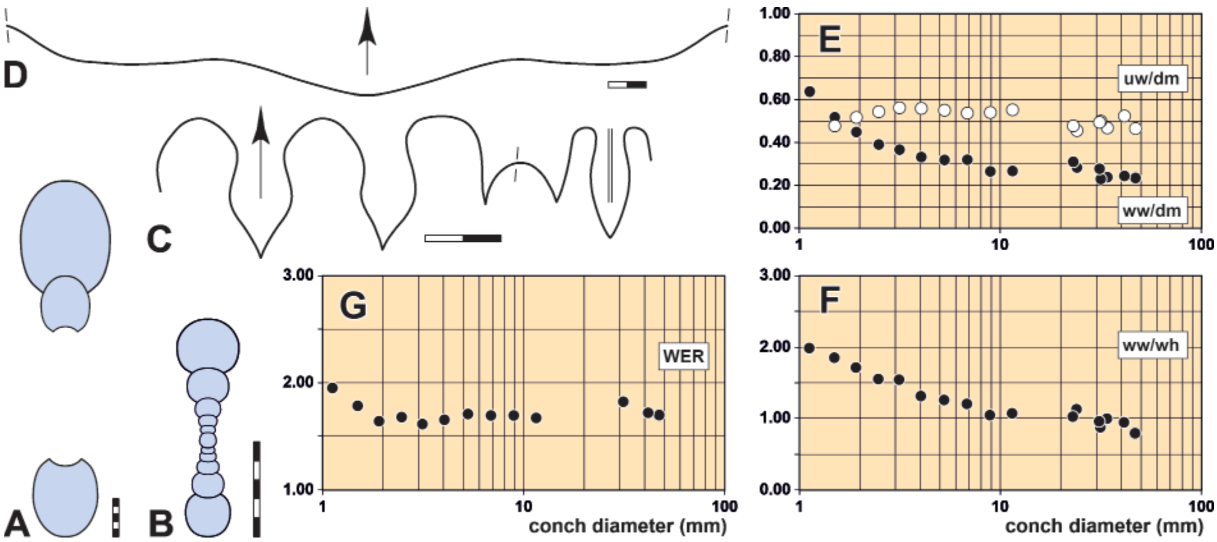

Fig. 126. *Eocanites delicatus* sp. nov. from the Oberrödinghausen railway cutting. **A**. Cross section of paratype GPIT-PV-64008 (Vöhringer Coll.) from bed 2. **B**. Cross section of paratype GPIT-PV-63981 (Vöhringer Coll.) from bed 2. **C**. Suture line of paratype GPIT-PV-63999 (Vöhringer Coll.) from bed 2, at ww = 6.8 mm, wh = 6.5 mm. **D**. Growth line course of paratype GPIT-PV-64008 (Vöhringer Coll.) from bed 1, at dm = 43.0 mm, ww = 11.0 mm, wh = 13.5 mm. **E–G**. Ontogenetic development of the conch width index (ww/dm), umbilical width index (uw/dm), whorl width index (ww/wh) and whorl expansion rate (WER) of selected specimens. Scale bar units = 1 mm.

E. supradevonicus with a value of ~0.55) and secondly, *E. delicatus* shows only very weak folds on the flank, which are developed much stronger in *E. supradevonicus*. *Eocanites delicatus* differs from the similar species *E. brevis* in the shape of the whorl profile, which in *E. delicatus* is still almost circular at 35 mm conch diameter, whereas in *E. brevis* it is already compressed at 10 mm conch diameter (ww/wh ~0.90). *Eocanites planus* and *E. tener* also differ from *E. delicatus* in this respect.

Eocanites planus (Schindewolf, 1926)
Fig. 127; Table 123

Protocanites planus Schindewolf, 1926: 105.

Protocanites planus planus – Vöhringer 1960: 174, pl. 6 fig. 3, text-fig. 49.
Eocanites planus – Korn 1994: 82, text-figs 73f, 74b.

Diagnosis

Species of the genus *Eocanites* with a conch reaching 50 mm diameter. Conch at 30 mm dm subevolute (uw/dm ~0.42) with weakly compressed whorl profile (ww/wh ~0.75) and broadly rounded venter. Ornament with very fine, rursiradiate, concavo-convex growth lines with moderately deep ventral sinus. Without ribs. Suture line with parallel-sided external lobe and lanceolate adventive lobe.

Material examined

Neotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 1; Vöhringer Coll.; illustrated by Vöhringer (1960: pl. 6 fig. 3) and Korn (1994: text-fig. 73f); re-illustrated here in Fig. 127A; GPIT-PV-64009.

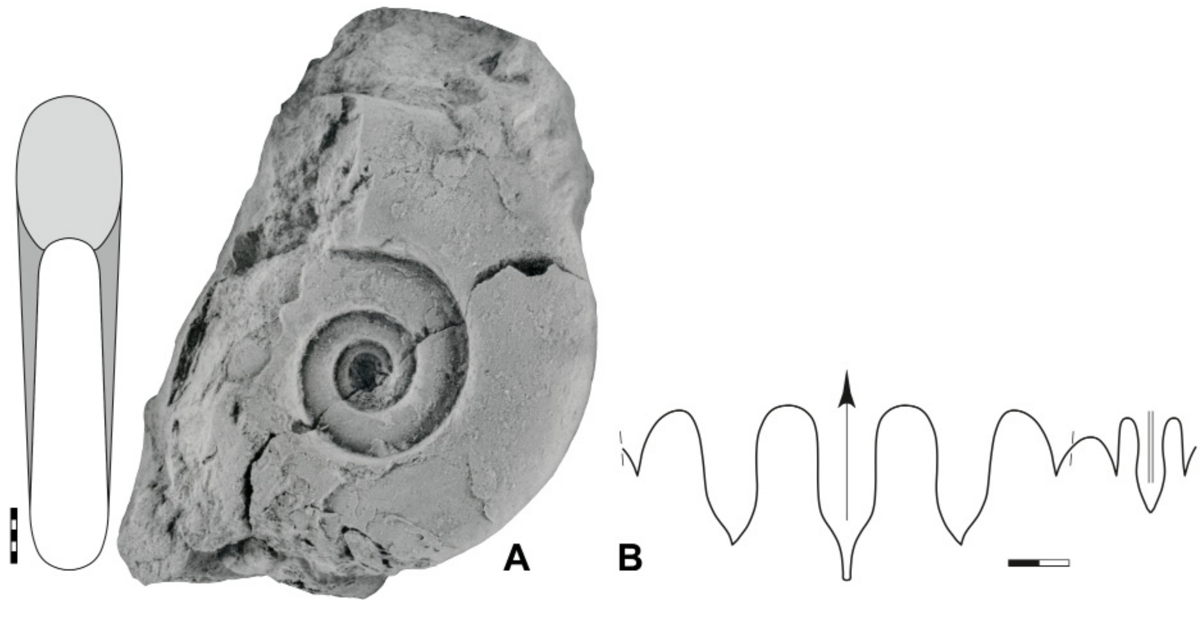

Fig. 127. *Eocanites planus* (Schindewolf, 1926) from the Oberrödinghausen railway cutting. **A**. Lateral view and dorsal reconstruction of neotype GPIT-PV-64009 (Vöhringer Coll.) from bed 1. **B**. Suture line of specimen GPIT-PV-63990 (Vöhringer Coll.) from an unknown bed, at ww = 6.2 mm, wh = 7.0 mm. Scale bar units = 1 mm.

Table 123. Conch measurements, ratios and rates (partly reconstructed) of *Eocanites planus* (Schindewolf, 1926).

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
GPIT-PV-64009	39.7	9.1	13.0	17.1	11.9	0.23	0.70	0.43	2.04	0.09
GPIT-PV-64009	27.8	6.8	9.7	12.2	–	0.25	0.71	0.44	–	–

Additional material

GERMANY • 1 specimen; Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, loose material; Vöhringer Coll.; GPIT-PV-63990.

Description

Neotype GPIT-PV-64009 is a shell-covered specimen of 40 mm conch diameter embedded in a limestone block (Fig. 127A). The conch is extremely discoidal and subevolute (ww/dm = 0.23; uw/dm = 0.43) with a compressed oval whorl profile (ww/wh = 0.70) and a high coiling rate (WER = 2.04). The shell surface appears to be smooth.

The suture line of specimen GPIT-PV-63990 shows a parallel-walled external lobe, a symmetrically rounded ventrolateral saddle and a lanceolate adventive lobe with parallel flanks (Fig. 127B).

Remarks

A type specimen was not selected when Schindewolf (1926b) described the species *Eocanites planus*; obviously no later author has determined a lectotype. In his monograph, Vöhringer (1960) also did not give any information on a type of the species. For this reason, a neotype from the Vöhringer Collection from the type locality is proposed here.

Eocanites planus differs from the other species of the genus from Central Europe in the narrower umbilicus and the higher coiling rate (WER exceeding 2.05); the uw/dm ratio is less than 0.45 in *E. planus* but 0.50 or more and the whorl expansion rate is below 2.00 in the other species.

Genus ***Nomismocanites*** gen. nov.

urn:lsid:zoobank.org:act:B644E02C-31E3-4979-B300-4AC631D7D8FD

Etymology

Combination of the genus names *Nomismoceras* and *Eocanites* because of its coin-shaped conch morphology.

Type species

Nomismocanites raritas gen. et sp. nov.

Diagnosis

Genus of the Subfamily Prolecanitinae with coin-shaped conch with high whorl overlap zone. Ornament with strongly concavo-convex, rectiradiate growth lines.

Remarks

Nomismocanites gen. nov. differs from all other Early Tournaisian prolecanitid ammonoids in the extremely discoidal conch and the relative high whorl overlap rate (IZR about 0.30 in *Nomismocanites* but 0.05 to 0.15 in species of *Eocanites*, for instance). Only *Kahlacanites* Ebbighausen, Bockwinkel, Korn & Weyer 2004 has a similar overlap rate but this genus differs in the much wider whorl profile.

Nomismocanites raritas gen. et sp. nov.
urn:lsid:zoobank.org:act:4A1A2F0D-59CF-4F75-97CD-8F2ED1381525
Fig. 128; Table 124

Etymology

From the Latin '*raritas*' = 'rarity', as only one specimen has been found so far.

Material examined

Holotype

GERMANY • Rhenish Mountains, Oberrödinghausen, railway cutting; Hangenberg Limestone, bed 3d1b; Weyer 1993–1994 Coll.; illustrated in Fig. 128; MB.C.31253.

Diagnosis

Species of the genus *Nomismocanites* gen. nov. with a conch reaching 25 mm diameter. Conch at 15 mm dm extremely discoidal and evolute (uw/dm ~0.55) with weakly compressed whorl profile (ww/wh ~0.90) and rounded venter. Ornament with lamellar, rectiradiate, concavo-convex growth lines with deep ventral sinus. With low, rounded crescent-shaped ventrolateral notches in the shell.

Description

Holotype MB.C.31253 has nearly 19 mm conch diameter and is rather well-preserved (Fig. 128). It is extremely discoidal (ww/dm = 0.22) and evolute (uw/dm = 0.49); during the last half volution, the uw/dm ratio decreases from 0.54 to 0.49. The flanks are subparallel, weakly convergent and flattened but the whorl profile changes on the last half volution; here it shows a weak depression in the outer flank area. The venter is slightly flattened, hence the conch shape reminds on a thick coin. The coiling rate is low (WER = 1.65) and the whorl overlap is rather high (IZR = 0.29) when compared with other prolecanitid ammonoids.

The shell ornament consists of lamellar concavo-convex growth-lines with a semicircular dorsolateral sinus, a moderately prominent ventrolateral projection and a deep ventral sinus. On the last 60 degrees segment, there are weak radial depressions visible on the outer flank in the area of the ventrolateral projection of the growth lines, whose course they follow.

The suture line is not visible in the specimen.

Fig. 128. *Nomismocanites raritas* sp. nov., holotype MB.C.31253 (Weyer 1993–1994 Coll.) from the Oberrödinghausen railway cutting, bed 3d1. Scale bar units = 1 mm.

Table 124. Conch measurements, ratios and rates of *Nomismocanites raritas* gen. et sp. nov.

specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.31253	18.8	4.1	5.9	9.3	4.2	0.22	0.69	0.49	1.65	0.29
MB.C.31253	14.7	3.2	3.4	8.0	–	0.22	0.92	0.54	–	–

Discussion

The railway cutting near Oberrödinghausen at the northern margin of the Rhenish Mountains is the cardinal section for the Early Tournaisian (Early Carboniferous; Mississippian) ammonoid succession. Although ammonoids from this outcrop had already been described monographically (Vöhringer 1960; Korn 1994), it has become apparent that new collections expand the species and genus spectrum of the assemblages and that nearly twenty new species have to be added. This high diversity is astonishing, as it occurs almost immediately after the Hangenberg Event, one of the major mass extinctions in Earth history.

For the revision of the ammonoids from this and neighbouring outcrops, the historical collections were used as well as so far undescribed new material. The ammonoid assemblages are composed of a total of 67 species, which occur in four successive ammonoid zones (*Acutimitoceras ucatum* sp. nov., *Paprothites dorsoplanus*, *Pseudarietites westfalicus*, *Eocanites delicatus* zones). The assemblages are composed of predominant prionoceratids (Order Goniatitina) with the twenty genera *Mimimitoceras* (two species), *Globimitoceras* (one species), *Paragattendorfia* (two species), *Kornia* (three species), *Stockumites* (eleven species), *Acutimitoceras* (two species), *Costimitoceras* (one species), *Nicimitoceras* (four species), *Imitoceras* (one species), *Voehringerites* (one species), *Gattendorfia* (eight species), *Zadelsdorfia* (two species), *Kazakhstania* (one species), *Gattenpleura* (one species), *Weyerella* (three species), *Hasselbachia* (three species), *Paprothites* (five species), *Pseudarietites* (three species), *Rodingites* gen. nov. (two species), *Paralytoceras* (one species) as well as subordinate eocanitids (Order Prolecanitida) with the genera *Eocanites* (eight species) and *Nomismocanites* gen. nov. (one species).

The new genera *Rodingites* gen. nov. and *Nomismocanites* gen. nov. as well as the new species *Mimimitoceras perditum* sp. nov., *Kornia fibula* sp. nov., *Kornia acia* sp. nov., *Stockumites parallelus* sp. nov., *Stockumites voehringeri* sp. nov., *Acutimitoceras ucatum* sp. nov., *Acutimitoceras paracutum* sp. nov., *Imitoceras initium* sp. nov., *Gattendorfia rhenana* sp. nov., *Gattendorfia bella* sp. nov., *Gattendorfia valdevoluta* sp. nov., *Gattendorfia schmidti* sp. nov., *Gattendorfia corpulenta* sp. nov., *Gattendorfia immodica* sp. nov., *Zadelsdorfia oblita* sp. nov., *Weyerella lenis* sp. nov., *Hasselbachia erronea* sp. nov., *Paprothites beckeri* sp. nov., *Paprothites kullmanni* sp. nov., and *Eocanites delicatus* sp. nov. and *Nomismocanites raritas* gen. et sp. nov. are described from Oberrödinghausen. *Mimimitoceras mina* sp. nov., *Stockumites marocensis* sp. nov., *Zadelsdorfia zana* sp. nov. and *Kazakhstania kana* sp. nov. are newly named for material from the Anti-Atlas of Morocco.

A total of 67 ammonoid species are now known from the *Gattendorfia* limestone of Oberrödinghausen. This means that the number of species has increased by about 50 % since the work by Vöhringer (1960). In view of this development, the question naturally arises to what extent future additional collections could further increase this number of species. In answering this, it must be borne in mind that several of the species are represented by only one or a few specimens. In addition, it must be taken into account that many of the species have a rather large morphological distance to each other; intermediate forms are therefore to be expected.

The high number of species in the less than 1.50 m thick Hangenberg Limestone of Oberrödinghausen is certainly also due to the fact that this rock formation has been studied as intensively as few others. In view of the outcrop conditions, new collections comparable to those of Vöhringer and Weyer are no longer possible. It is therefore to be expected that the diversity will not increase significantly.

The rather large number of more than 900 ammonoid specimens examined could tempt one to consider the Hangenberg Limestone as fossil-rich. However, this is not the case; only a few beds yielded larger quantities of ammonoids; several of the thicker beds (e.g., beds 6, 4, 1) are in fact rather fossil-poor. This fact is important when considering the possibilities of ammonoid stratigraphy at the Devonian–Carboniferous boundary: the rarity of the index fossils hardly allows ammonoids to be considered as an important group of organisms for this boundary. This is all the more true since other, even neighbouring, time-equivalent sections yield considerably fewer fossils than the Oberrödinghausen section.

Acknowledgements

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Appendix (continued on next four pages)

The specimens used by Vöhringer (1960) in his monograph with new identifications and catalogue numbers.

Vöhringer (1960)	**This paper**	**Previous number**	**New number**
Imitoceras trochiforme	*Nicimitoceras trochiforme*	GPIT 1130/1	GPIT-PV-63848
Imitoceras trochiforme	*Stockumites voehringeri*	GPIT 1130/2	GPIT-PV-63850
Imitoceras trochiforme	*Nicimitoceras trochiforme*	GPIT 1130/3	GPIT-PV-63849
Imitoceras trochiforme	*Stockumites voehringeri*	GPIT 1130/4	GPIT-PV-63851
Imitoceras subacre	*Nicimitoceras subacre*	GPIT 1130/5	GPIT-PV-63854
Imitoceras subacre	*Nicimitoceras subacre*	GPIT 1130/6	GPIT-PV-63853
Imitoceras subacre	*Nicimitoceras subacre*	GPIT 1130/7	GPIT-PV-63852
Imitoceras subacre	*Nicimitoceras subacre*	GPIT 1130/8	GPIT-PV-63855
Imitoceras acre	*Nicimitoceras acre*	GPIT 1130/9	GPIT-PV-63856
Imitoceras acre	*Nicimitoceras acre*	GPIT 1130/10	GPIT-PV-63857
Imitoceras acre	*Nicimitoceras acre*	GPIT 1130/11	GPIT-PV-63858
Imitoceras acre	*Nicimitoceras acre*	GPIT 1130/12	GPIT-PV-63859
Imitoceras varicosum	*Mimimitoceras perditum*	GPIT 1130/13	GPIT-PV-63873
Imitoceras varicosum	*Mimimitoceras perditum*	GPIT 1130/14	GPIT-PV-63861
Imitoceras varicosum	*Mimimitoceras perditum*	GPIT 1130/15	GPIT-PV-63863
Imitoceras varicosum	*Mimimitoceras perditum*	GPIT 1130/16	GPIT-PV-63864
Imitoceras varicosum	*Mimimitoceras perditum*	GPIT 1130/17	GPIT-PV-63862
Imitoceras liratum liratum	*Mimimitoceras hoennense*	GPIT 1130/18	GPIT-PV-63884
Imitoceras liratum liratum	*Mimimitoceras hoennense*	GPIT 1130/19	GPIT-PV-63866
Imitoceras liratum liratum	*Mimimitoceras hoennense*	GPIT 1130/20	GPIT-PV-63867
Imitoceras liratum exile	*Stockumites exilis*	GPIT 1130/21	GPIT-PV-63868
Imitoceras liratum exile	*Stockumites exilis*	GPIT 1130/22	GPIT-PV-63870
Imitoceras liratum exile	*Stockumites exilis*	GPIT 1130/23	GPIT-PV-64018
Imitoceras liratum exile	*Stockumites exilis*	GPIT 1130/24	GPIT-PV-64021
Imitoceras liratum exile	*Stockumites exilis*	GPIT 1130/25	GPIT-PV-63933
Imitoceras liratum simile	*Stockumites similis*	GPIT 1130/26	GPIT-PV-63894
Imitoceras liratum simile	*Stockumites similis*	GPIT 1130/27	GPIT-PV-63874
Imitoceras liratum simile	*Stockumites similis*	GPIT 1130/28	GPIT-PV-63876
Imitoceras liratum simile	*Stockumites similis*	GPIT 1130/29	GPIT-PV-63878
Imitoceras substriatum	*Stockumites kleinerae*	GPIT 1130/30	GPIT-PV-63880
Imitoceras substriatum	*Stockumites kleinerae*	GPIT 1130/31	GPIT-PV-63871
Imitoceras depressum	*Stockumites depressus*	GPIT 1130/32	GPIT-PV-63872
Imitoceras depressum	*Stockumites depressus*	GPIT 1130/33	GPIT-PV-63886
Imitoceras depressum	*Stockumites depressus*	GPIT 1130/34	GPIT-PV-63889
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/35	GPIT-PV-63891
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/36	GPIT-PV-63892
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/37	GPIT-PV-63860
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/38	GPIT-PV-63875
Imitoceras undulatum	*Stockumites undulatus*	GPIT 1130/39	GPIT-PV-63877
Imitoceras undulatum	*Stockumites undulatus*	GPIT 1130/40	GPIT-PV-64022
Imitoceras undulatum	*Stockumites undulatus*	GPIT 1130/41	GPIT-PV-63881

Appendix (continued)

The specimens used by Vöhringer (1960) in his monograph with new identifications and catalogue numbers.

Vöhringer (1960)	This paper	Previous number	New number
Imitoceras subbilobatum	*Stockumites voehringeri*	GPIT 1130/42	GPIT-PV-63883
Imitoceras subbilobatum	*Stockumites voehringeri*	GPIT 1130/43	GPIT-PV-63885
Imitoceras subbilobatum	*Stockumites voehringeri*	GPIT 1130/44	GPIT-PV-63888
Imitoceras subbilobatum	*Stockumites parallelus*	GPIT 1130/45	GPIT-PV-63890
Imitoceras heterolobatum	*Nicimitoceras heterolobatum*	GPIT 1130/46	GPIT-PV-63893
Imitoceras heterolobatum	*Nicimitoceras heterolobatum*	GPIT 1130/47	GPIT-PV-63895
Imitoceras heterolobatum	*Nicimitoceras heterolobatum*	GPIT 1130/48	GPIT-PV-63869
Imitoceras heterolobatum	*Nicimitoceras heterolobatum*	GPIT 1130/49	GPIT-PV-63897
Imitoceras heterolobatum	*Nicimitoceras heterolobatum*	GPIT 1130/50	GPIT-PV-63898
Imitoceras acutum	*Acutimitoceras ucatum*	GPIT 1130/51	GPIT-PV-63899
Imitoceras acutum	*Acutimitoceras ucatum*	GPIT 1130/52	GPIT-PV-63900
Imitoceras acutum	*Acutimitoceras ucatum*	GPIT 1130/53	GPIT-PV-63901
Imitoceras acutum	*Acutimitoceras ucatum*	GPIT 1130/54	GPIT-PV-63902
Imitoceras prorsum convexum	*Stockumites convexus*	GPIT 1130/55	GPIT-PV-63903
Imitoceras prorsum convexum	*Stockumites convexus*	GPIT 1130/56	GPIT-PV-63904
Imitoceras prorsum convexum	*Stockumites convexus*	GPIT 1130/57	GPIT-PV-63905
Imitoceras prorsum convexum	*Stockumites convexus*	GPIT 1130/58	GPIT-PV-63906
Imitoceras prorsum antecedens	*Stockumites antecedens*	GPIT 1130/59	GPIT-PV-63907
Imitoceras prorsum antecedens	*Stockumites antecedens*	GPIT 1130/60	GPIT-PV-63908
Imitoceras prorsum antecedens	*Stockumites antecedens*	GPIT 1130/61	GPIT-PV-63910
Imitoceras multisulcatum	*Hasselbachia multisulcata*	GPIT 1130/62	GPIT-PV-63911
Imitoceras multisulcatum	*Hasselbachia multisulcata*	GPIT 1130/63	GPIT-PV-63913
Imitoceras multisulcatum	*Hasselbachia multisulcata*	GPIT 1130/64	GPIT-PV-63915
Imitoceras multisulcatum	*Hasselbachia multisulcata*	GPIT 1130/65	GPIT-PV-63949
Imitoceras gracile	*Hasselbachia gracilis*	GPIT 1130/66	GPIT-PV-63917
Imitoceras gracile	*Hasselbachia gracilis*	GPIT 1130/67	GPIT-PV-63919
Imitoceras sphaeroidale	*Kornia sphaeroidalis*	GPIT 1130/68	GPIT-PV-63865
Imitoceras sphaeroidale	*Kornia sphaeroidalis*	GPIT 1130/69	GPIT-PV-63948
Imitoceras sphaeroidale	*Hasselbachia erronea*	GPIT 1130/70	GPIT-PV-63932
Imitoceras sphaeroidale	*Hasselbachia erronea*	GPIT 1130/71	GPIT-PV-63927
Imitoceras globiforme	*Globimitoceras globiforme*	GPIT 1130/72	GPIT-PV-63925
Imitoceras globiforme	*Globimitoceras globiforme*	GPIT 1130/73	GPIT-PV-63921
Imitoceras globiforme	*Globimitoceras globiforme*	GPIT 1130/74	GPIT-PV-63923
Imitoceras globiforme	*Globimitoceras globiforme*	GPIT 1130/75	GPIT-PV-63934
Imitoceras globosum	*Paragattendorfia sphaeroides*	GPIT 1130/76	GPIT-PV-63909
Imitoceras globosum	*Paragattendorfia sphaeroides*	GPIT 1130/77	GPIT-PV-63937
Imitoceras patens	*Paragattendorfia patens*	GPIT 1130/78	GPIT-PV-63912
Imitoceras patens	*Paragattendorfia patens*	GPIT 1130/79	GPIT-PV-63914
Imitoceras patens	*Paragattendorfia patens*	GPIT 1130/80	GPIT-PV-63916
Costimitoceras ornatum	*Costimitoceras ornatum*	GPIT 1130/81	GPIT-PV-63918
Costimitoceras ornatum	*Costimitoceras ornatum*	GPIT 1130/82	GPIT-PV-63920

Appendix (continued)

The specimens used by Vöhringer (1960) in his monograph with new identifications and catalogue numbers.

Vöhringer (1960)	This paper	Previous number	New number
Costimitoceras ornatum	*Costimitoceras ornatum*	GPIT 1130/83	GPIT-PV-63922
Gattendorfia subinvoluta	*Gattendorfia rhenana*	GPIT 1130/84	GPIT-PV-63939
Gattendorfia subinvoluta	*Gattendorfia rhenana*	GPIT 1130/85	GPIT-PV-63940
Gattendorfia subinvoluta	*Gattendorfia rhenana*	GPIT 1130/86	GPIT-PV-63946
Gattendorfia costata	*Gattendorfia costata*	GPIT 1130/87	GPIT-PV-63941
Gattendorfia costata	*Gattendorfia corpulenta*	GPIT 1130/88	GPIT-PV-63950
Gattendorfia costata	*Gattendorfia corpulenta*	GPIT 1130/89	GPIT-PV-63896
Gattendorfia costata	*Gattendorfia corpulenta*	GPIT 1130/90	GPIT-PV-63936
Gattendorfia tenuis	*Gattendorfia schmidti*	GPIT 1130/91	GPIT-PV-63952
Gattendorfia tenuis	*Gattendorfia schmidti*	GPIT 1130/92	GPIT-PV-63951
Gattendorfia tenuis	*Gattendorfia bella*	GPIT 1130/93	GPIT-PV-63942
Gattendorfia tenuis	*Gattendorfia schmidti*	GPIT 1130/94	GPIT-PV-63882
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/95	GPIT-PV-63924
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/96	GPIT-PV-63954
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/97	GPIT-PV-63953
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/98	GPIT-PV-63955
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/99	GPIT-PV-63947
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/100	GPIT-PV-63956
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/101	GPIT-PV-63945
Gattendorfia reticulum	*Weyerella reticulum*	GPIT 1130/102	GPIT-PV-63974
Gattendorfia reticulum	*Weyerella reticulum*	GPIT 1130/103	GPIT-PV-63975
Gattendorfia reticulum	*Weyerella reticulum*	GPIT 1130/104	GPIT-PV-63976
Gattendorfia reticulum	*Weyerella reticulum*	GPIT 1130/105	GPIT-PV-63979
Gattendorfia concava	*Gattenpleura concava*	GPIT 1130/106	GPIT-PV-63926
Gattendorfia concava	*Gattenpleura concava*	GPIT 1130/107	GPIT-PV-64020
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/108	GPIT-PV-63930
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/109	GPIT-PV-64003
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/110	GPIT-PV-63960
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/111	GPIT-PV-63961
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/112	GPIT-PV-63929
Gattendorfia evoluta	*Kazakhstania evoluta*	GPIT 1130/113	GPIT-PV-63963
Gattendorfia evoluta	*Kazakhstania evoluta*	GPIT 1130/114	GPIT-PV-63965
Pseuaarietites dorsoplanus dorsoplanus	*Paprothites dorsoplanus*	GPIT 1130/115	GPIT-PV-63967
Pseuaarietites dorsoplanus dorsoplanus	*Paprothites dorsoplanus*	GPIT 1130/116	GPIT-PV-63969
Pseuaarietites dorsoplanus dorsoplanus	*Paprothites dorsoplanus*	GPIT 1130/117	GPIT-PV-63971
Pseuaarietites dorsoplanus raricostatus	*Paprothites raricostatus*	GPIT 1130/118	GPIT-PV-63973
Pseudarietites westfalicus westfalicus	*Pseudarietites westfalicus*	GPIT 1130/119	GPIT-PV-63978
Pseudarietites westfalicus westfalicus	*Pseudarietites westfalicus*	GPIT 1130/120	GPIT-PV-63980
Pseudarietites westfalicus westfalicus	*Pseudarietites westfalicus*	GPIT 1130/121	GPIT-PV-63982
Pseudarietites westfalicus subtilis	*Pseudarietites subtilis*	GPIT 1130/122	GPIT-PV-63984

Appendix (continued)

The specimens used by Vöhringer (1960) in his monograph with new identifications and catalogue numbers.

Vöhringer (1960)	This paper	Previous number	New number
Pseudarietites westfalicus subtilis	*Pseudarietites subtilis*	GPIT 1130/123	GPIT-PV-63986
Pseudarietites westfalicus subtilis	*Pseudarietites subtilis*	GPIT 1130/124	GPIT-PV-63959
Pseudarietites planissimus	*Rodingites planissimus*	GPIT 1130/125	GPIT-PV-63962
Pseudarierites serratus	*Pseudarierites serratus*	GPIT 1130/126	GPIT-PV-63964
Karagandoceras peracutum	*Voehringerites peracutus*	GPIT 1130/127	GPIT-PV-63958
Karagandoceras peracutum	*Voehringerites peracutus*	GPIT 1130/128	GPIT-PV-63966
Protocanites nodosus	*Eocanites nodosus*	GPIT 1130/129	GPIT-PV-63968
Protocanites nodosus	*Eocanites ruani*	GPIT 1130/130	GPIT-PV-63970
Protocanites nodosus	*Eocanites nodosus*	GPIT 1130/131	GPIT-PV-63972
Protocanites carinatus	*Rodingites carinatus*	GPIT 1130/132	GPIT-PV-64011
Protocanites supradevonicus supradevonicus	*Eocanites delicatus*	GPIT 1130/133	GPIT-PV-64008
Protocanites supradevonicus supradevonicus	*Eocanites delicatus*	GPIT 1130/134	GPIT-PV-63981
Protocanites supradevonicus brevis	*Eocanites brevis*	GPIT 1130/135	GPIT-PV-63985
Protocanites supradevonicus brevis	*Eocanites brevis*	GPIT 1130/136	GPIT-PV-63983
Protocanites supradevonicus brevis	*Eocanites brevis*	GPIT 1130/137	GPIT-PV-63987
Protocanites planus planus	*Eocanites planus*	GPIT 1130/138	GPIT-PV-64009
Protocanites planus tener	*Eocanites tener*	GPIT 1130/139	GPIT-PV-64006
Protocanites planus tener	*Eocanites tener*	GPIT 1130/140	GPIT-PV-63994
Protocanites spiratissumus	*Eocanites spiratissumus*	GPIT 1130/141	GPIT-PV-64007
Protocanites spiratissumus	*Eocanites spiratissumus*	GPIT 1130/142	GPIT-PV-64012
Protocanites spiratissumus	*Eocanites spiratissumus*	GPIT 1130/143	GPIT-PV-64010
Imitoceras substriatum	*Stockumites kleinerae*	GPIT 1130/150	GPIT-PV-64004
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/151	GPIT-PV-64015
Imitoceras subbilobatum	*Stockumites voehringeri*	GPIT 1130/152	GPIT-PV-63995
Imitoceras subbilobatum	*Stockumites voehringeri*	GPIT 1130/153	GPIT-PV-64005
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/154	GPIT-PV-63993
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/155	GPIT-PV-64002
Imitoceras substriatum	*Stockumites kleinerae*	GPIT 1130/156	GPIT-PV-64014
Protocanites nodosus	*Eocanites ruani*	GPIT 1130/157	GPIT-PV-64001
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/158	GPIT-PV-63957
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/159	GPIT-PV-63928
Gattendorfia molaris	*Weyerella molaris*	GPIT 1130/160	GPIT-PV-63931
Protocanites supradevonicus supradevonicus	*Eocanites delicatus*	GPIT 1130/161	GPIT-PV-63997
Imitoceras depressum	*Stockumites voehringeri*	GPIT 1130/162	GPIT-PV-63988
Imitoceras substriatum	*Stockumites kleinerae*	GPIT 1130/163	GPIT-PV-64016
Imitoceras intermedium	*Stockumites intermedius*	GPIT 1130/164	GPIT-PV-64000
Imitoceras trochiforme	*Nicimitoceras trochiforme*	GPIT 1130/165a	GPIT-PV-63992
Imitoceras heterolobatum	*Nicimitoceras heterolobatum*	GPIT 1130/165b	GPIT-PV-63977
Imitoceras undulatum	*Stockumites undulatus*	GPIT 1130/167	GPIT-PV-63879
Imitoceras multisulcatum	*Hasselbachia multisulcata*	GPIT 1130/168	GPIT-PV-64017

Appendix (continued)

The specimens used by Vöhringer (1960) in his monograph with new identifications and catalogue numbers.

Vöhringer (1960)	**This paper**	**Previous number**	**New number**
Imitoceras multisulcatum	*Hasselbachia multisulcata*	GPIT 1130/169	GPIT-PV-63938
Imitoceras depressum	*Stockumites depressus*	GPIT 1130/170	GPIT-PV-63887
Imitoceras globosum	*Paragattendorfia sphaeroides*	GPIT 1130/171	GPIT-PV-63935
Imitoceras globiforme	*Globimitoceras globiforme*	GPIT 1130/172	GPIT-PV-63998
Imitoceras varicosum	*Mimimitoceras perditum*	GPIT 1130/173	GPIT-PV-64013
Imitoceras liratum exile	*Stockumites exilis*	GPIT 1130/174	GPIT-PV-64019
Gattendorfia tenuis	*Gattendorfia bella*	GPIT 1130/175	GPIT-PV-63989
Gattendorfia tenuis	*Gattendorfia valdevoluta*	GPIT 1130/176	GPIT-PV-63996
Gattendorfia crassa	*Zadelsdorfia crassa*	GPIT 1130/177	GPIT-PV-63944
Gattendorfia reticulum	*Weyerella reticulum*	GPIT 1130/178	GPIT-PV-63991
Protocanites planus planus	*Eocanites planus*	GPIT 1130/180	GPIT-PV-63990
Protocanites supradevonicus supradevonicus	*Eocanites delicatus*	GPIT 1130/181	GPIT-PV-63999
Gattendorfia tenuis	*Gattendorfia tenuis*	GPIT 1012/37	GPIT-PV-62426