

## Research article

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## The tornoceratid ammonoids from the Roteisenstein Formation of Dillenburg (Cephalopoda, Ammonoidea)

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**Abstract.** The ammonoids of the suborder Tornoceratina from the Middle to Late Devonian Red Ironstone Formation of the area around Dillenburg (eastern Rhenish Mountains) are revised, mainly based on historical collections stored in the Museum für Naturkunde, Berlin. The species *Tornoceras typus* (Sandberger & Sandberger, 1851), *Tornoceras frechi* Wedekind, 1918 and *Epitornoceras mithracoides* (Frech, 1888) are re-described based on the original material from the Red Ironstone. The new genus *Lentitornoceras* gen. nov. is proposed for the new species *L. materni* gen. et sp. nov.; the new genus *Paucitornoceras* gen. nov. is proposed with the type species *Goniatites paucistriatus*. *Epitornoceras transmediterraneum* sp. nov. is described from the Anti-Atlas of Morocco and compared with *E. mithracoides*.

**Keywords.** Ammonoidea, Middle Devonian, Late Devonian, Rhenish Mountains, taxonomy.

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### Introduction

The Roteisenstein near Dillenburg on the eastern margin of the Rhenish Mountains is one of the longest known formations containing Palaeozoic ammonoids in Central Europe. Fossils from this sedimentary rock were already known to the pioneers of palaeontology; ammonoids from this formation were first described in various papers (von Buch 1832; Beyrich 1837; d'Archiac & de Verneuil 1842; Sandberger & Sandberger 1850–1856). Subsequently, additional species from this formation were described, especially by Frech (1888), Wedekind (1918) and Matern (1931).

Three important clades of ammonoids are represented in the red ironstone of Dillenburg, (1) the suborder Pharciceratina with the genera *Maenioceras* Schindewolf, 1933, *Pharciceras* Hyatt, 1884, *Synpharciceras* Schindewolf, 1940, *Sandbergeroceras* Hyatt, 1884 etc., (2) the suborder Tornoceratina

Wedekind, 1914 with *Tornoceras* Hyatt, 1884, *Lentitornoceras* gen. nov., *Paucitornoceras* gen. nov. and *Epitornoceras* Frech, 1902, and (3) the suborder Gephuroceratina with the genera *Pseudoproboloceras* Bensaïd, 1974, *Beloceras* Hyatt, 1884, *Koenenites* Wedekind, 1913, *Manticoceras* Hyatt, 1884, etc. Of these three suborders, the Pharciceratina and the Gephuroceratina are by far the most important, both in terms of the number of specimens found and the diversity of species. The Tornoceratina are quite rare and only known from five species.

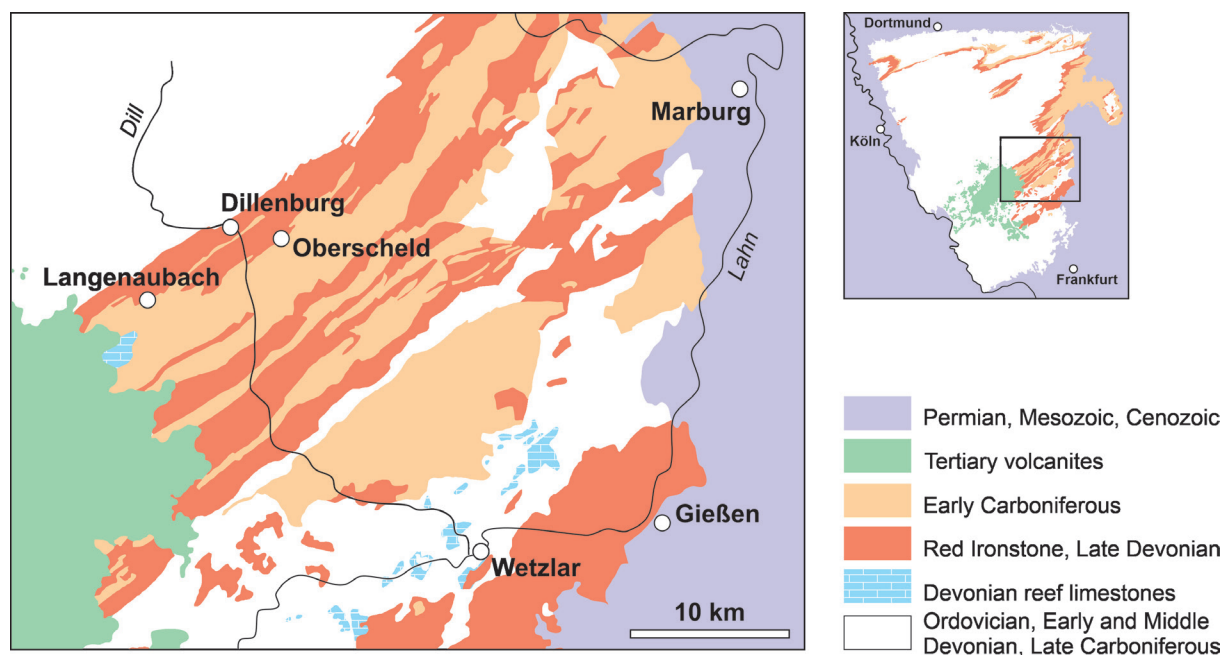
In a recently published monograph (Korn & Bockwinkel 2021), the material of the suborder Pharciceratina from Dillenburg was studied in detail. Here, we present the description of the Tornoceratina from the Roteisenstein of the Dillenburg region. As in the first part, this description is largely based on material repositied in the Museum für Naturkunde, Berlin.

## Material and methods

A total of 14 tornoceratid ammonoid specimens available from Oberscheld at the eastern margin of the Rhenish Mountains (Fig. 1). The specimens are preserved in iron-rich micritic or sparitic limestone or in haematitic ironstone. The shell ornamentation is partly preserved in the specimens.

The tornoceratid material from the Red Ironstone Formation comes from two principal stratigraphic intervals (Fig. 2):

- late Givetian (assemblage with *Pharciceras*, *Pseudoproboloceras*): *Epitornoceras mithracoides* (Frech, 1888) and *Lentitornoceras materni* gen. et sp. nov.
- middle Frasnian (Adorf Limestone; assemblage with *Manticoceras* and *Beloceras*): *Tornoceras typus* (Sandberger & Sandberger, 1851), *Tornoceras frechi* Wedekind, 1918 and *Paucitornoceras paucistriatum* (d'Archiac & de Verneuil, 1842).



**Fig. 1.** The geographic position of the fossil locality of Oberscheld in the Rhenish Mountains.

		“standard zones“	Rhenish Mountains	
L. DEVNIAN	FRASNIAN	<i>Crickites holzapfeli</i>	<i>Crickites holzapfeli</i> , <i>Cr. rickardi</i>	
		<i>Archoceras varicosum</i>	<i>Archoceras varicosum</i>	
		<i>Neomanticoceras paradoxum</i>	<i>N. paradoxum</i> , <i>Mat. sandbergeri</i>	
		<i>Playfordites tripartitus</i>	<i>Playf. tripartitus</i> , <i>C. nodulosum</i>	
		<i>Beloceras tenuistriatum</i>	<i>Beloceras tenuistriatum</i>	★ <i>Tornoceras typus</i>
		<i>Mesobeloceras kayseri</i>	<i>Mesobeloceras kayseri</i>	★ <i>Tornoceras frechi</i>
		<i>Prochorites alveolatus</i>		★ <i>Paucitornoceras paucistriatum</i>
		<i>Probeloceras lutheri</i>		
		<i>Sandbergeroceras syngonum</i>	<i>Sandbergeroceras costatum</i>	
		<i>Timanites keyserlingi</i>	<i>Koenenites lamellosus</i>	
		<i>Koenenites styliophilus</i>		
		<i>Petteroceras feisti</i>	<i>Ponticeras</i> spp.	
		M. DEVONIAN	GIVETIAN	<i>Petteroceras errans</i>
<i>Pseudoproboloceras pernai</i>	<i>Pseudoproboloceras pernai</i>			★ <i>Epitornoceras mithracoides</i>
<i>Synpharciceras clavilobum</i>	<i>Synpharciceras clavilobum</i>			★ <i>Lentitornoceras materni</i>
<i>Stenopharciceras lateseptatum</i>	<i>Stenopharciceras lunulicosta</i>			
<i>Pharciceras amplexum</i>	<i>Pharciceras tridens</i>			
<i>Afromaenioceras sulcastriatum</i>	<i>Afromaenioc. cf. sulcastriatum</i>			
<i>Maenioceras terebratum</i>	<i>Maenioceras terebratum</i>			
<i>Maenioceras molarium</i>				
<i>Maenioceras undulatum</i>	<i>Maenioceras undulatum</i>			

Fig. 2. Givetian and Frasnian ammonoid stratigraphy (after Becker & House 2000), probable extent of the Red Ironstone of Dillenburg and probable position of the ammonoid species described here.

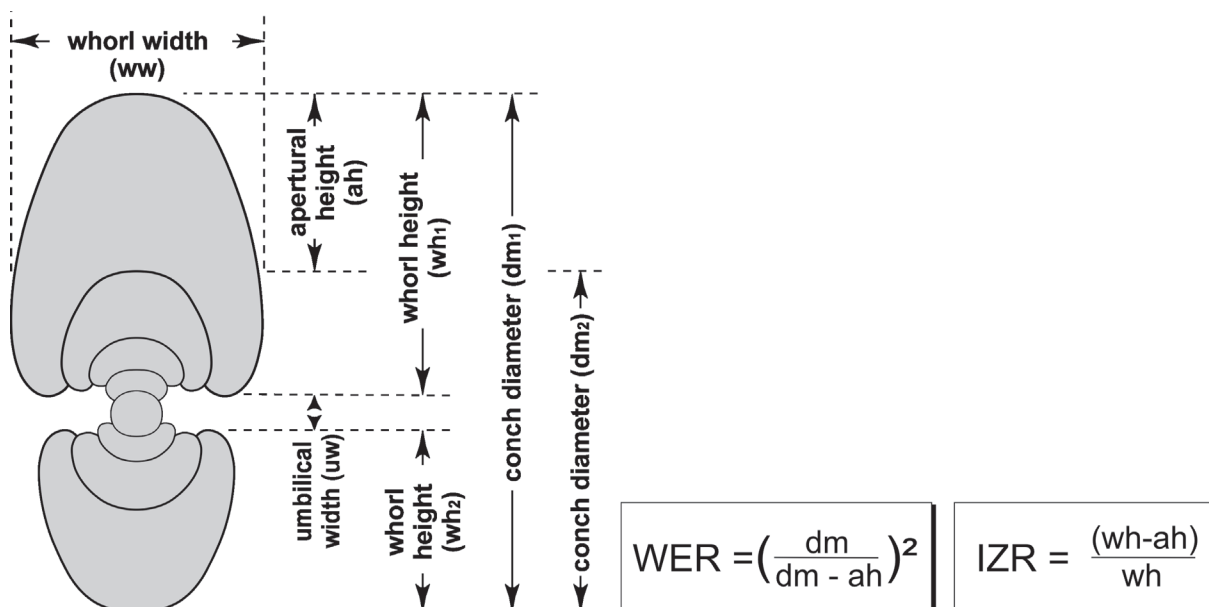


Fig. 3. The morphological terms used in the description of the ammonoid conchs.

Almost all the material consists of isolated specimens without assignment to any stratigraphic scheme. Information on the co-occurrence of taxa could only rarely be obtained from the context of the collections.

We studied the following tornoceratid species (with the number of specimens from the Red Ironstone).

*Tornoceras typus* (Sandberger & Sandberger, 1851) – four specimens

*Tornoceras frechi* Wedekind, 1918 – five specimens

*Epitornoceras mithracoides* (Frech, 1888) – two specimens

*Lentitornoceras materni* gen. et sp. nov. – one specimen

*Paucitornoceras paucistriatum* (d'Archiac & de Verneuil, 1842) – two specimens

The description of the material follows the scheme for Palaeozoic ammonoids outlined by Korn (2010) and Klug *et al.* (2015) (Fig. 3). Most of the specimens are kept in the collection of fossil cephalopods at the Museum für Naturkunde, Berlin (MfN), under catalogue numbers with the praefix 'MB.C.'. The praefix 'SMF.Mbg.' is for the former Marburg collection, which is now kept at the Senckenberg Museum, Frankfurt am Main (SMF).

### Abbreviations

ah	=	apertural height
dm	=	conch diameter
IZR	=	imprint zone rate
MB.C.	=	collection of fossil cephalopods in the Museum für Naturkunde, Berlin (MfN)
SMF.Mbg.	=	former collection of the Marburg University, now Senckenberg Museum, Frankfurt (SMF)
uw	=	umbilical width
WER	=	whorl expansion rate
wh	=	whorl height
ww	=	whorl width

## Results

### Taxonomy

Suborder Tornoceratina Wedekind, 1914  
 Superfamily Tornoceratoidea von Arthaber, 1911  
 Family Tornoceratidae von Arthaber, 1911

Subfamily **Tornoceratinae** von Arthaber, 1911

### Diagnosis

Subfamily of the family Tornoceratidae with compressed conch, umbilicus closed in the pre-adult and adult stage but slightly opened in the juvenile stage. Ventrolateral grooves, if present, in the juvenile stage. Ornament with biconvex growth lines, without ribs. Sutural formula E A L I or E A L<sub>2</sub> L<sub>2</sub> I; adventive lobe broadly rounded, asymmetric with steep dorsal flank.

### Included genera

*Tornoceras* Hyatt, 1884; *Domanikoceras* Becker & House, 1993; *Crassotornoceras* House & Price, 1985; *Lobotornoceras* Schindewolf, 1936; *Linguatornoceras* House, 1965; *Simicheiloceras* Becker, 1993; *Oxytornoceras* Becker, 1993; *Epitornoceras* Frech, 1902; *Lentitornoceras* gen. nov.

Genus *Tornoceras* Hyatt, 1884

**Type species**

*Goniatites uniangularis* Conrad, 1842; by original designation.

**Diagnosis**

Genus of the subfamily Tornoceratinae with compressed conch, umbilicus closed in the pre-adult stage but slightly opened in the juvenile stage. Usually without ventrolateral grooves. Growth lines biconvex, without ribs. Sutural formula E A L I; adventive lobe broadly rounded, asymmetric with steep dorsal flank.

**Included species**

*Tornoceras aequilobum* Söte, Becker, Herd & Bockwinkel, 2021, Rhenish Mountains; *Tornoceras (Tornoceras) uniangulare* var. *aldanense* House, 1965, New York; *Tornoceras (Tornoceras) amuletum* House, 1965, New York; *Tornoceras simplex* Mut. *angustelobata* Holzapfel, 1895, Rhenish Mountains; *Tornoceras (Tornoceras) arcuatum* House, 1965, Michigan; *Tornoceras (Tornoceras) arkonense* House, 1965, Ontario; *Goniatites Astarte* Clarke, 1885, New York; *Tornoceras baldisi* Leanza, 1968, Argentina; *Tornoceras Bertrandi* Frech, 1902, Montagne Noire; *Tornoceras (Tornoceras) bolivianum* Kullmann, 1980, Bolivia; *Tornoceras uniangulare* var. *compressum* Clarke, 1899: 116; New York; *Tornoceras (Tornoceras) concentricum* House, 1965, New York; *Tornoceras (Tornoceras) contractum* Glenister, 1958, Western Australia; *Tornoceras Edwin-Halli* Clarke, 1899, New York; *Tornoceras Frechi* Wedekind, 1918, Rhenish Mountains; *Tornoceras fundibulum* Korn, 2021, Rhenish Mountains; *Linguatornoceras holwilli* House, 2002, Devon; *Goniatites Hughesii* Whidborne, 1890, Devon; *Tornoceras (Tornoceras) iowaense* Miller, 1938, Iowa; *Gomi-monomeroceras (Tornoceras) kielcense* Sobolev, 1914, Holy Cross Mountains; *Tornoceras Lewinskii* Dybczynski, 1913, Holy Cross Mountains; *Tornoceras uniangulare* var. *obesum* Clarke, 1899, New York; *Tornoceras occasus* Korn, 2021, Anti-Atlas; *Tornoceras ortus* Korn, 2021, Anti-Atlas; *Tornoceras postsimplicius* Pajchlowa, 1972; *Tornoceras radialis* Becker, 1993, Rhenish Mountains; *Tornoceras subacutum* Makowski, 1991, Holy Cross Mountains; *Gomi-monomeroceras (Tornoceras) sublentiforme* Sobolev, 1914, Holy Cross Mountains; *Goniatites retrorsus* var. *typus* Sandberger & Sandberger, 1851, Rhenish Mountains; *Goniatites uniangularis* Conrad, 1842, New York; *Tornoceras varicatum* Grüneberg, 1925, Rhenish Mountains; *Tornoceras Verae* Frech, 1902, Montagne Noire; *Tornoceras vretterense* Korn, 2021, Rhenish Mountains; *Tornoceras Whidbornei* Foord & Crick, 1897, Devon; *Tornoceras (Tornoceras) uniangulare* var. *widderi* House 1965, Ontario; *Tornoceras wunderlichi* Bockwinkel & Korn, 2015, Rhenish Mountains;

**Remarks**

*Tornoceras* is a genus that has long been used as a taxon to group together most involute Late Devonian ammonoids with a simple suture line. Even after the revisions by House (1965) and Becker (1993) and their separation of a number of new genera, there is a long list of species assigned to the genus (Korn & Klug 2002). Most of these species are morphologically very similar and a detailed description of the ontogenetic development of the conch is lacking. A revision of the genus would require a careful description of the ontogeny, suture lineage and growth lineage of the material from the different geographical regions and stratigraphic units (Korn 2021a).

*Tornoceras typus* (Sandberger & Sandberger, 1851)

Fig. 4; Table 1

*Goniatites retrorsus* var. *typus* Sandberger & Sandberger, 1851: 109, pl. 10 fig. 14.

*Tornoceras simplex* Mut. *typus* – Holzapfel 1895: 98, text-fig. 6, pl. 6 fig. 11, pl. 7 fig. 9.

*Tornoceras typus* – Korn 2021b: 149, text-figs 2–5, 6a.

*Tornoceras typum* – Becker 1993: 182, pl. 3 figs 1–2. — Korn & Klug 2002: 156, text-fig. 139.

? *Goniatites retrorsus* var. *typus* – Sandberger & Sandberger 1851: pl. 10a figs 3–6, 10–11.

? *Tornoceras simplex* – Foord & Crick 1897: 69, 107, text-figs 25d–f, 48.

? *Tornoceras simplex* mut. *ovata* – Frech 1902b: 47, pl. 3 fig. 21.

non *Tornoceras typum* – Becker 1993: 182, pl. 3 figs 3–4, text-fig. 68a. — Becker *et al.* 2000: pl. 2 figs 7–8. — Korn & Klug 2002: 156, text-fig. 143a–c.

non *Tornoceras simplex* – Frech 1902: 47, pl. 5 fig. 8. — Wedekind 1918: 135, pl. 16 fig. 12, text-fig. 40a.

### Diagnosis

*Tornoceras* reaching about 90 mm conch diameter. Thickly pachyconic, subevolute early juvenile stage (ww/dm ~ 0.80; uw/dm ~ 0.35 at 2 mm dm), thickly discoidal and involute subadult stage (ww/dm ~ 0.58; uw/dm ~ 0.08 at 10 mm dm), thinly discoidal and involute adult stage (ww/dm ~ 0.42; umbilicus closed at 30 mm dm). Whorl profile as wide as high in the subadult stage (ww/wh ~ 1.00 at 10 mm dm) and strongly compressed in the adult stage (ww/wh ~ 0.75 at 30 mm dm); whorl expansion rate very high in the subadult and adult stage (WER = 2.30–2.45). Flanks convex, convergent, umbilical margin continuously rounded. Without any ventrolateral grooves. Suture line with broadly rounded, asymmetric adventive lobe and high ventrolateral saddle.

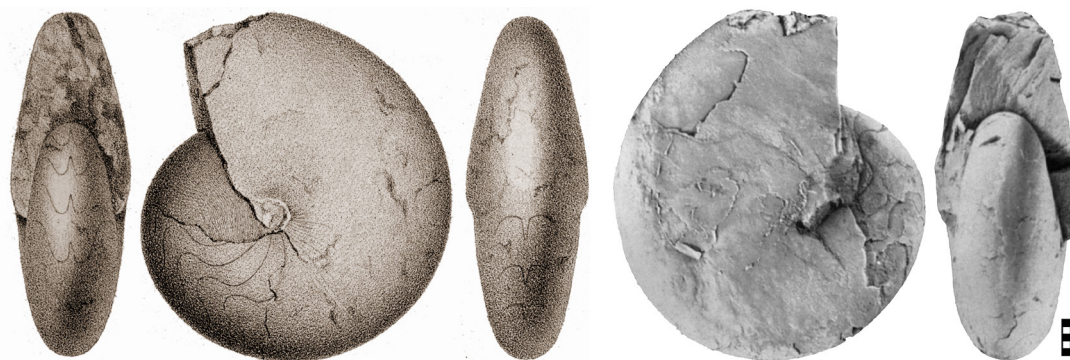
### Type material

#### Lectotype

GERMANY • Rhenish Mountains, Oberscheld; probably middle Frasnian (Adorf Limestone); designated by Becker (1993); figured by Sandberger & Sandberger (1850–1856: pl. 10 fig. 14), Becker (1993: pl. 3 figs 1–3) and Korn (2021b: text-fig. 2), re-illustrated here in Fig. 4; specimen 53a; Wiesbaden Museum.

#### Additional material examined

GERMANY • 1 spec.; Rhenish Mountains, Oberscheld; middle Frasnian (Adorf Limestone); Erbreich Coll.; MB.C.4466 • 1 spec.; Rhenish Mountains, Oberscheld; middle Frasnian (Adorf Limestone); Koch Coll.; MB.C.30409 • 1 spec.; Rhenish Mountains, Dillenburg, Eiserne Hand (Grube Friedrich); middle Frasnian (Adorf Limestone); MB.C.30410.



**Fig. 4.** *Tornoceras typus* (Sandberger & Sandberger, 1851), reproduction of the lectotype illustrations by Sandberger & Sandberger (1850–1856, pl. 10 fig. 14) and the photography by M.R. House in Becker (1993, pl. 3 figs 1–2). Scale bar units = 1 mm.

**Table 1.** Conch dimensions and ratios of *Tornoceras typus* (Sandberger & Sandberger, 1851), lectotype (Wiesbaden 53a).

Specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
Wiesbaden 53a	46.0	18.3	29.7	0.0	15.2	0.40	0.62	0.00	2.23	0.49

## Description

### Lectotype 53a (Wiesbaden Museum)

Fairly well-preserved specimen with 46 mm conch diameter in red limestone; it is largely chambered and the last half volution belongs to the body chamber (Fig. 4). It is a thinly discoidal conch ( $ww/dm = 0.40$ ) with a closed umbilicus. The body chamber is obviously slightly distorted, resulting in a stronger convergence of the flanks (as shown in the original illustration by Sandberger & Sandberger 1850–1856). Parts of the specimen are covered by shell material, which, however, is not well preserved and does not allow a detailed examination of the ornamentation. The suture line has a small, V-shaped outer lobe and a broadly rounded ventrolateral saddle. The adventitious lobe is twice as deep as the outer lobe and as deep as it is wide; it is broadly rounded and slightly asymmetric.

## Remarks

The species has been discussed several times in the literature. A detailed revision and discussion was carried out by Korn (2021b); in this paper both the taxonomic problems and the conch morphology as well as the ontogenetic development are presented on the basis of further material from the Rhenish Mountains.

### *Tornoceras frechi* Wedekind, 1918

Fig. 5; Table 2

*Tornoceras Frechi* Wedekind, 1918: 136, pl. 16 fig. 9, text-fig. 41.

*Phoenixites frechi* – Becker 1993: 198, pl. 6 figs 4–5, text-fig. 73b.

*Tornoceras frechi* – Korn 2021a: 292, text-figs 2–4, 6a.

*Ammonites retrorsus* – Beyrich 1837: 30, pl. 1 figs 10–11.

non *Tornoceras (Tornoceras) frechi* – Petter 1959: 195.

non *Tornoceras (Tornoceras) frechi frechi* – Buggisch & Clausen 1972: 143, pls 1–2, 5.

non *Tornoceras frechi* – Bensaid 1974: 118, pl. 5 figs 4, 4a. — Makowski 1991: 246, text-fig. 2.

non *Phoenixites frechi* – Becker 1993: 198, pl. 5 figs 12–17, pl. 6 figs 1–3, text-fig. 73a, c, g–i. — Belka *et al.* 1999: pl. 5 figs 3–4. — Becker *et al.*, 2000: pl. 3 figs 5–6. — Korn & Klug 2002: 160, text-fig. 146f, i. — Niechwedowicz & Trammer 2007: 66, text-fig. 3a–d.

## Diagnosis

*Tornoceras* reaching about 50 mm conch diameter. Thickly pachyconic, subinvolute early juvenile stage ( $ww/dm \sim 0.75$ ;  $uw/dm \sim 0.28$  at 2 mm dm), thickly discoidal and involute subadult stage ( $ww/dm \sim 0.45$ ;  $uw/dm \sim 0.05$  at 10 mm dm), thinly discoidal and involute adult stage ( $ww/dm \sim 0.35$ ; umbilicus closed at 30 mm dm). Whorl profile weakly compressed in the subadult stage ( $ww/wh \sim 0.75$  at 10 mm dm) and more strongly compressed in the adult stage ( $ww/wh \sim 0.65$  at 30 mm dm); whorl expansion rate very high in the subadult and adult stage ( $WER = 2.25$ – $2.40$ ). Flanks weakly flattened, converging, umbilical margin continuously rounded. Without any ventrolateral grooves.

**Type material****Holotype**

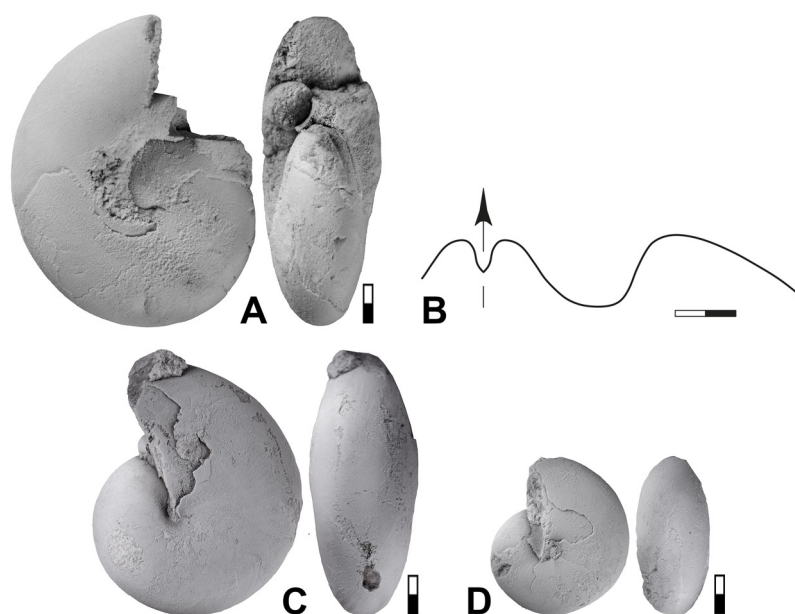
GERMANY • Rhenish Mountains, Martenberg near Adorf; middle Frasnian (Adorf Limestone); illustrated by Wedekind (1918: pl. 16 fig. 9, text-fig. 41) and Korn (2021a: text-fig. 2); SMF.Mbg.2328.

**Additional material**

GERMANY • 1 spec.; Rhenish Mountains, Sessacker near Oberscheld; middle Frasnian (Adorf Limestone); figured by Becker (1993, pl. 6 figs 4–5) and (Korn 2021a, text-fig. 3c), re-illustrated here in Fig. 5; Beyrich Coll.; MB.C.834 • 1 spec.; Rhenish Mountains, Sessacker near Oberscheld; middle Frasnian (Adorf Limestone); illustrated here in Fig. 5; Dannenberg Coll.; MB.C.30411 • 1 spec.; Rhenish Mountains, Sessacker near Oberscheld; middle Frasnian (Adorf Limestone); illustrated here in Fig. 5; MB.C.4490 • 2 specs; Rhenish Mountains, near Oberscheld; middle Frasnian (Adorf Limestone); Lotz 1901–1902 Coll.; MB.C.30412.1–2.

**Description****Specimen MB.C.834 (Fig. 5A)**

Thinly discoidal specimen with 17 mm conch diameter; it has a compressed whorl profile ( $ww/dm = 0.38$ ;  $ww/wh = 0.64$ ). The flanks are convexly curved and converge to the rather narrow, evenly rounded venter. The specimen is fully chambered with few shell remains and shows the suture line characteristic of the genus *Tornoceras* with a broadly rounded, slightly asymmetrical adventive lobe and very small external lobe (Fig. 5B).



**Fig. 5.** *Tornoceras frechi* Wedekind, 1918. **A.** Specimen MB.C.834 (Beyrich Coll.) from Sessacker near Oberscheld. **B.** Suture line of specimen MB.C.834 (Beyrich Coll.); at  $ww = 4.5$  mm,  $wh = 5.5$  mm. **C.** Specimen MB.C.30411 (Dannenberg Coll.) from Sessacker near Oberscheld. **D.** Specimen MB.C.4490 from Sessacker Oberscheld. Scale bar units = 1 mm.



**Table 2.** Conch dimensions and ratios of *Tornoceras frechi* Wedekind, 1918 from the Red Ironstone of Oberscheld.

Specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.834	16.9	6.5	10.2	0.2	6.0	0.38	0.64	0.01	2.38	0.41
MB.C.30411	13.2	5.7	8.1	0.3	4.5	0.43	0.70	0.02	2.30	0.44
MB.C.4490	8.4	3.7	4.8	0.4	2.7	0.44	0.77	0.05	2.17	0.44

**Specimens MB.C.30411 and MB.C.4490** (Fig. 5C–D)

The other two specimens MB.C.30411 (13 mm dm; Fig. 5C) and MB.C.4490 (8.5 mm dm; Fig. 5D) confirm the conch morphology of the former specimen. In both, the shell is well preserved, bearing wide growth lines with high, narrow ventrolateral projection.

**Remarks**

Specimen MB.C.834 is the invalid neotype of the species. The existence of the actual original specimen in the collection of the University of Marburg, which is now preserved at the Senckenberg Museum (Frankfurt a. M.), made the determination of the neotype by Becker (1993) obsolete (Korn 2021a). For a more detailed description of the species, see the latter paper.

Genus *Epitornoceras* Frech, 1902

**Type species**

*Tornoceras (Tornoceras) mithracoides* Frech, 1888; by original designation.

**Diagnosis**

Genus of the subfamily Tornoceratinae with compressed conch, umbilicus closed in the pre-adult stage but slightly opened in the juvenile stage. Usually without ventrolateral grooves. Ornament with biconvex growth lines, without ribs. Sutural formula E A L I; adventive lobe broadly rounded, asymmetric with steep dorsal flank; ventrolateral saddle narrow, subacute.

**Included species**

*Tornoceras (Tornoceras) mithracoides* Frech, 1888, Rhenish Mountains; *Goniatites peracutus* Hall, 1876, New York; *Epitornoceras transmediterraneum* sp. nov., Anti-Atlas.

**Remarks**

*Epitornoceras* differs from the other genera of the subfamily by the very narrow ventrolateral saddle of the suture line.

*Epitornoceras mithracoides* (Frech, 1888)

Figs 6–7; Table 3

*Goniatites (Tornoceras) mithracoides* Frech, 1888: 30, pl. 2 fig. 1.

*Tornoceras (Epitornoceras) mithracoides* – Frech 1902a: 174, text-fig. 2a; 1902b: 52, text-fig. 14b.

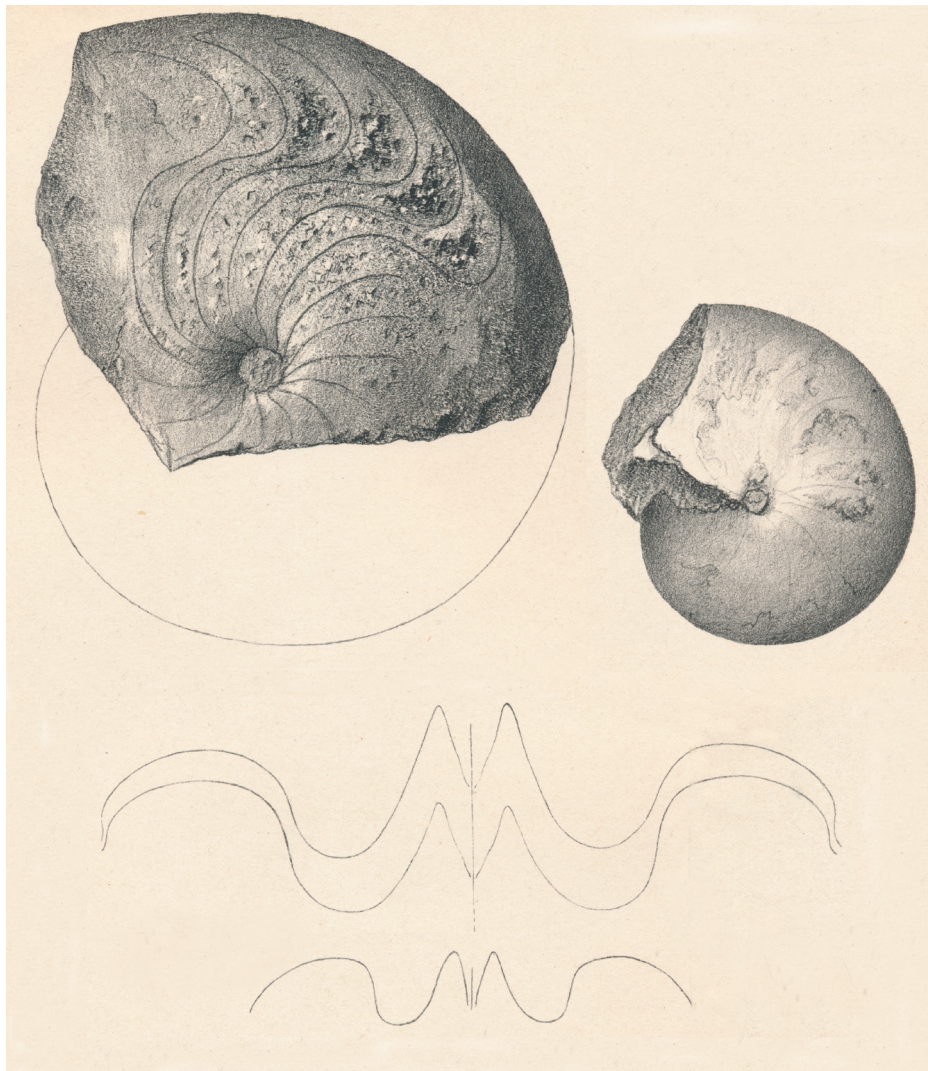
*Goniatites (Tornoceras) mithracoides* – Miller 1938: 141, text-fig. 30d.

*Epitornoceras mithracoides* – House 1978: 60, pl. 10 figs 2–3. — Korn & Klug 2002: 158. — Bockwinkel *et al.* 2013: 268, text-figs 11–12. — Bockwinkel & Korn 2015: 358, text-figs 9–10.

non *Epitornoceras mithracoides* – House *et al.* 1985: 5, text-figs 5a–b. — Dzik 2002: text-fig. 50n–o.  
— Korn & Klug 2002: text-fig. 144t. — Bockwinkel *et al.* 2009: 65, text-figs 1–2; 2013b: 57, text-figs 4d, 58–59; 2015: 148, text-figs 31–32; 2017: 346, text-figs 34–35.

### Diagnosis

*Epitornoceras* reaching about 200 mm conch diameter. Thinly discoidal and involute adult stage (ww/dm ~ 0.35; umbilicus closed at 50 mm dm); whorl profile compressed (ww/wh ~ 0.65 at 50 mm dm); whorl expansion rate high (WER ~ 2.20). Flanks weakly convex, convergent, umbilical margin pronounced in the juvenile stage but continuously rounded in the adult stage. Without any ventrolateral grooves. Suture line with broadly rounded, asymmetric adventive lobe with convergent flanks; width of the adventive lobe equals the lobe depth.



**Fig. 6.** *Epitornoceras mithracoides* (Frech, 1888), reproduction in original size of the illustration of the type material; paralectotype (MB.C.470) and lectotype (MB.C.469) by Frech (1888).

## Type material

### Lectotype

GERMANY • Rhenish Mountains, Oberscheld (Volpertseiche Mine); late Givetian (Red Ironstone); designated by Bockwinkel *et al.* (2009); figured by Frech (1888: text-fig. 1b, 1 $\beta$ ) and House (1978: text-figs 2–3), re-illustrated here in Fig. 7A; Koch Coll.; MB.C.469.

### Paralectotype

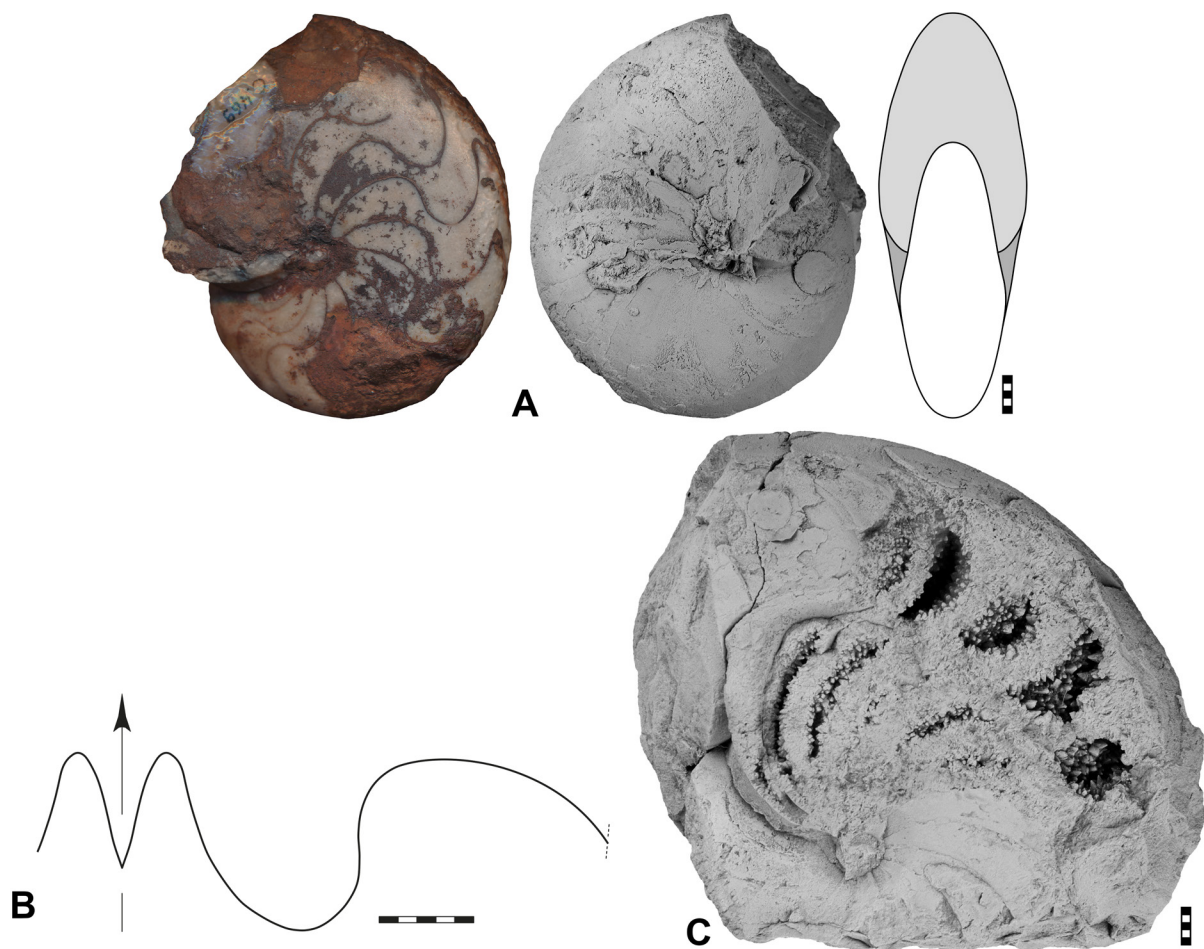
GERMANY • Rhenish Mountains, Oberscheld (Volpertseiche Mine); late Givetian (Red Ironstone); figured by Frech (1888: text-fig. 1a, 1 $\alpha$ ), re-illustrated here in Fig. 7C; Koch Coll.; MB.C.470.

## Description

Two specimens are selected for description and illustration.

### Lectotype (MB.C.469)

Completely chambered specimen with 53 mm conch diameter in haematitic limestone; it represents the inner portion of a phragmocone of a much larger specimen (Figs 6, 7A). It is a disc-shaped involute conch about 53 mm in diameter ( $ww/dm = 0.35$ ). It is widest at the closed umbilicus, from where the



**Fig. 7.** *Epitornoceras mithracoides* (Frech, 1888), specimens from the Volpertseiche Mine near Oberscheld (both Koch Coll.). **A.** Lectotype (MB.C.469). **B.** Suture line of lectotype (MB.C.469); at  $dm = 43.5$  mm;  $ww = 15.0$  mm;  $wh = 25.5$  mm. **C.** Paralectotype (MB.C.470). Scale bar units = 1 mm.

**Table 3.** Conch dimensions and ratios of *Epitornoceras mithracoides* (Frech, 1888), lectotype (MB.C.469).

Specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.469	52.7	18.4	28.0	0	–	0.35	0.66	0.00	2.20	0.40

flanks converge to the narrowly rounded venter. No shell remains are preserved; the specimen is covered by remains of the septa of the following volution. The suture line was already correctly illustrated by Frech (1888); it shows (Fig. 6) a V-shaped external lobe and a very narrow, subacute ventrolateral saddle. The adventive lobe is weakly asymmetric and broadly rounded with distinctly divergent flanks (Fig. 7B).

#### Paralectotype (MB.C.470)

Fragment of a completely chambered specimen with an estimated phragmocone diameter of 100 mm haematitic limestone (Figs 6, 7C). It is part of a phragmocone at least 100 mm in diameter; the total diameter together with the body chamber may therefore have been about 200 mm. The shape of the body corresponds to that of the lectotype. The paralectotype does not bear any shell remains either.

#### Remarks

Both specimens from Dillenburg are quite large; smaller specimens up to 15 mm in diameter were described by Bockwinkel *et al.* (2013b) and Bockwinkel & Korn (2015).

*Epitornoceras mithracoides* cannot really be confused with any other ammonoid species from the Rhenish Mountains because of the subacute ventrolateral saddle. Very similar forms have been reported from the Anti-Atlas of Morocco and identified as this species (Bockwinkel *et al.* 2009, 2013a, 2015, 2017). These specimens have a very similar conch form to the red ironstone specimens, but show a suture line with a considerably deeper adventive lobe characterised by nearly parallel flanks. The differences become clear when the suture lines are morphometrically recorded. Measured at half the depth of the adventive lobe, the width of this lobe is 100% of the lobe depth in *E. mithracoides*, but only about 75% in the North African specimens (Bockwinkel *et al.* 2009), which are described below as *E. transmediterraneum*. The shape of the umbilicus can be mentioned as a further criterion; the umbilical wall is evenly rounded in the adult stage in *E. mithracoides*, but it is obliquely flattened caused by an umbilical shell thickening in *E. transmediterraneum*, leading to a funnel-shaped umbilicus with a distinct umbilical edge of the internal mould.

#### *Epitornoceras transmediterraneum* sp. nov.

[urn:lsid:zoobank.org:act:CFD7324D-6824-4856-AD22-4792DB3CE1EF](https://zoobank.org/act:CFD7324D-6824-4856-AD22-4792DB3CE1EF)

*Epitornoceras mithracoides* – Bockwinkel *et al.* 2009: 65, text-figs 1–2; 2013a: 57, text-figs 4d, 58–59; 2015: 148, text-figs 31–32; 2017: 346, text-figs 34–35.

#### Diagnosis

*Epitornoceras* reaching about 100 mm conch diameter. Thinly discoidal and involute adult stage (ww/dm ~ 0.35; umbilicus closed at 50 mm dm); whorl profile compressed (ww/wh ~ 0.65 at 50 mm dm); whorl expansion rate high (WER ~ 2.20). Flanks weakly convex, convergent, umbilical margin pronounced, umbilical wall on the inside flattened caused by an internal shell thickening throughout ontogeny. Without any ventrolateral grooves. Suture line with broadly rounded, nearly symmetric adventive lobe with parallel flanks; width of the adventive lobe less than the lobe depth.

### Etymology

After the occurrence beyond the Mediterranean Sea.

### Type material

#### Holotype

MOROCCO • Anti-Atlas, Dar Kaoua; late Givetian; figured by Bockwinkel *et al.* (2009: text-fig. 2); MB.C.19101.1.

#### Paratypes

MOROCCO • 2 specs; Anti-Atlas, Tafilalt, Dar Kaoua; late Givetian; MB.C.19101.2–3 • 10 specs; Anti-Atlas, Tafilalt, Hassi Nebech; late Givetian; MB.C.22101.1–9, MB.C.22137 • 1 spec.; Anti-Atlas, Tafilalt, Ouidane Chebbi; late Givetian; MB.C.26510 • 6 specs; Anti-Atlas, Ma'der, “Butte 760” W of Ait Ou Amar, 8 km WSW of Bou Dib; late Givetian; MB.C.25114.1–6.

### Description

For a detailed description of the species (Bockwinkel *et al.* 2009, 2013a, 2015, 2017).

### Remarks

*Epitornoceras transmediterraneum* from the Anti-Atlas of Morocco differs in two aspects from *E. mithracoides* from the Rhenish Mountains: (1) the suture line; measured at half the depth of the adventive lobe characterised by nearly parallel flanks, the width of this lobe is 100% of the lobe depth in *E. mithracoides*, but only about 75% in *E. transmediterraneum*; (2) the shape of the umbilical wall is funnel-shaped in the juvenile stage but evenly rounded in the adult stage in *E. mithracoides*, but obliquely flattened caused by an umbilical shell thickening in *E. transmediterraneum*, leading to a funnel-shaped umbilicus with a distinct umbilical edge of the internal mould throughout ontogeny.

Genus *Lentitornoceras* gen. nov.

[urn:lsid:zoobank.org:act:99D306D3-03BA-4D2A-BBF6-9F47653F5907](https://zoobank.org/act:99D306D3-03BA-4D2A-BBF6-9F47653F5907)

### Type species

*Lentitornoceras materni* gen. et sp. nov.

### Diagnosis

Genus of the subfamily Tornoceratinae with strongly compressed conch, umbilicus closed in the adult stage. Without ventrolateral grooves. Ornament with biconvex growth lines, without ribs. Sutural formula E A L I; adventive lobe broadly rounded, asymmetric with steep dorsal flank; ventrolateral saddle narrow.

### Etymology

After the Latin nomen ‘*lens*’ = ‘lentic’, because of the conch shape, and the reference to the genus *Tornoceras*.

### Included species

Only the type species.

### Remarks

*Lentitornoceras* gen. nov. is easily distinguished from all other tornoceratids by its extremely discoidal conch shape. Furthermore, the course of the growth lines shows differences to other genera; in

*Lentitornoceras* a clear dorsolateral projection is developed, which is only very indistinct in the other genera.

*Lentitornoceras materni* gen. et sp. nov.

[urn:lsid:zoobank.org:act:267ABA4A-0287-4DEA-B888-4D391FB8D96D](https://zoobank.org/act:267ABA4A-0287-4DEA-B888-4D391FB8D96D)

Fig. 8; Table 4

**Diagnosis**

*Lentitornoceras* gen. nov. reaching about 45 mm conch diameter. Extremely discoidal and involute adult stage (ww/dm ~ 0.25; umbilicus nearly closed at 30 mm dm); whorl profile strongly compressed (ww/wh ~ 0.40); whorl expansion rate moderate (WER ~ 1.80). Flanks weakly convex, umbilical margin continuously rounded, venter very narrowly rounded. Ornament with lamellar, wide-standing biconvex growth lines.

**Type material**

**Holotype**

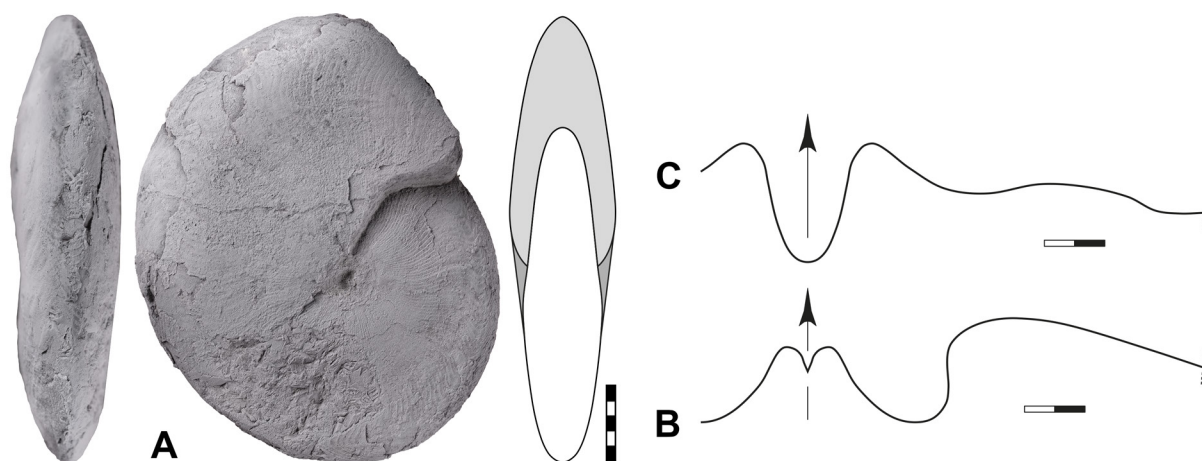
GERMANY • Rhenish Mountains, Oberscheld; late Givetian (from a Red Ironstone block together with *Pharciceras Oberscheldense*); Lotz 1901–1902 Coll.; illustrated in Fig. 8; MB.C.30413.

**Etymology**

After Hans Matern, to honour his studies on the ammonoids from the Dillenburg region.

**Description**

Only the holotype is available for description and illustration. It is a specimen of almost 30 mm diameter in iron-rich limestone, largely preserved with its shell (Fig. 8A). The shape is that of a flat lens; the ww/dm ratio is less than 25%. The umbilicus is almost completely closed; it is bounded by a very shallow umbilical margin. The flanks are slightly convex and converge slightly to the very narrowly rounded venter. The shell bears widespread, lamellar-appearing growth lines, which are biconvex with distinct dorsolateral projection and higher ventrolateral projection across the flank; the ventral sinus is narrow and deep (Fig. 8C). The growth lines are coarser on the venter than on the flanks. The suture line is



**Fig. 8.** *Lentitornoceras materni* gen. et sp. nov., holotype (MB.C.30413; Lotz 1901–1902 Coll.) from Oberscheld. **A.** Ventral view, lateral view and dorsal projection. **B.** Suture line; at dm = 26.0 mm; ww = 6.4 mm; wh = 15.2 mm. **C.** Growth line course; at dm = 26.0 mm; ww = 6.4 mm; wh = 15.2 mm. Scale bar units = 1 mm.

**Table 4.** Conch dimensions and ratios of *Lentitornoceras materni* gen. et sp. nov., holotype (MB.C.30413).

Specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.30413	29.4	6.9	16.8	0.6	7.4	0.23	0.41	0.02	1.79	0.57

typically tornoceratid with a wide, asymmetric adventive lobe, a narrow ventrolateral saddle and a small external lobe (Fig. 8B).

### Remarks

*Lentitornoceras materni* gen. et sp. nov. can hardly be confused with another species from the red ironstone because of its peculiar conch morphology. Tornoceratids from other localities and stratigraphic horizons usually have a much more broadly arched venter. A comparable form is the late Givetian '*Lobotornoceras bensaidi*' (Bockwinkel *et al.* 2013a); however, this form has a suture line with a very shallow adventive lobe.

### Subfamily **Aulatornoceratinae** Becker, 1993

### Diagnosis

Subfamily of the family Tornoceratidae with compressed conch, umbilicus narrow to moderately wide. With distinct ventrolateral grooves. Ornament with biconvex growth lines with very high ventrolateral projection, often with coarse ribs. Sutural formula E A L I.

### Included genera

*Aulatornoceras* Schindewolf, 1922; *Truyolsoceras* Montesinos, 1988; *Polonoceras* Dybczyński, 1913; *Planitornoceras* Becker, 1995; *Armatites* Becker, 1993; *Paucitornoceras* gen. nov.

### Genus ***Paucitornoceras*** gen. nov.

[urn:lsid:zoobank.org:act:63C6391D-3A33-428C-B981-55D56AE323F9](https://doi.org/10.3896/BI.2022.806.32.1)

### Type species

*Goniatites paucistriatus* d'Archiac & de Verneuil, 1842.

### Diagnosis

Genus of the subfamily Aulatornoceratinae with compressed conch, umbilicus moderately wide in the preadult and adult stage. With deep ventrolateral grooves. Ornament with biconvex growth lines with high ventrolateral projection, sharp ribs in the preadult stage, becoming finer in the adult stage.

### Etymology

After the Latin adjective '*paucis*' = 'few', because of the low number of ribs, and the reference to the genus *Tornoceras* and the type species *P. paucistriatum*.

### Included species

*Goniatites paucistriatus* d'Archiac & de Verneuil, 1842, Rhenish Mountains; *Tornoceras rhysum* Clarke, 1898, New York.

### Remarks

Miller (1938: 142) and House & Kirchgasser (2008: 175) already discussed the differentiation of species groups within the genus *Aulaternoceras*. The new genus differs from *Aulaternoceras* in the wider umbilicus (uw/dm is between 0.20 and 0.30, as opposed to about 0.15) and the considerably coarser ribs of *Aulaternoceras*.

***Paucitornoceras paucistriatum*** (d'Archiac & de Verneuil, 1842) gen. et comb. nov.  
Fig. 9; Table 5

*Goniatites paucistriatus* d'Archiac & de Verneuil, 1842: 339, pl. 25 fig. 8.

*Tornoceras paucistriatum* – Wedekind 1918: 137, pl. 16 fig. 11, text-fig. 42a.

*Tornoceras (Aulaternoceras) paucistriatum* – Grüneberg 1925: 68, pl. 1 figs 4–6.

non *Aulaternoceras paucistriatum* – House & Kirchgasser 2008: 178, pl. 32 figs 2–13, text-fig. 60d–f.

### Diagnosis

*Paucitornoceras* gen. nov. reaching about 25 mm conch diameter. Thinly discoidal and subinvolute adult stage (ww/dm ~ 0.40; uw/dm < 0.30 at 15 mm dm); whorl profile circular (ww/wh ~ 1.00 at 15 mm dm); whorl expansion rate low (WER ~ 1.70). Flanks convex, umbilical margin continuously rounded. With deep ventrolateral groove. Ornament with sharp ribs that become significantly weaker in the adult stage, internal shell thickenings.

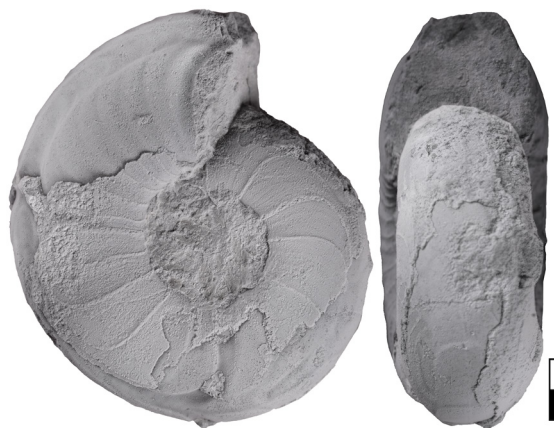
### Type material

**Lectotype** (designated here)

GERMANY • Rhenish Mountains, Oberscheld; late Givetian (Red Ironstone); designated here; Lyon, de Verneuil Collection.

### Additional material

GERMANY • Rhenish Mountains, Oberscheld; late Givetian (Red Ironstone); illustrated in Fig. 9; Koch Coll.; MB.C.30414.



**Fig. 9.** *Paucitornoceras paucistriatum* (d'Archiac & de Verneuil, 1842); MB.C.30414 (Koch Coll.) from Oberscheld. Scale bar units = 1 mm.



**Table 5.** Conch dimensions and ratios of specimen MB.C.30414 of *Paucitornoceras paucistriatum* gen. et comb. nov. (d'Archiac & de Verneuil, 1842).

Specimen	dm	ww	wh	uw	ah	ww/dm	ww/wh	uw/dm	WER	IZR
MB.C.30414	13.8	5.7	5.7	4.0	3.2	0.41	1.00	0.29	1.69	0.44

## Description

### Lectotype

The original specimen in the de Verneuil Collection (Lyon) has nearly 10 mm diameter and is embedded in dark-red limestone with other ammonoids and an orthoconic cephalopod. Unfortunately, it is a rather poorly preserved specimen that would require preparation from the other side to get a better view.

### Specimen MB.C.30414

Specimen MB.C.30414 is a 14 mm conch diameter specimen in pink limestone (probably Adorf Limestone). It is much better preserved than the lectotype. Only the last whorl is visible (Fig. 9); it has an almost circular whorl profile with convex flanks separated from the convex venter by a prominent ventrolateral groove, which is more strongly developed on the internal mould. The ornament consists of fine but very sharp ribs running straight across the flank and curving forward to form a prominent ventrolateral projection. Fine growth lines are visible between the ribs. The internal mould shows deep, broad constrictions running parallel to the ribs and forming a semicircular ventral sinus.

## Remarks

The original material is preserved in De Verneuil's collection, which is only partially preserved in Lyon (Emmanuel Robert, pers. comm. 7 Apr. 2021). D'Archiac & de Verneuil (1842: 339) stated that the species is common at Adorf and Oberscheld, of which the latter is the origin of the lectotype. The additional specimen MB.C.30414 described here agrees well in morphology and ornamentation with the lectotype as does the specimen illustrated by Wedekind (1918: pl. 16 fig.11), although that specimen shows the transition to the adult stage with clearly weakened sculpture.

*Paucitornoceras paucistriatum* differs from *P. rhysum* in the much wider umbilicus. The specimens described and illustrated by House & Kirchgasser (2008) and placed with '*Aulatornoceras paucistriatum*' are also more closely umbilicate; at the same conch diameter of about 13 mm, this material has a uw/dm ratio of about 0.20 (uw/dm ~ 0.30 in *P. paucistriatum*). The material from New York is possibly a new species.

## Discussion

The ammonoids of the suborder Tornoceratina form only a small part of the ammonoid assemblage from the Red Ironstone Formation in the area around Dillenburg (Eastern Rhenish Mountains). In terms of specimen abundance and species diversity, they are far behind the co-occurring suborders Pharciceratina (Korn & Bockwinkel, 2021) and Gephuroceratina. Their revision, mainly based on historical collections kept at the Museum für Naturkunde, Berlin, leads to the distinction of five species belonging to four genera:

*Tornoceras* with the species *T. typus* (Sandberger & Sandberger, 1851) and *T. frechi* Wedekind, 1918.

*Epitornoceras* with the species *E. mithracoides* (Frech, 1888), which is re-described here based on the original material from the Red Ironstone. It is separated from similar specimens from the Anti-Atlas of Morocco, which is newly described here as *Epitornoceras transmediterraneum* sp. nov.

The new genus *Lentitornoceras* gen. nov. with the single new species *L. materni* gen. et sp. nov.

The new genus *Paucitornoceras* gen. nov. with the type species *P. paucistriatum* (d'Archiac & de Verneuil, 1842).

Of these four genera, two (*Epitornoceras*, *Lentitornoceras* gen. nov.) occur in strata with *Pharciceras* (late Givetian) and the other two (*Tornoceras*, *Paucitornoceras* gen. nov.) occur in strata with *Manticoceras* and *Beloceras* (middle Frasnian).

## Acknowledgements

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