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The first record of Early Devonian ammonoids from Belgium and their stratigraphic significance

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ABSTRACT. The first ammonoids from the Lower Emsian (Devonian) of Belgium are described. They belong to the Anetoceratinae, which show the most plesiomorphic characters of all ammonoids. This is the second report of Early Emsian ammonoids within the Rhenish facies of the Rhenish Slate Mountains (Belgium, Germany), in this case from the Belgian part of the Eifel (Burg Reuland). It highlights the possible importance of ammonoids for the correlation of the Emsian in its traditional German sense and the Emsian in the global sense as delimited by the GSSPs. Newly collected, age-significant brachiopods of the genera *Arduspirifer* and *Euryspirifer* and other previously reported fossils indicate a middle or late Early Emsian (Singhofen or Vallendar) age (in German sense) for this locality. We extend the range of *Ivoites schindewolfi* outside of the Hunsrück Basin and further corroborate an age younger than Ulmen for parts of the Hunsrück Slate.

KEYWORDS: Ammonoidea, Brachiopoda, Early Devonian, Anetoceratinae, Systematics, biostratigraphy.

1. Introduction

Since the publications by Erben (1960, 1964a, 1965, 1966), an origin of ammonoids from a bactritoid ancestor is commonly accepted (e.g. Klug & Korn, 2004; Kröger & Mapes, 2007; De Baets et al., 2009). A key element was the transitional series from the cyrtoconic bactritoid *Cyrtobactrites* (Erben, 1960) to the convolutely coiled agoniatitid ammonoid *Mimagoniatites* (Eichenberg, 1930) present in the Early Devonian Hunsrück Slate (Erben, 1964a, 1966). The age of the Hunsrück Slate *sensu stricto* according to Mittmeyer (1980) is still debated (Bartels & Kneidl, 1981; Alberti, 1982, 1983; Erben, 1994; Bartels et al., 1998; Schindler et al., 2002; Carls & Valenzuela Ríos, 2007; Mittmeyer, 2008; Carls et al., 2008; Jansen, 2012; see De Baets et al., 2013a for a review). Until recently the phylogenetic sequence of early ammonoids could not be stratigraphically corroborated (Klug, 2001; Bartels et al., 2002; De Baets et al., 2013a). Erben (1964a, 1966, 1994) considered the Hunsrück Slate ammonoids the oldest in the world with the Hunsrück Basin as their place of origin, which was subsequently criticized (e.g. Becker & House, 1994; Jahnke & Bartels, 2000). A recent revision of the Hunsrück Slate ammonoids (De Baets et al., 2013a) showed that they are not necessarily older and some might even be slightly younger than the earliest ammonoids from China and Morocco (Ruan, 1981, 1996; Yu & Ruan, 1988; Becker & House, 1994; Belka et al., 1999; Klug et al., 2008; De Baets et al., 2010). In addition, several specimens could be assigned to taxa known from outside the Hunsrück Basin such as *Erbenoceras advolvens* (Erben, 1960), *Erbenoceras solitarium* (Barrande, 1865), *Gyroceratites heinricherbeni* De Baets et al., 2013a, *Mimagoniatites fecundus* (Barrande, 1865) and *Mimosphinctes tripartitus* Eichenberg, 1931. Only the range of species of the most loosely coiled taxa like *Metabactrites* Bogoslovsky, 1972 and *Ivoites* De Baets, Klug & Korn, 2009 could not be extended outside of the Hunsrück basin so far, which was hypothesized to be related with a preservational bias. Their commonly fragmentary preservation in most localities often hampers a taxonomic assignment on species level (Chlupáč & Turek, 1983; Klug, 2001; Klug et al., 2008; De Baets et al., 2009, 2010, 2013a), certainly when taking into account the sometimes larger intraspecific variability and overlap in coiling and ribbing parameters within and between genera (De Baets et al., 2013b). The presence of *Ivoites* with its plesiomorphic characters was one of the reasons why the Hunsrück Slate ammonoid fauna was considered one of the oldest in the world. In the meantime, the genus has become known from China, Czech Republic, Germany, Morocco, Novaya Zemlya, and Uzbekistan. It has been shown to have a considerable stratigraphic range throughout most of the Lower Emsian (compare De Baets et al., 2009, 2013a; Becker et al., 2010; Ferrová et al., 2012).

Early Devonian ammonoids are considered as a typical component of the pelagic Bohemian facies (Erben 1964b). In rare cases, they were also found in the neritic and siliciclastic Rhenish facies (Chlupáč, 1976; Mittmeyer, 1982; De Baets et al., 2009). Correlation between both facies has proven difficult, but is of particular importance as the traditional German and Belgian definitions of the Emsian (with slightly different lower boundaries) have been established in the Rhenish facies, while the Emsian in the GSSP sense is defined in the Bohemian facies (Jansen et al., 2007; Carls et al., 2008). Brachiopods and trilobites are commonly used for stratigraphic subdivision and correlation in the Rhenish facies, while ammonoids, conodonts and dacryoconarids are commonly used in the Bohemian facies (Carls, 1987; Jansen, 2001; Jansen et al., 2007; Carls et al. 2008; Mittmeyer, 2008). Interfacial correlations can be better constrained by the study of sequences yielding both Bohemian and Rhenish elements such as the Moroccan Dra Valley, the Celtiberian Chains, and the Hunsrück Slate or by studying groups occurring in both facies (e.g. Carls 1987, 1988, 1999; Jansen, 2001; Jansen et al., 2007; Carls et al., 2008; De Baets et al., 2009, 2010, 2013a). Note that, herein, we use the term "Emsian stage" as well as its subdivisions "Lower" and "Upper Emsian" (respectively "Early" and "Late Emsian") in the Rhenish (traditional German) sense in contrast to the classic three-fold subdivision in Luxemburg (e.g. Lucius, 1950).

The Early Devonian lithostratigraphic units of Belgium were reviewed by Bultynck & Dejonghe (2001), but no special reference was made to the Belgian part of the Eifel region. The locality of Burg Reuland is of particular interest as it yields a rich collection of open marine faunas (Asselberghs, 1921; Maillieux, 1937, 1941; Vandercammen, 1963; Godefroid, 1994; Franke, 2006; Müller & Alberti, 2010) and was recently correlated with the Vallendar stage of the SW Eifel (Franke, 2006 and references within). For over a century, the Late Devonian (Frasnian) ammonoids from the Matagne Formation of several localities in the southern part of the Dinant fold-and-thrust belt were the oldest known ammonoids from Belgium (see Foord & Crick, 1897; Matern, 1931; House & Price, 1985; House & Kirchgasser, 1993). Only recently, the Belgian ammonoid record could be extended into the Middle Devonian (Eifelian) with new finds (Becker in Schraut, 2000; Ebbighausen et al., 2011) from the southern part of the Dinant fold-and-thrust belt near the French border (Jemelle Formation at Olloy-sur-Viroin; compare

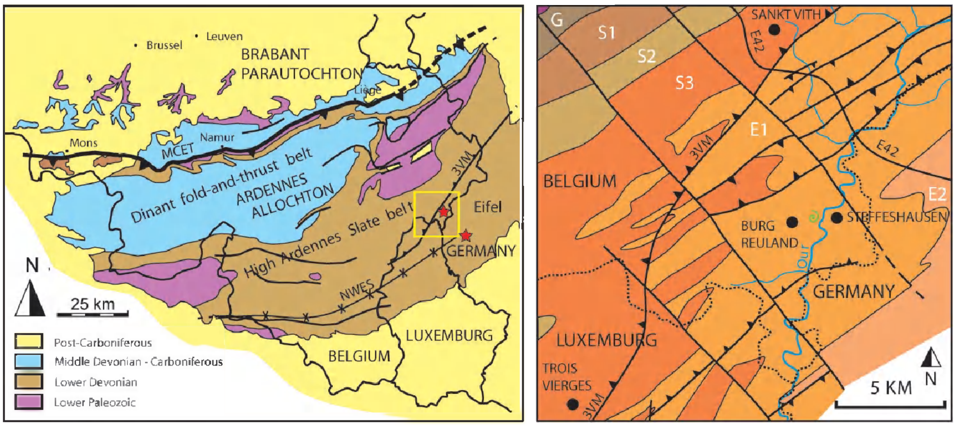

Figure 1. Geology and location of the study area. (A) General localisation within the Belgian part of the Rhenish Slate Mountains (modified from Bultynck & Dejonghe 2001; Van Baelen & Sintubin 2006). The star within the rectangle refers to the Auf Schleid Quarry and the star outside the rectangle refers to Neuerburg, the nearest Early Emsian ammonoid locality in Germany. Abbreviations: MCET: Midi-Condroz-Eifel Thrust; NWES: Neufchâteau-Wiltz-Eifel Syncline; 3VM: Trois Vierges – Malsbenden Backthrust. (B) Geological map of the study area (modified from Vandeven 1990). The ammonoid symbol refers to the Auf Schleid Quarry. Lithostratigraphy: E2: Clervaux Formation, E1: Breitfeld-Steinbrück Formation, S3: Sankt Vith Formation, S2: Longlier Formation, S1: Amel Formation, G: Waimes Formation, Age: E1-E2: Emsian, S1-S3: Pragian, G: Lochkovian. Abbreviations: 3VM: Trois Vierges – Malsbenden Backthrust.

Van Viersen, 2008 and Dumoulin & Blockmans, 2008). So far, no Early Devonian ammonoids have been reported from the Ardennes, although they are known from correlative levels at several localities in the Eifel region in Germany with the closest one only 10 km from the Belgian-German border (*Anetoceras arduennense*; De Baets et al., 2009; see Figure 1). Furthermore, *Ivoites*, which is very common in the Hunsrück Slate, has so far not been reported from the Eifel (De Baets et al., 2009). We herein describe the first Early Emsian ammonoids from Belgium as well as newly collected associated brachiopods from the same locality. Additionally, we discuss some stratigraphical aspects of the new findings.

2. Geological Setting

The fossils described in this paper derive from a small, but long-time active quarry. This quarry is located within the Our Valley in East Belgium, at the edge of Steffeshausen, near Burg Reuland, at the southeastern tip of the Preisberg-Auf Schleid hill (50°11'50.58"N, 6° 9'6.60"E; see Fig. 1B). Geologically, it is situated on the northern flank of the Neufchâteau-Wiltz-Eifel Syncline, East of the Malsbenden-Trois Vierges Backthrust, thus within the Belgian part of the Eifel depression of the Rhenish Slate Mountains (Fig. 1A). The Belgian Geological Survey geological mapping archives report on fossil collections from the quarry made in 1914 (by Timmermans, K.U. Leuven) and 1921 (by Maillieux, IRNSB), with identifications by Asselberghs (K.U. Leuven) (Sheet 235W, locality 2). Although detailed geological maps were never made from the area of Burg Reuland, Asselberghs (1946) and more recently Vandenven (1990) figured the quarry within Early Emsian strata (E1) (see Fig. 1). In the literature, the quarry is known as the "Burg Reuland" or the "Auf Schleid" Quarry, and the sediments exposed therein were either included within the "Quartzophyllades de Schutbourg [= "Schuttburg"]" (Maillieux, 1932; Godefroid 1994), the "Quartzophyllades de Burg-Reuland, Em1III" (Maillieux, 1937, 1941), the ""sandsteinreicher Komplex C (graues Unteremsium)"" (Furtak, 1965), the "Breitfeld-Steinebrück Formation" (Vandenven, 1990) or the "Klerf-Schichten" (Franke, 2006). A correlation of the finding horizon with the Klerf Beds in the Eifel ("Klerf Schichten" *sensu* Richter, 1919) is possible following Franke (2006), but how these relate with the Clervaux shales (or "schistes de Clervaux") of the type region near Clervaux needs to be further investigated. Vandenven (1990) argued that for the highly tectonised area between the Malsbenden-Trois Vierges Thrust and the Our Valley, it was even almost impossible to differentiate the lithological units "Schistes de Stolzenburg (Em 1a)" and "Quartzophyllades de Schüttburg (Em 1b)" and he therefore included both in the Breitfeld-Steinebrück Formation (Fig. 1B).

Regardless to which lithostratigraphical formation and member the marine sediments from the quarry should be referred to, the ammonoids occur in dark-grey siltstones associated with bivalves and mass abundance of the chonetid brachiopod *Plebejochonetes semiradiatus* (Sowerby, 1842). The ammonoid specimens were found by TR in 2007 and 2009 on a waste tip in front of the quarry. KDB, SG, and TR revisited the quarry in 2009. No additional and/ or *in situ* ammonoid specimens were discovered, but spiriferid brachiopods were collected from the same waste tip, which yielded the ammonoids in 2009 (see further). Some of the newly collected brachiopods are also determined and figured.

3. Systematic Palaeontology

The systematic description of the ammonoids follows Korn & Klug (2002) and De Baets et al. (2009). Morphological terms are applied following Klug (2001) and Korn (2010; more information in De Baets et al. 2013a).

Abbreviations of measured conch diameters are as follows: dm = conch diameter; ww = whorl width; wh = whorl height; wi = whorl interspace; uw = umbilical width; ah = apertural height; dmm = median diameter; ARI = absolute rib index; DWRA = demi-whorl rib angle.

We occasionally use the median diameter dmm (measured between the middle height of demi-whorl), which is more appropriate to compare flattened specimens and none flatted specimens (see De Baets et al. 2013a). The rib ARI_{xx} = the number of ribs counted mid-flank within a circle with a diameter of XX mm centered on the middle of the whorl height, which is less influenced by changes in coiling than the amount of ribs counted per demi-whorl (compare De Baets et al. 2009; 2013a). De Baets et al. (2013a) introduced the DWRA or the angle between the ribs, which are a demi-whorl or half-whorl apart. During the uncoiling phase the ribs become more rursiradiate and make a lower angle with each other than in the early and middle whorls (DWRA = 180° +/- 5°). This results in a higher DWRA (< 170°) during the uncoiling phase.

Specimens were whitened with ammonium chloride unless otherwise specified. Specimens are deposited in the Naturalis Biodiversity Center, Leiden (RGM) and the Paläontologisches Institut und Museum, Universität Zürich (PIMUZ). Synonymy lists follow the recommendations by Matthews (1973). The brachiopods are deposited at the Senckenberg Forschungsinstitut und Naturmuseum in Frankfurt am Main (SMF).

Order Agoniatitida Ruzhencev, 1957
Suborder Agoniatitina Ruzhencev, 1957
Superfamily Mimosphinctaceae Erben, 1953
Family Mimosphinctidae Erben, 1953
Subfamily Anetoceratinae Ruzhencev, 1957
Genus *Ivoites* De Baets, Klug & Korn, 2009

Type species. Anetoceras hunsrueckianum Erben, 1960, from the Early Emsian middle Kaub Formation of the Hunsrück region in Germany.

Remarks. Finely ribbed Anetoceratinae, which complete between about 1.5 and 2.75 whorls before (terminally) uncoiling are now referred to *Ivoites* instead of *Anetoceras* (De Baets et al., 2009, 2013a). *Anetoceras* has been used very inconsistently in the literature and specimens of *Anetoceras* sp. reported in the literature without photographs before 2009 could therefore belong to *Anetoceras*, *Ivoites*, or *Erbenoceras* and need to be verified.

Ivoites schindewolfi De Baets, Klug, Korn, Bartels & Poschmann, 2013
(Fig. 2A, B; Plate 1, Figs A-F)

p. 1934 *Anetoceras arduennense* Schindewolf, p. 268, pl. 19, fig. 8 (non text-fig. 2 = *Anetoceras arduennense*).
vp. 1953 *Anetoceras arduennense* Schindewolf; Erben, p. 194-196, fig. 10 (non pl. 18, fig. 1, 2 = *Erbenoceras* cf. *advolvens*).
vp. 1960 *Anetoceras hunsrueckianum* n. sp. or *arduennense* (Steininger), Erben, text-fig. 8a (non textfig. 8b = I. cf. *schindewolfi*)
p. 1960 *Anetoceras arduennense* Schindewolf; Erben, p. 54, text-fig. 10 (only early part of synthetogram).
p. 1962a *Anetoceras hunsrueckianum* Erben; Erben, p. 19-20, text-fig. 2 (non text-fig. 2 = *Ivoites hunsrueckianus*).
p. 1962a *Anetoceras* cf. *hunsrueckianum* Erben; Erben, p. 19, pl. 1, fig. 2.
vp.1962a *Anetoceras arduennense* auct.; Erben, p. 21-22, pl. 1, text-fig. 5 (non pl. 1, fig. 3 = *I.* cf. *opitzi*, non pl. 1, fig. 4 = *I.* cf. *schindewolfi*).
v 1962b *Anetoceras* cf. *hunsrueckianum* Erben; Erben, pl. 5, fig. 14.
vp.1964a *Anetoceras hunsrueckianum* Erben; Erben, p. 141, text-fig. 2d, pl. 7, fig. 2 (non text-figs 7, 8 = *I. hunsrueckianus, I. opitzi*).
p. 1964a *Anetoceras* aff. *hunsrueckianum*; Erben, p. 141, text-fig. 8.
vp.1964a *Anetoceras* (*Erbenoceras*) sp. A; Erben, p. 141 (non text-figs. 8, 9, 10 = *I. opitzi*).
p. 1965 *Anetoceras* (*Erbenoceras*) sp. A; Erben, p. 280, pl. 1, fig. 1 (non pl. 1, fig. 2 = *Ivoites opitzi*).
p. 1969 *Anetoceras arduennense* (Steininger); Bogoslovsky, p. 116, text-fig. 21, pl. 1, fig. 1.
v 1994 *Anetoceras* (*Anetoceras*) cf. *hunsrueckianum* Erben; Erben, p. 54, text-fig. 5.10.
v 2000 *Anetoceras* sp.; Keupp, p. 62.
p. 2002 *Anetoceras arduennense* (Steininger 1853); Korn & Klug, p. 58, text-fig. 60A.
vp. 2002 *Anetoceras* aff. *hunsrueckianum* Erben; Bartels et al., p. 114.
vp. 2002 *Anetoceras hunsrueckianum* Erben; Bartels et al., p. 114.
vp. 2009 *Ivoites arduennense* auct. Erben; De Baets et al., p. 373.
v 2011 *Ivoites* n. sp. A; De Baets et al., p. 162.
v 2011 *Ivoites schindewolfi*, De Baets et al., p. 163 (= nomen nudum)
* 2013a *Ivoites schindewolfi* n. sp.; De Baets et al., p. 37-40, text-fig. 2, pl. 1, fig. 6, pl. 4, figs 1, 3-12; pl. 5, figs. 2, 6 ; pl. 13, figs. 5A-N.

Material. Two specimens with at least a demi-whorl preserved from Steffeshausen in the Belgian Eifel region were studied first hand, which are deposited in Naturalis Biodiversity Center, Leiden, the Netherlands (RGM.791233, RGM.791234). An additional whorl fragment from the same locality is deposited in the Paläontologisches Institut und Museum, Zürich, Switzerland (PIMUZ 28899). All specimens were collected by TR and derive from the Lower Emsian of the Auf Schleid Quarry near Steffeshausen, Belgium.

Diagnosis. (Modified from De Baets et al., 2013a). Species of *Ivoites* with moderately large conch (maximal dm ~ 90 mm); umbilicus wide to very wide (uw/dm = 0.50–0.80); lowest whorl interspace at a point between the end of whorl 1 and 1.25 whorls; subsequently becoming more loosely coiled, but only markedly after about 1.35 whorls between 30 and 50 mm diameter, where the whorl interspace exceeds the whorl height (WII = 0.2–1.7); umbilical window very large, open (SA = 9–11 mm). Ornament with fine rursiradiate ribs and fine, parallel growth lines; 35–55 ribs per demi-whorl (ARI20 = 10–26 > 20 mm dmm; ARI10 = 11–23 < 20 mm dmm).

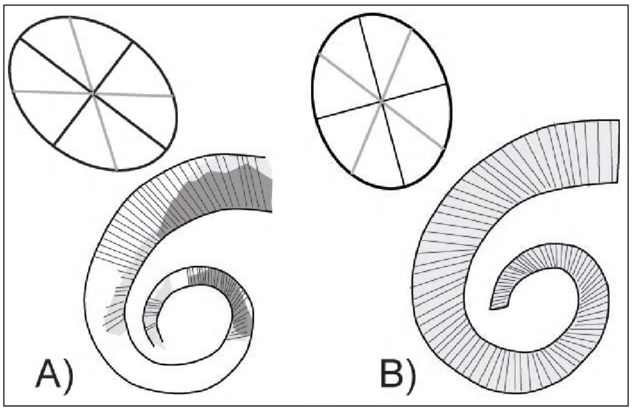

Figure 2. Reconstructions of *Ivoites schindewolfi* De Baets, Klug, Korn, Bartels & Poschmann, 2013, from the Lower Emsian of the Auf Schleid Quarry. Specimens are retrodeformed (see explanations in De Baets et al., 2013a) and missing parts extrapolated. The light grey color refers to aspects seen in the internal moulds, while the dark grey refers to parts seen in the negative or counterpart. The ellipses where circles with a diameter of 20 mm before retrodeformation A. RGM.791234. B. RGM.791233.

Description. The most complete specimen (RGM.791233; Fig. 2B, Plate 1D, E) has a conch diameter of 38 mm and possesses about 1.25 whorls. The embryonic shell is not preserved. The whorl interspace index continuously augments from 0.55 at 28 mm diameter (dmr = 25 mm) to 1.01 at its maximum diameter. The specimen markedly uncoils (DWRA < 170°) at about 35 mm diameter. It shows 37 fine ribs at about 15 mm diameter if retrodeformed (smallest preserved demi-whorl) to 43 fine ribs at its maximum diameter (last preserved demi-whorl). The suture line is not preserved.

The smaller specimen (RGM.791234; Fig. 2A, Plate 1B, C) possesses almost 1.5 whorls and has an estimated conch diameter of 36 mm (33 mm if retrodeformed). The whorl interspace becomes larger than the whorl height at 31 mm diameter if retrodeformed. The rib ARI_{10} varies from 11 (ARI_{20} = 23) at 7 mm whorl height (about 31 mm diameter) to 23 at 2.5 mm whorl height (or 14 mm diameter if retrodeformed: see Fig. 2A).

The additional whorl fragment (PIMUZ 28899; Plate 1A) has a rib index ARI_{20} of 6 at about 1 mm whorl height and a weakly compressed whorl section (wh/ww ~ 0.5), but these features might be altered due to flattening and lateral extension.

Remarks. The specimens resemble quite well those from the Hunsrück Slate in coiling and ribbing. The amount of ribs per demi-whorl (37 - 43) falls within the range of the Hunsrück Slate specimens of *Ivoites schindewolfi* between 15 and 38 mm median diameter (36 – 49). They uncoil at a similar diameter (30 – 40 mm) as some specimens of *Ivoites schindewolfi* (compare text-fig. 9; plate 4; figs 1, 3-12; plate 5, figs 2, 6 in De Baets et al., 2013a) from the Hunsrück Slate. *Ivoites opitzi* terminally uncoils at a large diameter. A small percentage of specimens of this species from the middle Kaub Formation (Hunsrück Slate s.s.) shows peculiar, spirally arranged, paired pits (“Opitzian Pits”) on the phragmocone and the body chamber in internal mould preservation (compare De Baets et al., 2011, 2013a). They were not observed in the specimens from Steffeshausen, but this might be a sampling bias.

4. Brachiopod fauna

A few, fairly well-preserved spiriferid and terebratulid specimens were collected in 2009 and derive from the waste tip, where TR found the ammonoids in 2007 and 2009. They are characterized in the following:

Arduspirifer Mittmeyer, 1972. – *Ard. arduennensis* n. ssp. cf. *latestriatus* (Maurer, 1886) (Fig. 3D; = *latestriatus sensu*

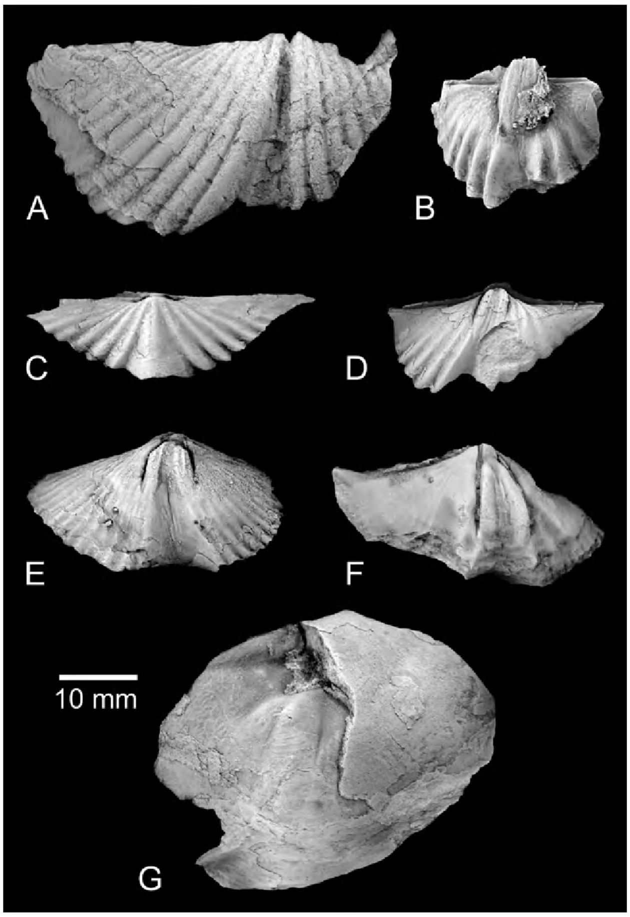

Figure 3. Selection of brachiopods from the Lower Emsian of the Auf Schleid Quarry. A. *Euryspirifer* cf. *assimilis latissimus* Mittmeyer, 2008; ventral valve exterior, SMF 94010. B. *Arduspirifer arduennensis antecedens* (Frank, 1898); internal mould of ventral valve, SMF 94012. C. *Arduspirifer arduennensis prolatestriatus* ? Mittmeyer, 1973; internal mould of dorsal valve, SMF 94013a. D. *Arduspirifer arduennensis* n. ssp. cf. *latestriatus* (Maurer, 1886); internal mould of ventral valve, SMF 94014. E. *Incertia* sp. cf. *subincertissima* Mittmeyer, 2008; internal mould of ventral valve, SMF 94015. F. *Tenuicostella* sp., internal mould of ventral valve, SMF 94011. G. *Meganteris ovata* Maurer, 1879; internal mould of dorsal valve, SMF 94010. All pictures in natural size.

Franke, 2006) resembles the Vallendar age taxon *latestriatus* but differs in the presence of 6 ribs per flank on the internal mould, longer free portions of dental plates and a small and narrow, subparallel-sided muscle field. Another internal mould of a ventral valve represents a typical *Ard. ard. antecedens* (Frank, 1898) with strongly elevated mould of the muscle field extending to the posterior over the hinge-line (Fig. 3B), whereas an internal mould of a dorsal valve (Fig. 3C) closely resembles *Ard. ard. prolatestriatus* Mittmeyer, 1973 in outline and style of ribbing, pleading for an Ulmen to Singhofen age (Mittmeyer, 2008). Solle (1953, p. 56) identified a specimen from "75-175 m south of the railway station of Burg-Reuland" as cf. *latestriatus*, what could mean a closer affinity either to *Ard. ard. prolatestriatus* or *Ard. ard. latestriatus*, and another specimen from the same section as *antecedens* (p. 67).

Euryspirifer Wedekind, 1926. – Only one specimen of the age-significant *Eu. assimilis* (Fuchs, 1915) – *dunensis* (Kayser, 1889) group is in our fauna: The ventral valve (Fig. 3A) shows nine moderately strong inner ribs plus three or four fine posterolateral ones per flank, a moderately transverse outline lacking mucronate cardinal extremities and a relatively shallow sulcus. Ongoing studies on Emsian representatives of *Euryspirifer* (by UJ) have shown that species of the *assimilis-dunensis* group are characterized by a strong intraspecific variability, so that the determination of a single specimen can be problematical. The specimen studied is determined as *Eu.* cf. *assimilis latissimus* Mittmeyer, 2008. This preliminary identification would implicate a Singhofen age of the fauna (Mittmeyer, 2008), but the uncertainty of the determination does not preclude an Ulmen or even a Vallendar age, either. The study of more material is necessary to further clarify the stratigraphic assignment. Additionally, *Eu. dunensis*, which is restricted to the upper Singhofen (?; all investigated *Euryspirifer* investigated by UJ from the Neichnerberg Formation belong to *E. assimilis latissimus*) to Vallendar substages according to Mittmeyer, 2008, was also reported from the Auf Schleid Quarry (see Franke, 2006).

Meganteris Suess, 1856. – The terebratulid *M. ovata* Maurer, 1879 s. s. which is most common in strata of Singhofen and Vallendar age (UJ, work in progress), is represented by a typical dorsal valve (Fig. 3G).

Further taxa. – Internal moulds of the spiriferids *Incertia* sp. cf. *subincertissima* Mittmeyer, 2008 (Fig. 3E) and *Tenuicostella* sp. (Fig. 3F) fit to an Early Emsian age, but do not allow further stratigraphic conclusions. Further brachiopod taxa recorded (but largely not figured) by Maillieux (1941), Vandercammen (1963) and Franke (2006) from Burg-Reuland are only partly helpful in our age evaluation. Vandercammen's understanding of the Late Emsian taxon *Euryspirifer paradoxus* (von Schlotheim, 1813) and late Late Emsian to early Eifelian *Spinocyrtia* [today: *Alatiformia*] *alatiformis* (Drevermann, 1907), which he reported from Burg Reuland, does certainly not reflect the present state of research. *Hysterolites crassicostatus* [today: *Brachyspirifer crassicosta*] (Scupin, 1900) is well consistent with an Early Emsian age. The assemblage of *Tropidoleptus rhenanus* Frech, 1897, *Cryptonella rhenana* (Drevermann, 1902), *Iridistrophia maior* (Fuchs, 1915) and "*Uncinulus*" *antiquus* (Schnur, 1853), recorded by Maillieux (1941) and Franke (2006), supports the Early Emsian age, as well.

Summarizing the present results (combined ranges), a Singhofen or Vallendar age is regarded as most probable for our *Arduspirifer*, *Euryspirifer* and *Meganteris* specimens (see Fig. 3). Nevertheless, part of the sequence around Burg Reuland might be considerably older as Godefroid (1994) reported *Euryspirifer* cf. *assimilis* (Fuchs, 1915), which is very close to the nominal subspecies known from the Ulmen substage.

5. Significance of the ammonoid finds

5.1. Ivoites *from the Hunsrück Slate*

Ivoites schindewolfi was so far only reported from the middle Kaub Formation (Hunsrück Slate s.s.) of the Central Hunsrück Basin (De Baets et al., 2013a). The age of the taxon was poorly constrained as it might have a late Ulmen, Singhofen and/or Vallendar age (Fig. 4). The taxon occurs in at least two members of the middle Kaub Formation, the Bocksberg Member and the Wingertshell Member. Mittmeyer (in Bartels et al., 2002, p. 114) reported *Ard. arduennensis prolatestriatus* from the latter member (De Baets et al., 2013a). If correctly identified, this might indicate an Ulmen to Singhofen age for the lower part of the Wingertshell Member (and the underlying members of the Hunsrück Slate). This member might, however, already partially of Vallendar age, because poorly preserved specimens of ?*Mimagoniatites* occur in these beds (compare Bartels et al., 2002; De Baets et al., 2013a). Note, that the members of the middle Kaub Formation have considerable thicknesses and the exact position of the ammonoids and co-occurring taxa are not exactly known. The new finds of *Ivoites schindewolfi* in the dark-grey siltstones exposed in the Auf Schleid quarry show the taxon to occur outside of the Hunsrück Basin for the first time. This could recently also be shown for several other ammonoid taxa long thought to be endemic to Hunsrück Basin (De Baets et al., 2013a).

5.2. Ammonoids from the Lower Emsian of the Eifel region

So far, no early ammonoids had been reported from the Klerf Formation of the Eifel region which is considered as contemporaneous by Franke (2006). Ammonoids (*Anetoceras arduennense*) are, however, known from beds traditionally assigned to the underlying "Stadtfelder Schichten" at several localities (Lauzert near Niederstadtfeld, Neuerburg, Sankt Johann: compare Kutscher, 1933; Chlupáč, 1976; Mittmeyer, 1982; De Baets et al., 2009). The facies of the ammonoid-bearing siltstones is strikingly

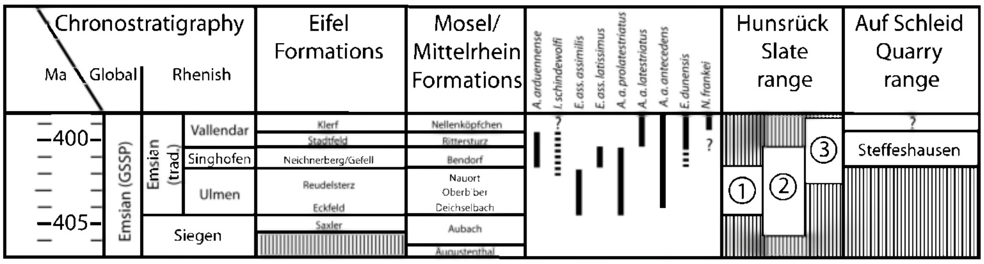

Figure 4. Time-scale (modified from Kaufmann 2006), stratigraphic correlations (modified from Weddige 1996, Weddige et al. 2005; De Baets et al., 2013a), ranges of some important taxa used for biozonation or discussed in the text (compiled from Jansen 2001; Brauckmann et al., 2002; Schemm-Gregory & Jansen 2006; De Baets et al., 2009), proposed age ranges of the Hunsrück Slate (1 = Mittmeyer 1980, 2008; 2 = Bartels et al., 1998; 3 = De Baets et al., 2013a for the ammonoid-bearing middle Kaub Formation) and proposed age of the ammonoid-bearing level in the Auf Schleid quarry. The rectangle refers to the possible correlation with the Gefell (Singhofen) to Stadtfeld Formation (Vallendar) proposed herein, while the bar reflects the possible correlation with the Klerf Formation (Vallendar) as suggested by Franke (2006). More details are discussed in the text.

similar to the ones from Steffeshausen (compare De Baets et al., 2009). The Stadtfeld Formation in the "restricted modern sense" (type locality: Humerich near Oberstadtfeld; Mittmeyer, 2008) is of early Vallendar age and contains *Arduspirifer arduennensis latestriatus* and *Euryspirifer dunensis* (Mittmeyer, 1982, 2008). The traditional "Stadtfelder Schichten", in contrast, contain strata of Singhofen (possibly even Ulmen?) to early Vallendar age (compare Fuchs, 1971). The ammonoid-bearing strata probably occur in different levels (Fig. 4). The Sankt Johann ammonoid locality yields *Eu. dunensis* which point to a late Singhofen (?) or Vallendar age and typical *Ard. ard. Antecedens* ranging from the late Singhofen to Vallendar age (Jansen, 2008, UJ unpublished data; study material stored in the Museum für Naturkunde, Berlin). The Lauzert near Niederstadtfeld ammonoid locality belongs to the Gefell Formation, which overlies the Reudelsterz Formation (upper Ulmen substage). The Gefell Formation is suggested to be of early Singhofen age due this position within the stratigraphical succession and its faunal content: many typical *Pseudoleptostrophia dahmeri* (Rösler, 1954) in combination with *Eu. assimilis latissimus* Mittmeyer, 2008 (see Fuchs & Plusquellec, 1982; Mittmeyer, 2008; Jansen, 2012).

Anetoceras as revised by De Baets et al. (2009) has been consistently reported below occurrences of *Mimagoniatites fecundus* (and also *Mimosphinctes tripartitus*) and their stratigraphic ranges have not been shown to overlap (Ruan 1981; De Baets et al., 2010). As *Anetoceras* is known to range into the Vallendar (De Baets et al., 2009), a partial Vallendar age of the middle Kaub Formation (the parts containing *Mimagoniatites fecundus* and/or *Mimosphinctes tripartitus*) is very likely. Our brachiopod material corroborates a partial Singhofen to Vallendar age for the middle Kaub Formation, in addition to the Ulmen age of its lower part (De Baets et al., 2013a). If correlation of the sequence at Burg Reuland with the Klerf Formation proposed by Franke (2006) is correct, the range of *Ivoites schindewolfi* could be extended above the range of *Anetoceras arduennense*. This is not surprising as *Ivoites* has a much longer range than *Anetoceras* as revised by De Baets et al. (2009, 2013b). *Ivoites* has been found below or together with *Anetoceras* in some of the earliest ammonoids localities of China (Zlichovensis dacryconarid Zone; Ruan, 1981, 1996; Yu & Ruan, 1988; Becker & House, 1994) and ranges up into the late part of the Early Emsian (Elegans Zone; see Chlupáč et al., 1979; Chlupáč, I. & Lukeš, 1999; Becker et al., 2010; Ferrová et al. 2012) above the range of *Anetoceras*. The report of *Anetoceras* sp. in the Elegans Zone by Ferrová et al. (2012), which was probably derived from Chlupáč et al. (1979), is erroneous and should be referred to *Ivoites* sp (KDB, unpublished data). Note, that in publications older than 2009 (e.g., Chlupáč et al., 1979; Chlupáč, I. & Lukeš, 1999), *Anetoceras* has not only been used to refer to *Ivoites* (as introduced by De Baets et al. 2009) or *Anetoceras* (as revised by De Baets et al. 2009), but also to refer to *Erbenoceras* (e.g., *Erbenoceras solitarium*: see also Chlupáč & Turek, 1983). Finally, it has to be stated that no ammonoids have been reported from Siegenian strata so far (De Baets et al., 2013a).

5.3. Correlation of the Burg Reuland Ammonoid Locality

The dark-grey siltstones exposed at Burg Reuland were long correlated with the Luxemburgian "Schüttburg-Schichten" (Maillieux, 1932; Asselberghs, 1946; Godefroid, 1994). From palynological, macrofloral and faunal data a middle to late Early Emsian age or even a probable Late Emsian age was assumed for the strata in the type region of this unit (Steemans et al., 2000; Delsate et al., 2004; Franke, 2006), but the correlation with the Belgian succession at Burg Reuland remains uncertain. Franke (2006) argued with the occurrence of "*Dilophaspis*" cf. *frankei* Brauckmann, Koch & Groening, 2002 (now *Nahecaris* cf. *frankei*: see Briggs & Bartels, 2003), which has so far only been reported from latest Early Emsian beds (upper Vallendar) of the Nellenköpfchen Formation, a correlative of the Klerf Formation (see Weddige et al., 2005, Fig. 4) and early Late Emsian beds of the Wiltz Formation (Brauckmann et al., 2002). Its occurrence might be highly dependent on the presence of suitable facies conditions and does not necessarily imply a Vallendar age or an assignment to the Klerf Formation.

The age of the recently exploited layers in the Burg Reuland Quarry and the ammonoid level is probably middle or late Early Emsian (Singhofen or Vallendar age) as indicated by the recently found brachiopods (Fig. 4). A correlation of the sequence at Steffeshausen with the Middle Kaub Formation (Hunsrück) appears possible due to the occurrences of *Ivoites schindewolfi* in both regions and partial post-Ulmen age (Singhofen-Vallendar) of the Hunsrück Slate (De Baets et al., 2013a). This is opposed to the views of Mittmeyer (1980, 2008), who considers the Hunsrück Slate sensu stricto (including the middle Kaub Formation) to be of Ulmen age. The first appearance of early ammonoids in several localities in the Eifel (Auf Schleid, Lauzert) and the middle Kaub Formation might be related with a regional (Rhenish?) transgressive event at the beginning of the Singhofen rather than a global transgression (Becker & Kullmann, 1996). Such a transgressive event follows the regressive tendencies documented in the Reudelsterz Formation (Fuchs 1982) and has already been suggested for the appearance of ammonoids in the middle Kaub Formation of the Hunsrück Slate (Sutcliffe, 1997; Briggs & Bartels, 2001; Schindler et al., 2002; De Baets et al., 2013a).

6. Conclusions

We report the first discovery of Early Emsian ammonoids from the Belgian part of the Rhenish Slate Mountains in Burg Reuland. Together with previously reported faunal elements (see review in Franke, 2006) they further corroborate the normal marine character of the Burg Reuland sequence. The combined ranges of *Euryspirifer* cf. *assimilis latissimus*, *Eu. dunensis* ? and *Arduspirifer arduennensis antecedens* plus the phylogenetic development of *Ard. ard.* n. ssp. cf. *latestriatus* speak for a Singhofen or Vallendar age of the recently exploited layers. Franke (2006) correlated the sequence with the Klerf Formation, but a partial correlation with the interval Gefell to Stadtfeld formations is more probable due to the finds of early ammonoids in both, partly similar facies, and the occurrence of comparable representatives of *Euryspirifer* and *Arduspirifer*. The finds of Early Emsian ammonoids with a Singhofen to Vallendar age in Belgium (*Ivoites schindewolfi*) and in the northeast Eifel (*Anetoceras arduennense*; De Baets et al., 2009) corroborate the recently proposed partial Singhofen-Vallendar age of the middle Kaub Formation of the Hunsrück Slate (De Baets et al., 2013a). The appearance of Early Emsian ammonoids in the Post-Ulmen (Singhofen – Vallendar) in many parts of the Eifel and the Middle

Kaub Formation coincides with a transgressive event, which can at least be regionally recognized in the Rhenish Mountains (Eifel, Hunsruck, Taunus), but not necessarily globally (compare Becker & Kullmann 1996).

The finds illustrate the possible importance of the outcrops around Steffeshausen for the correlation of the Belgian Early Emsian sequences with the coeval German and Luxemburgian sequences and also the correlation of Bohemian and Rhenish facies within in the Rhenish Slate Mountains. It also highlights the importance of studying several fossil groups (ammonoids, brachiopods, …) in the same outcrops. A correlation of the layers at Steffeshausen with the middle Kaub Formation appears likely due to the occurrence of *Ivoites schindewolfi*. Nevertheless, these stratigraphic interpretations need to be further corroborated by *in-situ* collection of faunas once a suitable section is cropping out. Such investigations might partially be hampered by the scattered occurrence of fossiliferous layers and tectonic deformations, but these problems could be partially overcome by applying the new techniques introduced by Michel et al. (2010). We herein extended the range of *Ivoites schindewolfi*, which shows some of the most plesiomorphic characters of all ammonoids, outside of the Hunsrück Basin.

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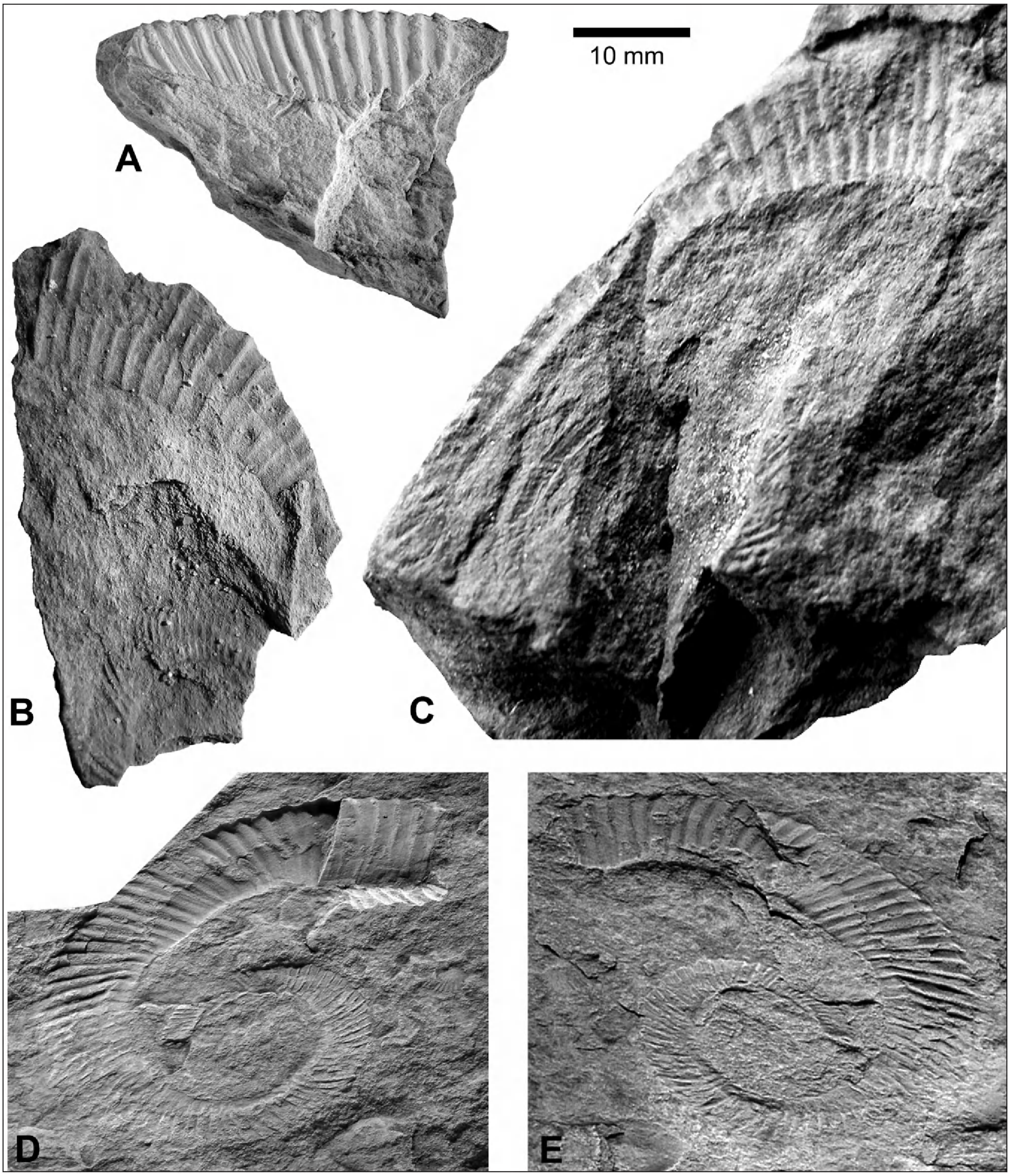

Plate 1. *Ivoites schindewolfi* De Baets, Klug, Korn, Bartels & Poschmann, 2013a from the Lower Emsian of the Auf Schleid Quarry. A. PIMUZ 28899. B, C. RGM.791234, left lateral view of the internal mould and counterpart (negative). D, E. RGM.791233, counterpart (negative) and left lateral view of the internal mould. All pictures have an enlargement of 2X.