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Publisher: Taylor & Francis

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Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/sgff20>

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Published online: 05 Feb 2014.



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To cite this article: Lutz Koch, Thomas Servais, Jörg Maletz, Thijs R.A. Vandenbroucke & Jacques Verniers (2014) The Ordovician of the Ebbe Inlier (Rhenish Massif, western Germany) revisited, GFF, 136:1, 142-146, DOI: [10.1080/11035897.2013.876658](https://doi.org/10.1080/11035897.2013.876658)

To link to this article: <http://dx.doi.org/10.1080/11035897.2013.876658>

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The Ordovician of the Ebbe Inlier (Rhenish Massif, western Germany) revisited

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Koch, L., Servais, T., Maletz, J., Vandenbroucke, T.R.A. & Verniers, J., 2014: The Ordovician of the Ebbe Inlier (Rhenish Massif, western Germany) revisited. *GFF*, Vol. 136 (Pt. 1, March), pp. 142–146. © Geologiska Föreningen. doi: <http://dx.doi.org/10.1080/11035897.2013.876658>.

Abstract: Outcrops of Ordovician sediments in western Germany are of very limited extent. In the Ebbe Inlier (Rhenish Massif) strongly tectonized, mostly fine-grained detrital Middle to Upper Ordovician rocks have been described since the 1910s. These sediments underwent a careful revision in the last 20 years. Four formations, attributed to the Herscheid Group, yielded diverse fossil assemblages (including trilobites, graptolites, ostracods, chitinozoans, acritarchs and other groups) that allow attribution to age intervals between the Abereiddian (Darriwilian) and the Streffordian (early Katian). The sedimentary facies shows greatest resemblance to the successions of the Condroz Inlier in Belgium. Palaeogeographically, they constitute the southeasternmost part of eastern Avalonia.

Keywords: Ordovician; Germany; eastern Avalonia; biostratigraphy; trilobites.

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Manuscript received 5 June 2013. Revised manuscript accepted 15 December 2013.

Introduction

Most of the Ordovician outcrops of Germany lie in the central and eastern parts of the country and are related to the Variscan Orogenic Belt that includes the Saxo-Thuringian and the Moldanubian Zones (e.g. Linnemann et al. 2000). There are few outcrops in the western part of Germany, with the most fossiliferous succession being a series of siliciclastic formations of Middle to Late Ordovician age in the Ebbe and Remscheid–Altena inliers in the northeastern part of the Rhenish Massif (Rheinisches Schiefergebirge), east of the river Rhine. The objective of this study is to summarize the extensive (mostly palaeontological) studies in the Ebbe Inlier that have been carried out since the 1990s. The stratigraphical succession can now be dated and the four lithological entities are calibrated against the revised Ordovician chronostratigraphic chart and the stage slices of Bergström et al. (2009). The palaeoenvironment and the palaeogeography of the Ebbe Inlier are also shortly summarized.

Ordovician sediments in western Germany and the Ebbe Inlier

There are few outcrops of Ordovician rocks in western Germany. The Stavelot Inlier in eastern Belgium has a small

extension into Germany, near Aachen, with the lowermost part of the Ordovician (lower part of the Belgian Salm Group) being present in several outcrops. The Ordovician succession comprises two lithological units: the Wehebach-Jalhay Formation containing Tremadocian graptolites and acritarchs and the unfossiliferous Thönbach-Ottre Formation of uncertain age (Ribbert et al. 2001).

Farther to the south, several other areas with possible Ordovician rocks are located in the Rheno-Hercynian nappes found in central Germany as far south as the Northern Phyllite Belt (Servais et al. 2008). The age of these sediments is not clearly known, with different units (including the “Andreas-teich-Quarzit”) being tentatively placed in the Ordovician (Servais et al. 2008). A few formations (Mömbris Formation, Hörstein-Huckelheim Formation and Geiselbach Formation) have been placed in a late Cambrian to Silurian interval but lack precise palaeontological or stratigraphical data (Servais et al. 2008).

The only other area in southwestern Germany with fossiliferous Cambrian–Ordovician rocks lies in the Black Forest. This massif also constitutes a part of the Variscan Orogenic Belt, which extends from the Iberian Peninsula to the Bohemian Massif. In the Black Forest, some parts of the

metasediments of the Traischbach series are dated as Late Cambrian–Early Ordovician (Montenari & Servais 2000; Montenari et al. 2000), based on palynological (acritarch) data that indicate correlation with the Villé schists of the northern Vosges Mountains, where Reitz & Wickert (1989) identified a similar acritarch assemblage.

Similar to the Black Forest, most other areas in western Germany with possible Lower Palaeozoic rocks have not been precisely dated and their stratigraphical position thus remains highly speculative (Servais et al. 2008).

The only exception are the exposures of Ordovician and Silurian sediments, structurally surrounded by Lower Devonian (Lochkovian) rocks, which occur in two tectonic inliers in the northeastern part of the Rhenish Massif: the Ebbe Inlier and the Solingen-Remscheid-Altena Inlier in the Sauerland, east of Cologne.

Ebbe Inlier stratigraphy

The oldest sediments of the northeastern part of the Rhenish Massif are found in the Ebbe Inlier. The geological mapping of this area began in the 1910s by Alexander Fuchs (e.g. 1922) who recognized “pre-Devonian” sediments that he attributed to the “Herscheider Schiefer”. Richter & Richter (1937) described the first Ordovician trilobites in the succession, followed by Eisenack (1939) who confirmed the Ordovician age of the Herscheid Group with his discovery and study of acritarchs and chitinozoans. Subsequently, Jentsch & Stein (1961) reported a few graptolites and trilobites.

The Ebbe Inlier displays Ordovician sediments that have been attributed to four different formations, although the lithological monotony of the succession makes it difficult to distinguish between them (Eiserhardt et al. 1981, 2001a). The sediments comprise strongly tectonized black and grey mudstone and siltstone, a clastic succession with an estimated thickness of 800 m and no carbonate content (Degens et al. 1980).

The oldest formation is the Plettenberg Bänderschiefer Fm., up to 65 m thick, consisting of monotonous dark-grey to bluish compact mudstones with abundant thin silty layers and common pyrite (Eiserhardt et al. 1981, 2001a). This formation has almost the same fossil content as the Huy Formation in the Condroz Inlier in Belgium. Most of the graptolites and acritarchs are identical (Servais & Maletz 1992).

The overlying 150–200 m thick Kiesbert Tonschiefer Fm. comprises dark-grey to bluish and black mudstone with infrequent sandy layers. It has almost the same fossil content as the underlying formation, with trilobites and graptolites, ostracods, phyllocarids, conulariids, brachiopods and ichnofossils (see below).

The Rahlenberg Grauwackenschiefer Fm. is estimated to be about 300 m thick and consists of massive black to grey and bluish grey silty mudstone with sandy layers. Macrofossil groups are very rare, but include conulariids, trilobites, malacostracans and graptolites.

The presumably youngest of the Herscheid Group units is the Solingen Tonschiefer Fm., a dark-grey to black mudstone with coarser silty or sandy bands, which reaches about 200 m thickness in the Ebbe Inlier. This formation contains far fewer fossils, with only a few trilobites, very few graptolites and phyllocarids, and rare trace fossils. Only recent palynological investigations provided data for a more precise age of the upper two formations (see below).

Fossils, biostratigraphy and palaeobiogeography

Trilobites

Trilobites have been investigated in detail with a large number of publications in the last 20 years (e.g. Koch & Lemke 1994, 1995, 1997; Koch 1999a, 1999b; Koch et al. 2011a, 2011b; for complete references, see Owens & Servais 2007). Trilobites are scarce, but sustained collecting by the senior author has produced about 80 specimens from localities in the vicinity of Plettenberg and Kiesbert. The most abundant faunas are present in the Plettenberg Bänderschiefer Fm. and the Kiesbert Tonschiefer Fm., attributed to the British Aberiddian regional stage (lower Llanvirn, Darriwilian). The faunas clearly represent the cyclopygid trilobite biofacies, with a domination of cyclopygids that comprise between 60% and 85% of the trilobites present. *Pricyclopyge binodosa* Salter is the most widespread species together with *Waldminia spinigera* Koch & Lemke, which is similar to, and perhaps congeneric with *Girvanopyge* (Owens & Servais 2007). Most of the other trilobites are blind forms representing an atheloptic fauna.

Graptolites

Graptolite collections allowed Maletz & Servais (1993) to attribute the Plettenberg Bänderschiefer to the “lower Llanvirn (Darriwilian) *Didymograptus artus* graptolite Biozone”. Subsequently, Eiserhardt et al. (2001a) suggested the *Holmograptus lentus* graptolite Biozone (lower part of the *D. artus* zone). The overlying Kiesbert Tonschiefer Fm. is slightly younger than the Plettenberg Bänderschiefer Fm. and corresponds to the *Nicholsonograptus fasciculatus* graptolite Biozone (Maletz & Servais 1993; Eiserhardt et al. 2001a). The graptolites of the two overlying units are not sufficiently diagnostic to be biostratigraphically useful, although the presence of a possible *Pseudoclimacograptus* sp. in the Rahlenberg Grauwackenschiefer Fm. suggests an early Caradoc (Sandbian) age (Maletz 2000).

Ostracods and foraminifera

Ostracods of the Ebbe Inlier were investigated by Schallreuter & Koch (1999, 2011) following their discovery in the 1990s. Only four taxa are identified, and three further taxa have been described in open nomenclature. Schallreuter & Koch (2011) indicated that the fauna is one of the very few known pelagic ostracod communities from the Ordovician, which probably lived epiplanktonically within floating seaweed in the Rheic Ocean on the margin of Perigondwana. In addition, a few agglutinated foraminifera have also been described from the Plettenberg Bänderschiefer Fm. by Riegraf & Niemeyer (1996).

Phyllocarids

Koch & Brauckmann (1998) described phyllocarid crustaceans from the Plettenberg Bänderschiefer Fm. and the Kiesbert Tonschiefer Fm. and attributed the determinable specimens to *Caryocaris wrightii* Salter and *Caryocaris* sp. This discovery was included in the general revision of phyllocarid crustaceans by Vannier et al. (2003) who showed that these organisms indicate the beginning of a cosmopolitan arthropod zooplankton distribution in the Ordovician seas.

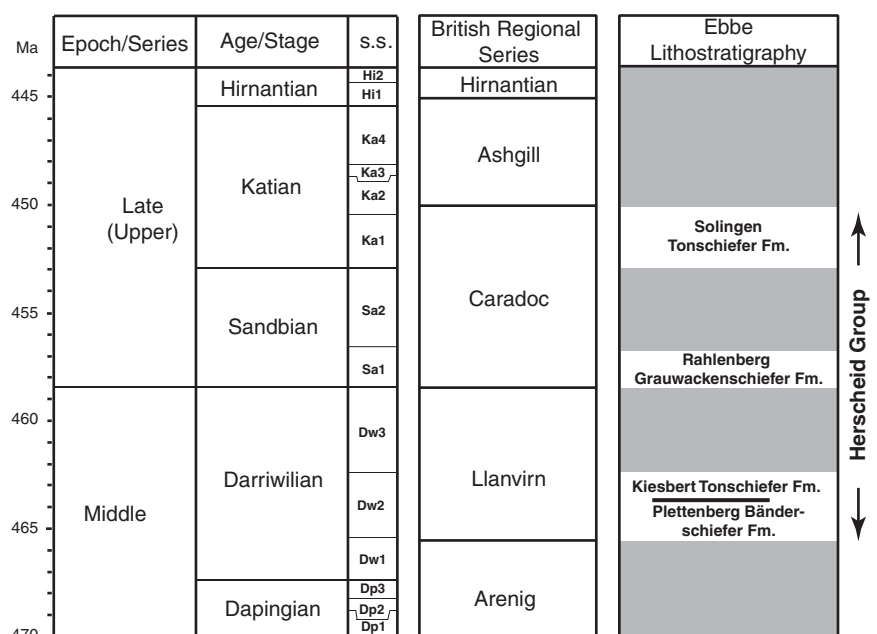
Ichnofossils

Besides the ichnofossil *Chondrites*, the mysterious fossil *Tomaculum* Groom is commonly found in the lower part of the Herscheid Group. *Tomaculum* is fairly abundant and was therefore used as a biostratigraphical index fossil to recognize the Plettenberg Bänderschiefer Fm. and the Kiesbert Tonschiefer Fm. Eiserhardt et al. (2001b) revised the genus and its nomenclatural history in detail. They noted that *Tomaculum* is the senior synonym of *Syncoprulus* Richter & Richter. They also suggested that *Tomaculum* pellets and strings are the faecal pellets of an epibenthic animal, possibly a gastropod, and that the ichnogenus is indicative for the Ordovician only in the broadest sense. Most interestingly, *Tomaculum* shows very similar distribution patterns and abundances in the Huy Formation of the Belgian Condros Inlier (Servais & Maletz 1992).

Acritarchs and chitinozoans

Although already analysed by Eisenack (1939), no further palynological studies were carried out before the more recent investigations by Maletz & Servais (1993), who recovered moderately abundant and diversified acritarch assemblages, which confirmed the early Llanvirn (Darriwilian) age provided by graptolites of the two lowermost formations. Samuelsson et al. (2002) confirmed the age of the Plettenberg Bänderschiefer Fm. with chitinozoans that also indicate an Aberiidian (early Llanvirn, Darriwilian) age, while the Kiesbert Tonschiefer Fm. provided chitinozoans of a late Aberiidian to Llandeilian (Llanvirn, Darriwilian) age (Samuelsson et al. 2002). The first precise biostratigraphical data for the Rahlenberg Grauwackenschiefer Fm. were provided by the chitinozoan studies of Samuelsson et al. (2002) indicating an Aurelucian (earliest Caradoc, Sandbian) age. Chitinozoans indicate that the topmost part of the Solingen Tonschiefer Fm. falls within an age range of early to late Caradoc (Sandbian–Katian). Combined with the Nd-isotope data, this was refined to a probable late Caradoc age (early Katian) (Samuelsson et al. 2002).

Fig. 1. Revised chronostratigraphy of the four formations of the Herscheid Group. s.s. = stage slices, after Bergström et al. (2009). Calibration with the British chronostratigraphy after Cocks et al. (2010).



Chronostratigraphy

From the palaeontological data collected in recent years, the chronostratigraphic position of the four formations occurring in the Ebbe Inlier is now more or less precisely known (Fig. 1). Based on graptolite and chitinozoan faunas, the Plettenberg Bänderschiefer Fm. can clearly be attributed to the Darriwilian (upper part of the Middle Ordovician), corresponding to the British Aberiidian stage (lower Llanvirn Series, Darriwilian). In terms of stage-slices (Bergström et al. 2009), the Plettenberg Bänderschiefer Fm. can be attributed to the stage-slice Dw2. The Kiesbert Tonschiefer Fm. is slightly younger, also belonging to the Aberiidian, most probably belonging to stage-slice Dw2.

The Rahlenberg Grauwackenschiefer Fm. can be placed into the lower Sandbian (Upper Ordovician), corresponding to the British Aurelucian stage (lower part of the British Caradoc), corresponding to stage-slice Sa1. The Solingen Tonschiefer Fm. is less precisely positioned, but chitinozoans and Nd-isotopes indicate a middle Katian (Upper Ordovician) position, in terms of British stratigraphy corresponding to the upper Caradoc, possibly the Streffordian stage, which places this formation in stage-slices Ka1-2.

Palaeoenvironment and palaeobiogeography

The Ordovician sequence of the Ebbe Inlier indicates deeper water facies, probably corresponding to the outer shelf and upper slope, as clearly indicated by the cyclopygid trilobite biofacies and other fossils (Fig. 2).

The sequence cannot be related to any other Ordovician succession in Germany occurring farther south and east, which all belong to different parts of the tectonostratigraphic entities within the Variscan Orogenic Belt. However, the Ordovician succession in the Ebbe Inlier is surprisingly similar to the Ordovician sequence in the Condros Inlier in Belgium, both in terms of litho- and biostratigraphy (Servais & Maletz 1992; Owens & Servais 2007). In addition, the successions of Rügen and western Pomerania (northeastern Germany and northwestern Poland) show many similarities in both biofacies and fossil content, with similar graptolites (Maletz 1998), acritarchs and chitinozoans

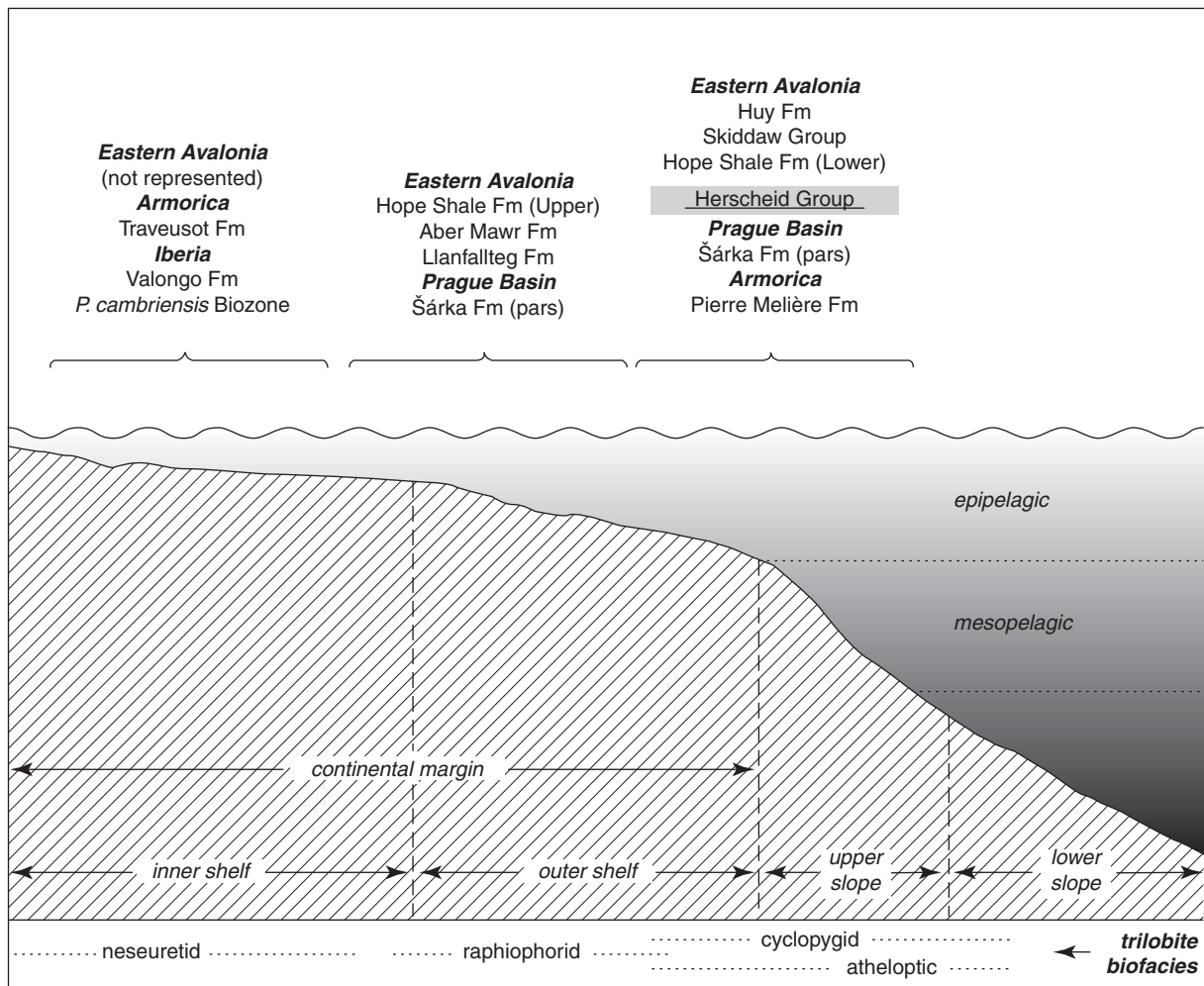


Fig. 2. Biofacies of the Herscheid Group, modified after Owens & Servais (2007), and comparison with units from Avalonia (UK; Belgium) and the Gondwanan margin.

(Servais 1994; Servais et al. 2001). As suggested in previous studies (e.g. Katzung et al. 1995), it now appears that the Ordovician of the Ebbe Inlier and the Ordovician succession of the Belgian Condros Inlier might have been deposited in the same sedimentary basin and that this sedimentary environment possibly extended to northern Germany to the Island of Rügen. This conclusion supports the idea of a continuation of eastern Avalonia east of the Brabant Massif into western and northeastern Germany. Most interestingly, the Nd-isotope studies of Samuelsson et al. (2002) show a remarkable similarity between the Ebbe Inlier and the Stavelot-Venn Inlier and the Brabant Massif in Belgium, and also with the English Lake District and the Welsh Basin. The Skiddaw Group of the English Lake District was indeed deposited in a very similar environment and displays comparable faunas (e.g. Cooper et al. 2000). The Ebbe Inlier thus most probably constitutes the southeasternmost part of the microcontinent Avalonia.

Acknowledgements – The authors acknowledge the referees Robert Owens (Cardiff) and Oliver Lehnert (Erlangen) for their valuable comments and suggestions. This paper is a contribution to IGCP 591 (The Early to Middle Palaeozoic Revolution).

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