

## Reply to the Comment to the “The Devonian-Carboniferous boundary in the Graz Paleozoic (Eastern Alps, Austria) and its global significance” by Ana-Voica Bojar and Franz Neubauer

### Respuesta al Comentario a “The Devonian-Carboniferous boundary in the Graz Paleozoic (Eastern Alps, Austria) and its global significance” de Ana-Voica Bojar y Franz Neubauer

Sandra I. Kaiser<sup>1,\*</sup> , Bernhard Hubmann<sup>2</sup> 

<sup>1</sup> Formerly at State Museum of Natural Science Stuttgart. Rosenstein 1, 70191 Stuttgart, Germany.

<sup>2</sup> Institute of Earth Sciences, Karl-Franzens University of Graz. Universitaetsplatz 3 8010 Graz, Austria.

\* Corresponding author:  
(S. I. Kaiser) [dr.sandra.kaiser@gmail.com](mailto:dr.sandra.kaiser@gmail.com)

#### 0. <Paleozoic deposits around Graz>

It is correct, as the comment notes, that the Paleozoic deposits around Graz have been the subject of geological research since they were first mentioned by Leopold von Buch (1820). Hubmann and Krenn (2022) recently provided an overview of the highlights of the 200-year research history of these geological sequences, which were much later referred to as the “Graz Paleozoic.” And yes, it is also true that the less metamorphic sequences of the Graz Paleozoic “*have been the subject of numerous paleontological and sedimentological studies,*” as Kaiser and Hubmann (2024) correctly mentioned. A comprehensive bibliographic review of the geological literature on the Graz Paleozoic covering the period up to the turn of the millennium is available (Hubmann 2000). It lists almost 590 specialist articles and around 150 references to “gray literature.” Therefore, we consider it justified to mention only the most recent works on “*paleontological and sedimentological investigations*” and “*the nappe structure of the Graz Paleozoic*” as examples (hence “*e.g.*”), because this is necessary for the readability of our study – its focus is, after all, on the significance of the “*Devonian-Carboniferous boundary*”, as the title suggests.

#### 1. <Worldwide the Hangenberg Event at the DCB is characterized by either the transgressive Hangenberg Black Shale and regressive Hangenberg sandstone deposits.>

It is correct that several authors, among them Walliser (1984), Caplan and Bustin (1999) and Schmidt (1924), first mentioned the Hangenberg Shale at the Devonian-Carboniferous boundary (DCB). However, Kaiser et al. (2016) has been cited in Kaiser and Hubmann (2024) because this publication gives an extended review summary, and all these three works mentioned above are cited in Kaiser et al. (2016). Further, the Hangenberg Shale is meanwhile differentiated, based on the Rhenish successions, into the Hangenberg Black Shale (HBS), subordinate the regressive Hangenberg Shale (HS), and the regressive Hangenberg Sandstone (HBS), see for example Bless et al.

#### How to cite this article:

Kaiser, S. I., & Hubmann, B. (2026). Reply to the Comment to the “The Devonian-Carboniferous boundary in the Graz Paleozoic (Eastern Alps, Austria) and its global significance” by Ana-Voica Bojar and Franz Neubauer. *Boletín de la Sociedad Geológica Mexicana*, 78(1), A140925. <https://doi.org/10.18268/BSGM2026v78n1A140925>

Reply received: September 10, 2025.

Peer Reviewing under the responsibility of Universidad Nacional Autónoma de México.

This is an open access article under the [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/) (<https://creativecommons.org/licenses/by-nc-nd/4.0/>)

(1993), Kaiser et al. (2016) and Becker et al. (2016, 2021).

## 2. <Overview of geology and facies development in the Graz Paleozoic>

The thin shaly layer (argillaceous layer) is interpreted by Kaiser's studies as an equivalent of the Hangenberg Black Shale (HBS), or *ckI*, respectively. This assumption is based on the stratigraphic position of this layer (main extinctions among conodonts, major conodont faunal change, last occurrence of *Bispathodus costatus* below and first occurrence of *Protognathodus kockeli* above=*costatus-kockeli* Interregnum, *ckI*) which is correlative with the Hangenberg Black Shale (or Hangenberg Shale/Hangenberg Sandstone) level. This interpretation does not exclude a tectonic disturbance (steep fault zone) at this level as described by Flügel & Ziegler (1957). Therefore, Flügel and Ziegler (1957) have been cited by Kaiser (2005), Kaiser et al. (2008), Kaiser et al. (2020) and Kaiser and Hubmann (2024) when referring to the lithologic section at Trolp.

## 3. <Geochemistry and conodonts of the DCB transition at Trolp>

It is correct that the first occurrence (FO) of *Siphonodella sulcata* defines the DCB, and we agree with this definition, and use the FO of *Siphonodella sulcata* for defining the DCB.

Bojar et al. (2013) fix the DCB level with the FO of *Siphonodella sulcata* recorded by Ebner (1980) - which is Bed 8 of Ebner (1980), and not the bottom of Bed 7 as the authors wrote (see their Fig. 3a in Bojar et al. 2013) –and they correlate this Bed 8 (Bed 7?) with Kaiser's FO of *Siphonodella sulcata* in Bed 16 (see Fig. 3b in Bojar et al. 2013). Kaiser's DCB position (Kaiser et al. 2020, Kaiser and Hubmann 2024) which is based on the joint FO of *Siphonodella sulcata*, *Polygnathus purus subplanus*, and *Protognathodus kühni* (Bed 16),

is correlated by Kaiser and Hubmann (2024) with Ebner's DCB position (Bed 4: FO of *Polygnathus purus subplanus*, Ebner 1980). Because *Siphonodella sulcata* could have a late entry, and has obviously a late record in Ebner (1980), alternative index fossils such as *Polygnathus purus subplanus* or *Protognathodus kühni* are used in conodont stratigraphy to fix the DCB position (*e.g.*, Kaiser et al. 2009; Spalletta et al. 2017; see extended discussions in Kaiser et al. 2020).

Regarding Fig. 8 in Kaiser and Hubmann (2024), we do not state that Ebner (1980) recorded *Protognathodus kühni* (he did not) but the joint *sulcata/kühni* Zone is used as a biozone; this biozone was established previously, instead of the *sulcata* Zone (see extended discussions in Kaiser et al. 2020; Becker et al. 2021).

A further comment to La Serre É: The position of the DCB and the GSSP was ratified at the base of Bed 89 at La Serre (Flajs and Feist 1988), but conodont studies of Kaiser (2005, 2009) recorded the FO of *Siphonodella sulcata* as defining species of the DCB in stratigraphic older levels (Bed 84b).

Regarding the conodont record of Nössing (1975),

- Section 2 and Section 3 were exchanged in Fig. 1 by Nössing (1975).
- The sampling density of Nössing's studies was relatively low.
- The successions shown in his Fig. 1 are inverted. Kaiser and Hubmann (2024) in Fig. 8 referred to the FO of relevant index conodonts of Nössing (1975). Therefore, only sample numbers of the oldest stratigraphic level (=the first occurrence) are shown in Fig. 8 (which is Sample 118, and Sample 209 of the basal *sulcata* Zone=DCB level). Nössing (1975) recorded at the top of the thin-bedded limestones the FO of *Siphonodella sulcata* (oldest stratigraphic level=Sample 118, Section 1) and FO of *Protognathodus kockeli* (oldest stratigraphic level=Sample 118, Section 1, Sample 209, Section 2), *Polygnathus purus subplanus* (oldest stratigraphic level= Sample 209, Section 2) and *Protognathodus kühni* (oldest stratigraphic level= Sample 209, Section 2). Therefore,

Sample 115 yielding *Protognathodus kühni* is not relevant for the study of Kaiser and Hubmann (2024) and therefore not shown in Fig. 8, because it is a younger stratigraphic level probably in the Tournaisian.

- In summary, Nössing (1975) recorded the FO of *Siphonodella sulcata* in Section 1, preceding the FO of *Polygnathus purus subplanus*, and he recorded at coeval levels the FO of *Polygnathus purus subplanus* in Section 2, preceding the FO of *Siphonodella sulcata*. Probably, this record of Nössing (1975) led to the conclusion of Ebner (1980) to fix the DCB with the FO of *Polygnathus purus subplanus* (his Table 8).

Last, moving the boundary 10 cm below, as the authors stated, the negative excursion of Bojar et al. (2013) is not just at the DCB, and is thus not associated with environmental changes during the Hangenberg Event, but it is in younger stratigraphic levels in the Tournaisian (*sulcata-duplicata* conodont Zones).

We agree with the authors that the occurrence of *Siphonodella sulcata* (note: *Si. sulcata* M5) remains a reliable criterion for establishing the DCB worldwide, and for establishing the DCB at Steinberg/Tropl. It has to be mentioned that the work of Bojar et al. (2013) is an important contribution to the studies at Tropl and studies at the DCB, and the investigated locality, as shown in their Figure 3d (Bojar et al. 2013), is exceptional because it is deposited in continuous limestones facies during the first order Hangenberg mass-extinction Event at the DCB.

## References

- Becker, R. T., Kaiser, S. I., Aretz, M. (2016). Stratigraphical review of the global Hangenberg Crisis and Devonian–Carboniferous transition. In R. T. Becker, R. Königshof, C. E. Brett (Eds.), *Devonian Climate, Sea Level and Evolutionary Events*. Geological Society, London, Special Publications 423, 1–38.
- Becker, R. T., Hartenfels, S., & Kaiser, S. I. (2021). Review of Devonian–Carboniferous Boundary sections in the Rhenish Slate Mountains (Germany). *Palaeobiodiversity and Palaeoenvironments*, 101(2), 357–420. <https://doi.org/10.1007/s12549-020-00469-6>
- Bless, J. M., Becker, R. T., Higgs, K., Paproth, E. & Streel, M. (1993). Eustatic cycles around the Devonian–Carboniferous boundary and the sedimentary and fossil record in Sauerland (Federal Republic of Germany). *Annales de la Société Géologique de Belgique*, 115(2), 689–702.
- Bojar, A.V., Neubauer, F. & Koeberl, Ch. (2013). Geochemical record of Late Devonian to Early Carboniferous events, Palaeozoic of Graz, Eastern Alps, Austria. In A. Gasiewicz, M. Slowakiewicz (Eds.), *Palaeozoic Climate Cycles: Their Evolutionary and Sedimentological Impact* (pp. 87–108). Geological Society London. <https://doi.org/10.1144/SP376.15>
- Buch, L. V. (1820). Ueber einige Berge der Trappformation in der Gegend von Grätz. *Abhandlungen der physikalischen Klasse der Königlich-Preußischen Akademie der Wissenschaften*, 111–118.
- Caplan, M. L., & Bustin, R. M. (1999). Devonian–Carboniferous Hangenberg mass extinction event, widespread organic-rich mudrock and anoxia: causes and consequences. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 148(4), 187–207. [https://doi.org/10.1016/S0031-0182\(98\)00218-1](https://doi.org/10.1016/S0031-0182(98)00218-1)
- Ebner, F. (1980). Conodont localities in the surroundings of Graz/Styria. *Abhandlungen der Geologischen Bundesanstalt Wien*, 35, 101–127.
- Flajs, G. & Feist, R. (1988). Index conodonts, trilobites and environment of the Devonian–Carboniferous boundary beds at La Serre (Montagne Noire, France). *Courier Forschungs-Institut Senckenberg*, 100, 53–107.
- Flügel, H. & Ziegler, W. (1957). Die Gliederung des Oberdevons und Unterkarbons am Steinberg westlich von Graz mit Conodonten. *Mitteilungen des naturwissenschaftlichen Vereines für Steiermark*, 87, 25–60.
- Hubmann, B. & Krenn, K. (2022). Zweihundert

Jahre erdwissenschaftliche Forschungs- und Ideengeschichte des Grazer Paläozoikums im Überblick. *Res Montanarum. Zeitschrift des Montanhistorischen Vereins für Österreich*, 62, 61–76.

- Hubmann, B. (2000). Grazer Paläozoikum: Bibliographie 1819-1999. In H.W. Flügel & B. Hubmann (Eds.), *Das Paläozoikum von Graz: Stratigraphie und Bibliographie*. (pp. 61–118). Österreichische Akademie der Wissenschaften Wien.
- Kaiser, S. I. (2005). *Mass Extinction, Climatic and Oceanographic Changes at the Devonian–Carboniferous Boundary*. [Doctoral Thesis] Faculty of Natural Sciences, Ruhr University of Bochum.
- Kaiser, S. I. (2009). The Devonian/Carboniferous boundary stratotype section (La Serre, France) revisited. *Newsletters on Stratigraphy*, 43(2), 195–205. <https://doi.org/10.1127/0078-0421/2009/0043-0195>
- Kaiser, S. I., & Hubmann, B. (2024). The Devonian-Carboniferous boundary in the Graz Paleozoic (Eastern Alps, Austria) and its global significance. *Boletín de la Sociedad Geológica Mexicana*, 76(3), A210524. <https://doi.org/10.18268/BSGM2024v76n3a210524>
- Kaiser, S. I., Aretz, M. & Becker, R.T. (2016). The global Hangenberg Crisis (Devonian-Carboniferous transition)—review of a first order mass extinction. In Becker, R.T., Königshof, R., Brett, C.E. (Eds.), *Devonian Climate, Sea Level and Evolutionary Events*. (pp. 387–437). Geological Society, London. <https://doi.org/10.1144/SP423.9>
- Kaiser, S. I., Becker, R. T., Spalletta, C. & Steuber, T. (2009). High-resolution conodont stratigraphy, biofacies and extinctions around the Hangenberg Event in pelagic successions from Austria, Italy and France. *Palaeontographica Americana*, 63, 97–139.
- Kaiser, S. I., Kumpan, T. & Rasser, M. W. (2020). High-resolution conodont biostratigraphy in two key sections from the Carnic Alps (Grüne Schneid) and Graz Paleozoic (Trolp) - implications for the biozonation concept at the Devonian-Carboniferous boundary. *Newsletters on Stratigraphy*, 53(3), 249-274. <https://doi.org/10.1127/nos/2019/0520>
- Kaiser, S. I., Steuber, T., & Becker, R. T. (2008). Environmental change during the Late Famennian and Early Tournaisian (Late Devonian–Early Carboniferous): implications from stable isotopes and conodont biofacies in southern Europe. *Geological Journal*, 43(2–3), 241–260. <https://doi.org/10.1002/gj.1111>
- Nössing, L. (1975). Die Sanzenkogel-Schichten (Unterkarbon), eine biostratigraphische Einheit des Grazer Paläozoikums. *Mitteilungen des Naturwissenschaftlichen Vereins für Steiermark*, 105, 79–92.
- Schmidt, H. (1924). Zwei Cephalopodenfaunen an der Devon-Karbon-Grenze im Sauerland. *Jahrbuch der Preussischen Geologischen Landes-Anstalt*, 44, 98–171.
- Spalletta, C., Perri, M. C., Over, J. & Corradini, C. (2017). Famennian (Upper Devonian) conodont zonation: revised global standard. *Bulletin of Geosciences*, 92(1), 31–57. <https://doi.org/10.3140/bull.geosci.1623>
- Walliser, O. H. (1984). Pleading for a natural D/C boundary. *Courier Forschungsinstitut Senckenberg*, 67, 241–246.