Annales Societatis Geologorum Poloniae (2015), vol. 85: 697–701. doi: http://dx.doi.org/10.14241/asgp.2015.035

AMBIGUITIES IN CONCHOSTRACAN BIOSTRATIGRAPHY: A CASE STUDY OF THE PERMIAN–TRIASSIC BOUNDARY

Anna BECKER

Polish Geological Institute-National Research Institute, 4 Rakowiecka Str., 00-975 Warszawa, Poland; e-mail: anna.becker@pgi.gov.pl

Becker, A., 2015. Ambiguities in conchostracan biostratigraphy: a case study of the Permian–Triassic boundary. *Annales Societatis Geologorum Poloniae*, 85: 697–701.

Abstract: In recent years, conchostracan biostratigraphy has become a popular tool for the recognition of the Permian–Triassic boundary and for the chronostratigraphic subdivision of the Triassic in intracontinental settings, including also the bone-bearing Keuper strata of Poland. The ambiguous nature of the new bio-chronostratigraphic approach was characterized in a case study of the Permian–Triassic boundary interval. The most important problems were: (1) the lack of documentation of the index species, (2) the indirect correlation with the conodont stratigraphy in marine reference sections through the sporomorph spectra, (3) the lack of definition and documentation of supporting palynologic zones, and (4) difficulties in reliable taxonomic determination of Conchostraca. Testing and, if necessary, revision of the zonation by several independent research groups is suggested.

Key words: Conchostraca, stratigraphy, Permian–Triassic boundary.

Manuscript received 1 April 2015, accepted 14 October 2015

INTRODUCTION

Conchostraca, in the Polish literature known as Estheriae, are small phyllopod crustaceans with a chitinous bivalved carapace (Webb, 1979). They are numerous in the gray and red sediments of the intracontinental Triassic basins of Europe, otherwise lacking in fossils. Therefore, they became a source of interest as an easily accessible and effective biostratigraphic tool (see Kozur and Seidel, 1983b), and for the dating of the key bone-bearing sections of Upper Silesia (Olempska, 2004; Dzik and Sulej, 2007; Kozur and Weems, 2010; Sulej *et al.*, 2011; see review in Szulc *et al.*, 2015).

Conchostracan zones were defined for the first time by Kozur and Seidel (1983b) for the Zechstein–Buntsandstein boundary interval of central Germany. Further development enabled the construction of a complete conchostracan zonation scheme for the entire Triassic succession of Central Europe and other intracontinental basins of the northern hemisphere (see Kozur and Weems, 2010).

Despite its efficiency, the biostratigraphic tool still remains controversial. This is mainly because of insufficient documentation and ambiguous chronostratigraphic interpreation. The aim of the paper is to outline the fundamental problem with regard to the conchostracan biostratigraphy of the Permian–Triassic boundary interval. The following critical discussion is the modified version of an article already published in Polish (Becker, 2014).

CONCHOSTRACAN ZONES OF THE PERMIAN–TRIASSIC BOUNDARY INTERVAL

The Permian–Triassic boundary (PTB) has been defined at Meishan, China, by the first occurrence of the conodont *Hindeodus parvus* (Kozur and Pjatakova) in an open-shelf carbonate succession (Yin *et al.*, 2001; Gradstein *et al.*, 2004). According to Bachmann and Kozur (2004), Kozur and Bachmann (2005) and Ogg (2012), it coincides with the boundary between the Falsisca postera and Falsisca verchojanica conchostracan zones (Fig. 1). Both zones were established from the Falsisca eotriassica Zone after Kozur and Seidel (1983b), the first conchostracan zone encompassing the Zechstein–Buntsandstein transition, where the PTB was expected to occur. The Falsisca eotriassica Zone *sensu* Kozur and Seidel (1983b) was subdivided into three subzones: the lowermost subzone I with the characteristic species *F. eotriassica eotriassica* Kozur and Seidel, the middle subzone II with the guide species *F. eotriassica postera* Kozur and Seidel and the uppermost subzone III with a diagnostic unrecognized form between *F. eotriassica* n. subsp. and *F.* n. sp. aff. *verchojanica* (Molin) (Fig. 2). After Kozur and Seidel (1983a, b), the characteristic conchostracan forms for all subzones around the PTB were subspecies of *F. eotriassica* Kozur and Seidel. This implies the similarity of them.

Kozur (1999) modified the conchostracan stratigraphy, establishing new, separate zones from the former subzones.

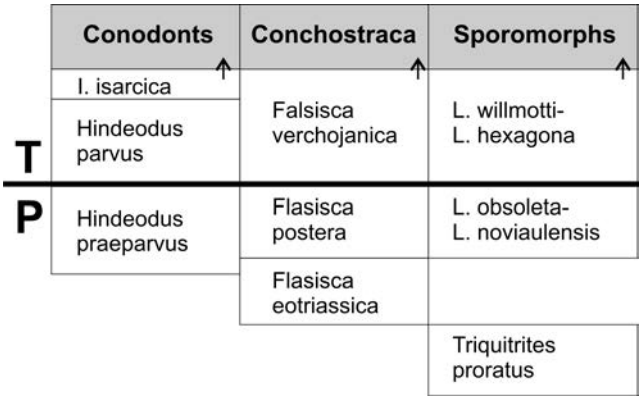

Fig. 1. Stratigraphy of the Permian–Triassic boundary interval in conodont, conchostracan and palynologic zonations after Bachmann and Kozur (2004, fig. 1) and Kozur and Bachmann (2005). Arrows mean continuation of zones beyond the figure.

Subzone I became the Falsisca eotriassica Zone, subzone II the Falsisca postera Zone and subzone III the Falsisca n. sp. aff. F. verchojanica Zone. It is noteworthy that all index forms were unrelated species and the range of the F. eotriassica Zone was reduced to its former first subzone (Fig. 3). Kozur (1999) placed the PTB at the boundary between the F. postera and the F. n. sp. aff. F. verchojanica zones. Kozur (1998a, b) discussed two conchostracan forms with respect to the PTB, i.e. *F. postera* and *F. verchojanica* (not the *F.* n. sp. aff. *F. verchojanica*), which probably was what led him to rename the F. n. sp. aff. F. verchojanica Zone as F. verchojanica Zone (see e.g., Bachmann and Kozur, 2004). Eventually Bachmann and Kozur (2004) established two "verchojanica" zones: the F. verchojanica Zone from the uppermost part of the F. postera Zone (see Kozur, 1993, fig. 1 and Bachmann and Kozur, 2004, fig. 11) and the Falsisca cf. verchojanica Zone from the former F. n. sp. aff. F. verchojanica Zone (Kozur, 1993, 1999; Bachmann and Kozur, 2004). So Bachmann and Kozur (2004) placed the PTB lower than Kozur (1999) had done, at the boundary of the F. postera and F. verchojanica zones, without providing an explanation (Fig. 3). Kozur and Weems (2010) finally stressed that lowermost part of the F. verchojanica Zone could be Permian in age, but nonetheless placed the PTB at the boundary of F. postera and F. verchojanica zones.

Falsisca eotriassica Zone		
Subzone I	Subzone II	Subzone III
F. eotriassica eotriassica		
F. eotriassica postera (only in the upper part of the subzone I)	***F. eotriassica postera***	
Euestheria gutta gutta	*Euestheria gutta gutta*	*Euestheria gutta gutta*
Palaeolimnadia sp. aff. *cishycranica* (only in the lower part of the subzone I)	*Euestheria gutta oertlii*	*Euestheria gutta oertlii*
	Euestheria jakutica	
		F. eotriassica* n. subsp. / F. n. sp. aff. *verchojanica

Fig. 2. Assemblages of conchostracan taxa occurring in Permian–Triassic boundary interval, after Kozur and Seidel (1983a, b). Index taxa are given in bold print.

CORRELATION OF CONCHOSTRACAN-BASED PTB WITH CONODONT STANDARD ZONATION

The methods and pathways of chronostratigraphic correlation, which allowed the conchostracan PTB to be established are summarized in Figure 4, on the basis of an analysis of the publications of Kozur (1987, 1989, 1993, 1998a, b, 1999). The publications discussed the age interpretation of the diagnostic conchostracan species: *Falsisca eotriassica*, *F. postera* and *F. verchojanica* (not the *F.* n. sp. aff. *F. verchojanica*).

Falsisca eotriassica, found in the Nadaskut Dolomite Member in Hungary, was dated as late Chnagsingian, with reference to the accompanying sporomorph assemblage, which resembled the assemblage from the alpine Tesero Oolite, dated as late Changsingian by means of conodonts (Kozur, 1987). The age interpretation of *Falsisca postera* and *F. verchojanica* was more complicated. Both species were found in Dalongkou, Tien-Shan, co-occurring with vertebrates of the genera *Dicynodon* and *Lystrosaurus.* There was a discussion in the literature of the region, as to whether the PTB should be placed at the last-appearance datum of *Dicynodon* or at the first occurrence of *Lystrosaurus* (Cheng *et al.*, 1989, *vide* Kozur, 1998a), because both genera coexist in a transitional zone. The conchostracan sequence of *Falsisca postera* followed by *F. verchojanica* was found precisely in such a transitional zone.

The first conclusion, based on the superposition of both species in the Tien-Shan vertebrate profile, was that *F. verchojanica* is younger than *F. postera* and most probably Triassic in age. Furthermore, *F. verchojanica* was found in south-eastern Siberia, occurring together with a sporomorph assemblage of Permian aspect, but including the Triassic form *Lunatisporites hexagonalis* (Jansonius). This was enough for Kozur (1998a) to interpret the age of the assemblage as Early Triassic. So, thanks to the sporomorph assemblage from south-eastern Siberia, *F. verchojanica* became Early Triassic in age. The older *F. postera* was dated as late Changsingian, on the basis of its co-occurrence with *Dicynodon*. The last-appearance datum of *Dicynodon* was chosen as a PTB indicator, based on conchostracans (Kozur, 1998a). It is worth noting that the position of the PTB in vertebrate sections is still discussed in recent papers (Lucas, 2009; Metcalfe *et al.*, 2009). Metcalfe *et al.* (2009) found the placement of the PTB in the Dalongkou section to be equivocal after extensive multiproxy studies, including the documentation of conchostracans.

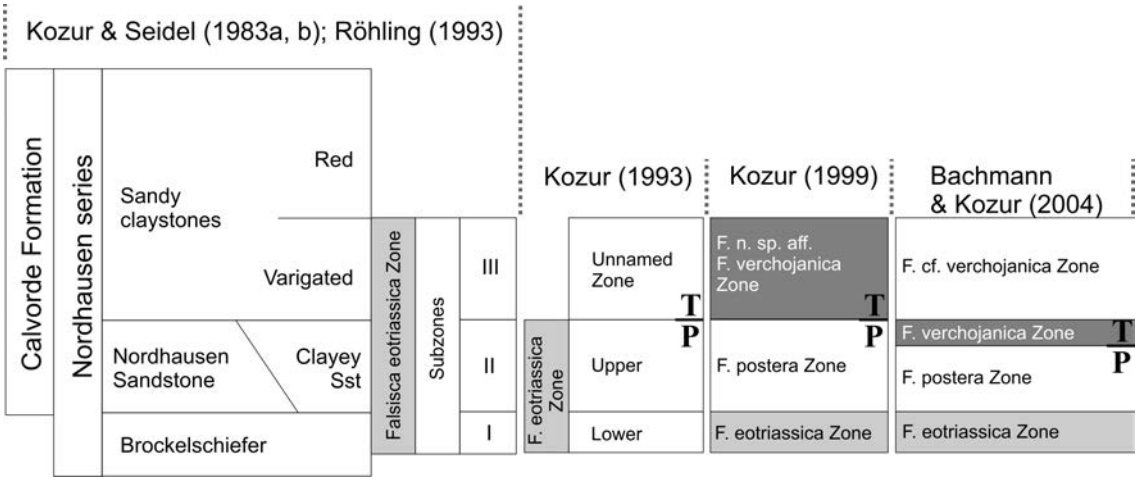

Fig. 3. Evolution of conchostracan zonation of the Permian–Triassic boundary interval, after Kozur and Seidel (1983a, b), Kozur (1993, 1999), Röhling (1993) and Bachmann and Kozur (2004, fig. 11).

PALYNOSTRATIGRAPHY SUPPORTING THE CONCHOSTRACAN STRATIGRAPHY

The fundamental publications, in terms of the chronostratigraphy of the palynological zones of the Permian–Triassic transition, are the works of Balme (1979) from Greenland and of Orłowska-Zwolińska (1984) from Poland (see Kürschner and Herngreen, 2010). The Early Triassic Lundbladispora obsoleta – Protohaploxypinus pantii Zone of Orłowska-Zwolińska (1984) was often discussed critically in terms of conchostracan stratigraphy. Orłowska-Zwolińska (1984) documented and defined the zone carefully, providing a broad discussion of the possible chronostratigraphic interpretation. Later authors acknowledged its credibility (e.g., Ecke, 1986; Reitz, 1988; Kürschner and Herngreen, 2010).

In publications based on conchostracan stratigraphy or cited therein, another palynostratigraphic zonation has been favoured (e.g., Kozur, 1989, 1998a, b, 1999; Szurlies *et al.*, 2003; Bachmann and Kozur, 2004). The two following palynostratigraphic zones enabled the recognition of the Permian and Triassic successions, i.e.: the Lundbladispora obsoleta – Lunatisporites noviaulensis Zone of Permian age and the Lundbladispora willmotti – Lunatisporites hexagona Zone (or – L. hexagonalis Zone; see Fig. 1) of Triassic age. During the preparation of this paper, it was impossible

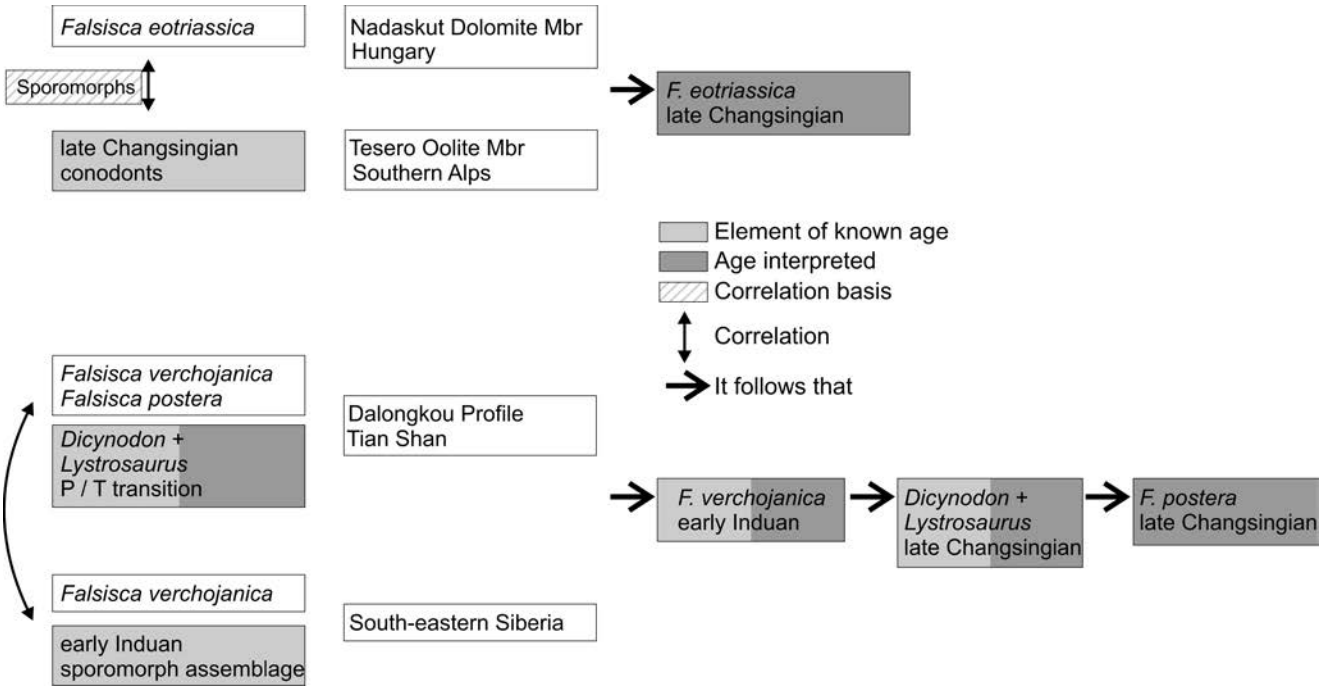

Fig. 4. Diagram of chronostratigraphic interpretation of conchostracan index taxa for the Permian–Triassic boundary, based on Kozur (1987, 1989, 1993, 1998a, b, 1999).

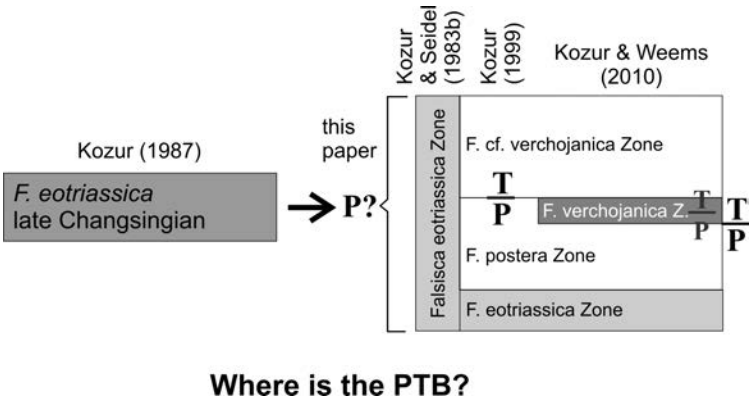

Fig. 5. Uncertainties arising from unresolved problems of conchostracan stratigraphy of the Permian–Triassic transition.

to find a publication, where both zones were precisely defined, documented and discussed. The list of species of the *Lundbladispora obsoleta – Lunatisporites noviaulensis* assemblage with a short commentary could be found only in figure caption 1 (*sic*!) by Kozur (1994). It is not clear what makes the difference between the two zones and the L. obsoleta – P. pantii Zone. In Western Poland, *Lunatisporites noviaulensis* (Leschik) de Jersey can be found up to the Upper Buntsandstein and *Lundbladispora willmotti* was found in all samples with the *Lundbladispora obsoleta – Protohaploxypinus pantii* assemblage (Orłowska-Zwolińska, 1984).

PROBLEMS OF CONCHOSTRACAN TAXONOMIC DETERMINATION

The taxonomic identification of conchostracans appears to be difficult. The most successful results on conchostracan biostratigraphy were those published by Heinz Kozur and co-workers. The publications of independent teams are scarce. Kozur's team was forced to correct the taxonomic determinations of others. Ptaszyński and Niedźwiedzki (2004, 2006) were corrected by Kozur and Weems (2010, p. 365), and Orlova (1990, *vide* Kozur and Weems, 2011) was corrected by Kozur and Weems (2011, pp. 24–25). Even the determinations in the standard publication of Kozur and Seidel (1983a) had to be revised (Kozur and Weems, 2010, p. 364). Kozur and Weems (2010) repeatedly stressed the high susceptibility of conchostracan carapaces or their imprints to plastic deformation in fine-grained deposits, which caused erroneous determinations. The lack of informed discussion of the taphonomically-controlled changes, possibly influencing taxonomic determination, is a basis for additional doubts as to which interpretation is actually correct.

CONCLUSIONS

The study of conchostracan biostratigraphy of the Permian–Triassic boundary interval yielded a number of unresolved problems, summarized below.

1. In the literature on conchostracan stratigraphy, the taxonomic determination of index forms is imprecise and insufficiently documented. It is unclear if index species for the Permian–Triassic boundary interval are the subspecies of one species or unrelated species.

2. The ranges of conchostracan zones were changed without explanation and commentary, e.g. in the case of the F. eotriassica Zone, making the refined analysis of zonal documentation almost impossible.

3. The definition of the base of the Triassic is unclear in conchostracan stratigraphy (Fig. 5). The first Triassic F. verchojanica Zone can be partly Permian in age (Kozur and Weems, 2010) and *F. eotriassica*, originally thought to be diagnostic for the whole Permian–Triassic transitional zone (Kozur and Seidel, 1983b), is late Changsingian in age after Kozur (1987).

4. The correlation of conchostracan zonation with the conodont-based Permian–Triassic boundary in marine successions was carried out indirectly using sporomorph assemblages and vertebrates from different parts of the world. The correlation tools frequently suffer from doubtful documentation and imprecise resolution.

5. An analysis of literature shows that a reliable taxonomic determination of conchostracans is difficult to achieve, raising doubts to its usefulness in stratigraphy. One of the reasons reported by Kozur and Weems (2010) themselves can be the variable preservation of conchostracans carapaces.

These conclusions cast doubt on the results achieved by the biostratigraphic approach reported for zonation of the Upper Triassic, as well. Maron *et al.* (2015) recently highlighted speculative terrestrial-marine correlations in the case of late Carnian conchostracan-based stratigraphy. Therefore, there is an urgent need to test and possibly to revise the Triassic conchostracan zonation for a credible and efficient biostratigraphic method, which could be very helpful for further research on the intracontinental Triassic basins.

Acknowledgements

The research was financed from statutory funds (PGI-NRI Grant No. 6.90.0034.00.0). The author would like to acknowledge the very helpful remarks of S. G. Lucas and R. E. Weems, which allowed her to improve the manuscript.

REFERENCES

Bachmann, G. H. & Kozur, H. W., 2004. The Germanic Triassic: correlations with the international chronostratigraphic scale, numerical ages and Milankovitch cyclicity. *Hallesches Jahrbuch für Geowissenschaften*, 26: 17–62.

Balme, B. E., 1979. Palynology of Permian–Triassic boundary beds at Kap Stosch, east Greenland. *Meddele Grønland*, 200, 6: 1–37.

Becker, A., 2014. Conchostracan stratigraphy of the Permian/Triassic boundary interval – reality or myth? *Przegląd Geologiczny*, 62: 184–189. [In Polish, with English summary.]

Cheng, Z., Han, Y., Hou, J., Li, J., Li, P., Li, Y., Liu, S., Liu, Y., Qu, L., Shen, B., Sun, S., Wu, S., Xiao, S., Yang, J. & Zhang, Z., 1989. *Research on the boundary between Permian and Triassic strata in Tianshan Mountain of China*. China Ocean Press, Beijing, 165 pp.

Dzik, J. & Sulej, T., 2007. A review of the early Late Triassic Krasiejów biota from Silesia, Poland. *Palaeontologia Polonica*, 64: 3–27.

Ecke, H.-H., 1986. *Palynologie des Zechsteins und Unteren Buntsandsteins im Germanischen Becken*. Unpublished PhD thesis, University of Göttingen, 117 pp.

Gradstein, F., Ogg, J. & Smith, A. (eds), 2004. *A Geologic Time Scale 2004*. Cambridge University Press, Cambridge, 589 pp.

Kozur, H., 1987. Stratigraphisch wichtige Fossilfunde in der Werfen-Gruppe des Balaton-Hochlandes (vorläufige Mitteilung). *Geologisch-Paläontologische Mitteilungen, Innsbruck*, 14 (7): 157–167.

Kozur, H., 1989. The Permian–Triassic boundary in marine and continental sediments. *Zentralblatt für Geologie und Paläontologie Teil I*, 1988: 1245–1277.

Kozur, H. W., 1993. Range charts of conchostracans in the Germanic Buntsandstein. In: Lucas, S. G. & Morales, M. (eds), *The nonmarine Triassic*. *New Mexico Museum of Natural History & Science Bulletin*, 3: 249–253.

Kozur, H., 1994. The correlation of the Zechstein with the marine standard. *Jahrbuch der Geologischen Bundesanstalt*, 137: 85–103.

Kozur, H. W., 1998a. Some aspects of the Permian–Triassic boundary (PTB) and of the possible causes for the biotic crisis around this boundary. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 143: 227–272.

Kozur, H. W., 1998b. Problems for evaluation of the scenario of the Permian–Triassic boundary biotic crisis and of its causes. *Geologia Croatica*, 51: 135–162.

Kozur, H. W., 1999. The correlation of the Germanic Buntsandstein and Muschelkalk with the Tethyan scale. *Zentralblatt für Geologie und Paläontologie Teil I*, 1998: 701–725.

Kozur, H. W. & Bachmann, G. H., 2005. Correlation of the Germanic Triassic with the international scale. *Albertiana*, 32: 21–35.

Kozur, H. & Seidel, G., 1983a. Revision der Conchostracen-Faunen des unteren und mittleren Buntsandsteins. Teil I. *Zeitschrift für geologische Wissenschaften*, 11: 295–423.

Kozur, H. & Seidel, G., 1983b. Die Biostratigraphie des unteren und mittleren Buntsandsteins des Germanischen Beckens unter besonderer Berücksichtigung der Conchostracen. Teil II. *Zeitschrift für geologische Wissenschaften*, 11: 429–464.

Kozur, H. W. & Weems, R. E., 2010. The biostratigraphic importance of conchostracans in the continental Triassic of the northern hemisphere. In: Lucas, S. G. (ed.), *The Triassic timescale*. *Geological Society Special Publication*, 334: 315–417.

Kozur, H. W. & Weems, R. E., 2011. Detailed correlation and age of continental late Changhsingian and earliest Triassic beds: Implications for the role of the Siberian Trap in the Permian–Triassic biotic crisis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 308: 22–40.

Kürschner, W. M. & Herngreen, G. F. W., 2010. Triassic palynology of central and northwestern Europe: a review of palynofloral diversity patterns and biostratigraphic subdivisions. In: Lucas, S. G. (ed.), *The Triassic timescale*. *Geological Society Special Publication*, 334: 263–283.

Lucas, S. G., 2009. Timing and magnitude of tetrapod extinctions across the Permo–Triassic boundary. *Journal of Asian Earth Sciences*, 36: 491–502.

Maron, M., Rigo, M., Bertinelli, A., Katz, M. E., Godfrey, L., Mariachiara, Z. & Muttoni, G., 2015. Magnetostratigraphy, biostratigraphy, and chemostratigraphy of the Pignola-Abriola section: New constraints for the Norian-Rhaetian boundary. *Geological Society of America Bulletin*, 127: 962–974.

Metcalfe, I., Foster, C. B., Afonin, S. A., Nicoll, R. S., Mundil, R., Wang, X. & Lucas, S. G., 2009. Stratigraphy, biostratigraphy and C-isotopes of the Permian–Triassic non-marine sequence at Dalongkou and Lucaogou, Xinjiang Province, China. *Journal of Asian Earth Sciences*, 36: 503–520.

Ogg, J. G., 2012. Triassic. In: Gradstein, F. M., Ogg, J. G., Schmitz, M.& Ogg, G. (eds), *The Geologic Time Scale 2012, Volume 2*. Elsevier BV, Oxford-Amsterdam-Waltham, pp. 681–730.

Olempska, E., 2004. Late Triassic spinicaudatan crustaceans from SW Poland. *Acta Palaeontologica Polonica*, 49: 429–442.

Orlova, E.F., 1990. Novye dannye o konchostrakakh *Rodendorfium* i *Bipemphigu*s iz vulkanogennykh permotriasovykh otlozheniy Tungusskoy sineklize. *Paleontologicheskiy Zhurnal,* 1: 66–75, Moskva. [In Russian.]

Orłowska-Zwolińska, T. 1984. Palynostratigraphy of the Buntsandstein in sections of western Poland. *Acta Palaeontologica Polonica*, 29: 161–194.

Ptaszyński, T. & Niedźwiedzki, G., 2004. Conchostraca (clam shrimps) from the lowermost Buntsandstein at Zachełmie, Holy Cross Mts, central Poland. *Przegląd Geologiczny*, 52: 1151–1155. [In Polish, with English summary.]

Ptaszyński, T. & Niedźwiedzki, G., 2006. Buntsandstein in the Holy Cross Mountains: chronostratigraphy and lithostratigraphical correlation with the Thuringian Basin. *Przegląd Geologiczny*, 54: 252–533. [In Polish, with English summary.]

Reitz, E., 1988. Palynostratigraphie des Buntsandsteins in Mitteleuropa. *Geologisches Jahrbuch Hessen*, 116: 105–112.

Röhling, H.-G., 1993. Der untere Buntsandstein in Nordwest- und Nordostdeutschland – ein Beitrag zur Vereinheitlichung der stratigrafischen Nomenklatur. *Geologisches Jahrbuch*, A142: 149–183.

Sulej, T., Bronowicz, R., Tałanda, M. & Niedźwiedzki, G., 2011. A new dicynodont-archosaur assemblage from the Late Triassic (Carnian) of Poland. *Earth & Environmental Science: Transactions of the Royal Society of Edinburgh*, 101: 261–269.

Szulc, J., Racki, G., Jewuła, K. & Środoń, J., 2015. How many Upper Triassic bone-bearing levels are there in Upper Silesia (southern Poland)? A critical review of stratigraphy and facies. *Annales Societatis Geologorum Poloniae*, 85, 587–626.

Szurlies, M., Bachmann, G. H., Menning, M., Nowaczyk, N. R. & Käding, K., 2003. Magnetostratigraphy and high-resolution lithostratigraphy of the Permian–Triassic boundary interval in Central Germany. *Earth and Planetary Science Letters*, 212: 263–278.

Webb, J. A., 1979. A reappraisal of the palaeoecology of conchostracans (Crustacea: Branchiopoda). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 158: 259–275.

Yin, H. F., Zhang, K. X., Tong, J. N., Yang, Z. Y. & Wu, S. B., 2001. The global stratotype section and point (GSSP) of the Permian–Triassic boundary. *Episodes*, 24: 102–114