

## **UPDATED CORRELATION OF THE GERMANIC TRIASSIC WITH THE TETHYAN SCALE AND ASSIGNED NUMERIC AGES**

Heinz W. KOZUR <sup>1</sup> & Gerhard H. BACHMANN <sup>2</sup>

<sup>1</sup> Rézsü u. 83, Budapest, H-1029. [kozurh@helka.iif.hu](mailto:kozurh@helka.iif.hu)

<sup>2</sup> Institut f. Geowissensch., Martin-Luther-Univ. Halle-Wittenberg, Von-Seckendorff-Pl. 3, Halle/Saale, D-06120

The correlation of the Germanic Triassic with the Tethyan Triassic is well constrained biostratigraphically. However, radiometrical data are lacking and have to be imported for numerical calibration of lithostratigraphic units. These imported data can be extended to intervals without primary numerical data by astronomical calibration with Milankovitch cycles that are well recognisable in continental lake deposits of the Germanic Triassic, and correlated to the marine realm. Such cross-correlation is a powerful method for improving numerical stage ages in the marine realm.

The numerical ages (in Ma) of Figs. 1–3 were calculated by KOZUR (2003), KOZUR & BACHMANN (2003) and BACHMANN & KOZUR (2004), and for the base Jurassic by KOZUR & WEEMS (2007), by improved biostratigraphic dating of radiometric data in continental magmatics and by cross correlation of marine beds (with radiometric data) with lake deposits (containing well recognisable Milankovitch cycles). Our calculations are remarkably close to the subsequently published most recent radiometric data of different authors (Figs. 1, 4, FURIN et al., 2006; GALFETTI et al., 2007, LEHRMANN et al., 2006; OVTCHAROVA et al., 2006). A particularly good example is the numerical age (improved by astronomic calibration) of 252.6 Ma for the Permian-Triassic boundary (PTB) that was published by KOZUR (2003), which age was later confirmed with new radiometric data by MUNDIL et al. (2004).

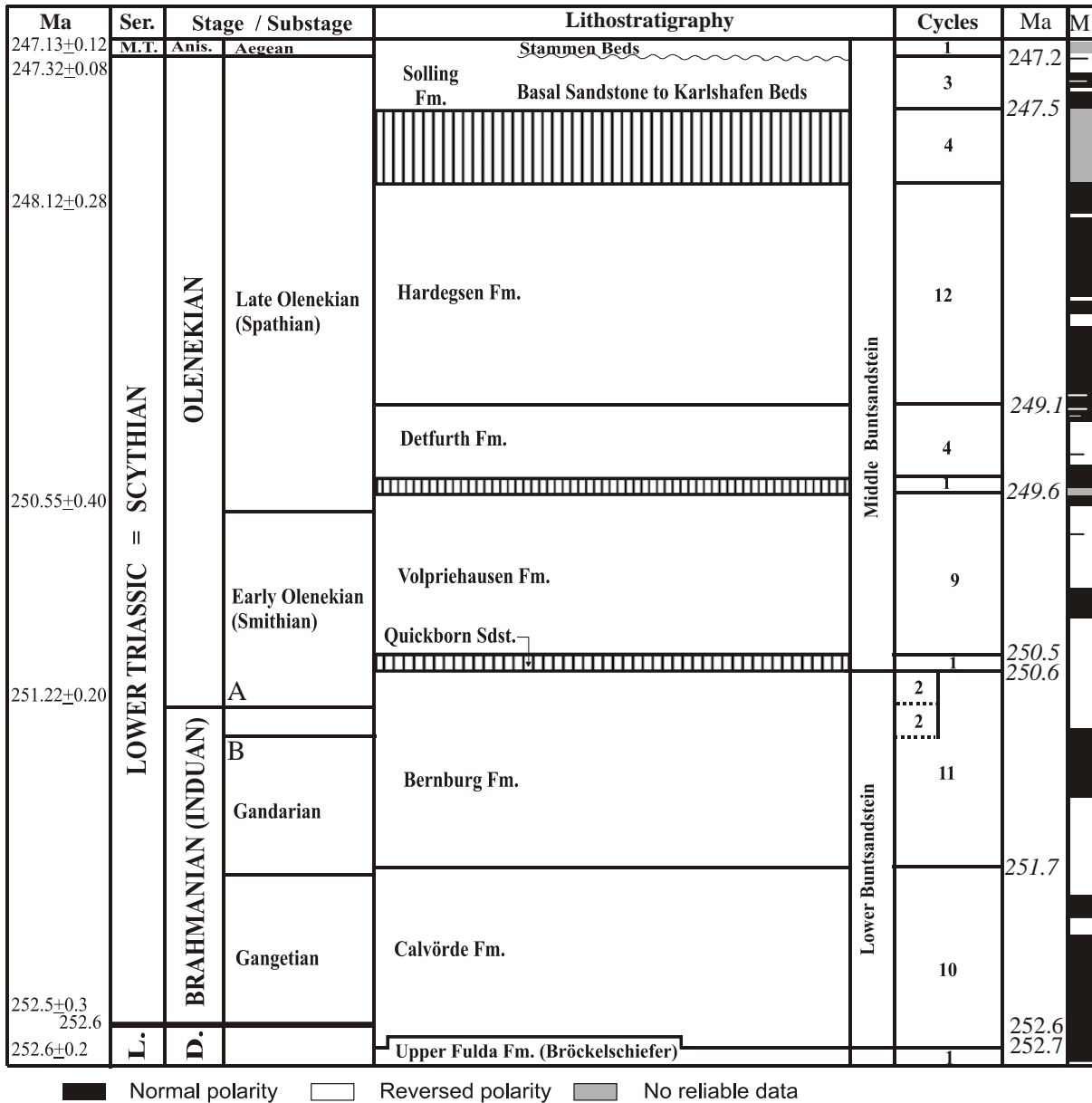


Figure 1: Numeric ages, cyclicity and palaeomagnetic of the Lower Triassic in the Germanic Basin. Slightly modified after Kozur & Bachmann (2003) und Bachmann & Kozur (2004). Palaeomagnetic and cyclicity after Szurlies (2007), but 11 cycles in the Bernburg Fm. Left column: Compiled new radiometric ages of the marine Lower Triassic after Galfetti et al. (2007), Lehrmann et al. (2006), Mundil et al. (2004) and Ovtcharova et al. (2006). Right column: Extrapolated numerical ages of the Germanic Triassic in italic script. A: Biostratigraphically correlated base of the Olenekian after Kozur & Seidel (1983) and Kozur (1999). B: Olenekian base by palaeomagnetic correlation (Bachmann & Kozur, 2004; Szurlies, 2007).



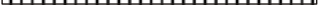

Ma		Stage / Substage	Lithostratigraphy		Cycles	
237.0	MIDDLE TRIASSIC	LADINIAN		Middle Keuper	1	
			Grabfeld Fm. (Lower Gypsum Keuper) without "Estheria" Beds		9	
238 237.9			Longobardian	Erfurt Fm. (Lettenkeuper)	Lower Keuper	8
238.8 239.0					2	
		Fassanian	Meißner Fm.	Upper Muschelkalk	28	
240.5						
241.2		ANISIAN	Illyrian	CB <i>Spinosus</i> Zone	Upper Muschelkalk	12
				TB 10, base of <i>Compressus</i> Zone Trochitenkalk Fm.		
				Diemel Fm.		1
				Heilbronn Fm.	M. M.	7
			Karlstadt Fm.		1	
244.6		Pelsonian	Schaumkalk Member TB Jena Fm.	Lower Muschelkalk	3 9 21	
	Bithynian	OB	9			
	Aegean	DGB	Röt Fm. 	Upper Buntsandst.	2	
					9	11
247.2			Stammen Beds of Solling Fm. 		1	

Figure 2: Numeric ages of the Germanic Middle Triassic after Bachmann & Kozur (2004), slightly modified.

DGB: Dolomitische Grenzbank, LO of *Costatoria costata*, FAD of *Myophoria vulgaris*. OB: Oolithbänke.

TB: Terebratelbänke. CB: Cycloidesbank. TB: Trochitenbank. M. M.: Middle Muschelkalk.

Numeric ages in bold script: Compiled measured radiometric data.

Numeric ages in italic script: Calculated numeric ages for the base of the Anisian, Ladinian and Carnian stages as well as Longobardian substage.

Ma	Stage	Substage	Lithostratigraphy			
201.5	Rhaetian		Triletes Beds		U. Keuper	
			Contorta Beds			
			Trossingen Fm. (Knollenmergel)			
			4. Stubensandstein (u. Löwenst. Fm.)	Postera Sandstone		Exter Fm.
206	Norian	Sevatian	Löwenstein Fm., pars (1. - 3. Stubensandstein + 1. - 3. Hangendletten, uppermost Obere Bunte Mergel)	Arnstadt Fm. without Steinmergel	lower & middle Postera Beds	
		Alaunian		Arnstadt Fm. (with common Steinmergel)		
		Lower Norian ("Lacian")				
225 ± 3 226	Carnian	Tuvalian	Mainhardt Fm. (Heldburggips / Obere Bunte Mergel, pars)	Heldburggips	Middle Keuper	
227.8±0.3*			Hassberge Fm. (Coburg-Sandstein and Blasensandstein)	Weser Fm. (Upper Gypsum Keuper)		
			Steigerwald Fm.	Lehrberg Beds Rote Wand		Lehrb. Beds Rote Wand
230.91±0.33		Julian	Schilfsandstein Formation (Stuttgart Fm.)			
237		Cordevolian	upper Grabfeld Fm. ("Estheria" Beds)			

Figure 3: Numeric ages of the Germanic Upper Triassic, modified after Bachmann &amp; Kozur (2004).

\*<sup>40</sup>Ar/<sup>39</sup>Ar data from the Adamanian of Ischigualasto, Argentina (Rogers et al.1993), corresponding to a middle to late Tuvalian level between the Lehrberg Beds and the top of the Weser Fm. Only very few radiometric data are known from the Late Triassic. The 230.91±0.33 Ma of Furin et al. (2006) is from the basal *Carnepigondolella zoeae* Zone, a level somewhat older than the Lehrberg Beds of the Weser Fm. The 225±3 Ma (Gehrels et al., 1986, 1987) is from volcanics in the lower Norian *E. quadrata* Zone in SE Alaska. The 201.5 Ma for the Triassic-Jurassic boundary is based on a biostratigraphic re-dating (Kozur & Weems, 2007) as latest Rhaetian of the lower lava flow of the CAMP volcanics in the Newark Supergroup, and on new radiometric data from a well-dated Rhaetian-Hettangian boundary section in Peru by Schaltegger et al. (2008). Calculated numeric ages for the base of the Carnian, Norian and Rhaetian stages in italic script.

Figure 4 (next page): Calculated numeric ages for selected lithostratigraphic units of the Germanic Triassic and most important radiometric ages of the marine Triassic. Not to scale. Gaps not shown.

\* = <sup>40</sup>Ar/<sup>39</sup>Ar age; all other radiometric ages are zircon U-Pb ages.

The first numeric ages for the lithostratigraphic units of the Germanic Triassic were estimated by Menning (1991–2002). Menning did not take into account the late Tuvalian (Adamanian) <sup>40</sup>Ar/<sup>39</sup>Ar age of 227.8±0.3 Ma from Ischigualasto (Argentina) by Rogers et al. (1993), the basal Norian 225±0.3 Ma age from SE Alaska (Gehrels et al., 1986, 1987), and the estimated duration of the lithostratigraphic units was partly arbitrary. Such caused a jitter of several million years in the assumed numeric ages of Menning (1991) to Menning et al. (2005 a, b), referred to as "paternoster stratigraphy" by Menning et al. (2005b). Later, Bachmann & Kozur (2004) calculated the duration of the lithostratigraphic units by using Milankovitch cycles; data that seem to have been adopted by Menning et al. (2005a).

Menning 1991	Menning 1995	Menning 1997	Menning et al. 2002	Bachm. & Kozur 2004	Menning et al. 2005a	This paper	Selected Lithostratigraphic Units	Radiometric data outside Germanic B.	
208	208	206	199.6	199.6	199.6	201.5	Triletes Beds	201.5	
	208.5		201.5		201.4		Contorta Beds	Rhaetian	
	210		203.5		203.3		Trossingen Fm.		
			206.5		206.5		4. Stubensandstein		
	212	210	207	206	207	206	Arnstadt Fm., pars, with common Steinmergel/ 1.-3. Stubensandstein + Hangendletten, upperm. Obere Bunte Mergel	Norian	
222	220	218	221	226	226	226	W e s e r  F m  Heldburggips	225 ± 3	
							Lehrberg Beds	227.8 ± 0.3	
224.5	224	222	224.5	231	230	232	Rote Wand	230.91 ± 0.33	
							Schilfsandstein Fm. (Stuttgart Fm.)	Carnian	
225.5	225	223	226		231		" <i>Estheria</i> " Beds		
	229	226	231	237	237	237	Grabfeld Fm.	238.0 + 0.4/-0.7	
228.5	230	228.5	232.5	238	239	238	Erfurt Fm	Ladinian	
230	232	231	235	238.8	240	238.8		238.8 + 0.5/-0.2	
234	234	234	235.8	240.5	241	240.5	Meißner Fm.		
			237	241.8	242	241.8	Upper Muschelkalk	241.2 ± 0.8	
234.5	235.5	235	238.5	243.0	343.4	243	Trochitenkalk Fm.	242.6 ± 0.7	
236	237	236.5	240	243.9	244.6	243.9	Middle Muschelkalk	Anisian	
							Lower Muschelkalk (Jena Fm.)		244.6 ± 0.36
239.5	240	240	243	246	246.6	246	Röt Fm.		246.77 ± 0.13
	242	242	244.5	246.9	247.4	247.1	Stammen Beds	247.13 + 0.12	
				247		247.2	Solling Fm.	247.32 ± 0.08	
242	243		245	247.4	247.8	247.5	Hardeggen Fm.	248.12 ± 0.28	
	245	245	247	248.6	249	249.1	Detfurth Fm.	Olenekian	
	246		247.5	248.9	249.4	249.5	Volpriehausen Fm.	250.55 ± 0.4	
244.5	247.6	247.7	249	250.2	250.6	250.5	Bernburg Fm.	251.22 ± 0.2	
	249.2		250	251.6	251.6	251.7	Calvörde Fm.	Brahmanian (Induan)	
				252.6		252.6		252.5 ± 0.3	
247	251	251	251	252.7	252.6	252.7	Zechstein, pars	252.6 ± 0.2	
								Changhsing. pars	

Figure 4

## References

- BACHMANN, G.H. & KOZUR, H.W. (2004): The Germanic Triassic: correlations with the international scale, numerical ages and Milankovitch cyclicity.– *Hallesches Jahrb. Geowiss.*, B **26**: 17–62.
- FURIN, S., PRETO, N., RIGO, M., ROGGI, G., GIANOLLA, P., CROWLEY, J.L., & BOWRING, S.A., (2006): High-precision U-Pb zircon age from the Triassic of Italy: Implications for the Triassic time scale and the Carnian origin of calcareous nanoplankton and dinosaurs.– *Geology*, **34**: 1009–1012.
- GALFETTI, T., BUCHER, H., OVTCHAROVA, M., SCHALTEGGER, U., BREYARD, A., BRÜHWILER, T., GOUEMAND, N., WEISSERT, H., HOCHULI, P.A., CORDEY, F. & GUODUN K. (2007): Timing of the Early Triassic carbon cycle perturbations inferred from new U-Pb ages and ammonoid biochronozones.– *Earth and Planetary Science Letters*, **258**: 593–604.
- KOZUR, H.W. (1999): The correlation of the Germanic Buntsandstein and Muschelkalk with the Tethyan scale.– *Zbl. Geol. Paläont. Teil I*, **1998**: 701–725.
- KOZUR, H.W. (2003): Integrated ammonoid, conodont and radiolarian zonation of the Triassic.– *Hallesches Jahrb. Geowiss.*, B **25**: 49–79.
- KOZUR, H.W. & BACHMANN, G.H. (2003): Remarks on the numerical age of the Triassic stages. Triassic geochronology and cyclostratigraphy. - A Field Symposium, St.Christina/Val Gardena, Dolomites, Italy: 41–42.
- KOZUR, H. & SEIDEL, G. (1983): Die Biostratigraphie des unteren und mittleren Buntsandsteins unter besonderer Berücksichtigung der Conchostracen. – *Z. geol. Wiss.*: **11**, 429–464.
- KOZUR, H.W. & WEEMS, R.E. (2007): Upper Triassic conchostracan biostratigraphy of the continental rift basins of eastern North America: its importance for correlating Newark Supergroup events with the Germanic Basin and the international geologic time scale. In: Lucas, S.G. & Spielmann, J.A. (eds.): *The Global Triassic*.– New Mexico Museum of Natural History and Science, Bull., **41**: 137–188.
- LEHRMANN, D.J., RAMEZANI, J., BOWRING, S.A., MARTIN, M.W., MONTGOMERY, P., ENOS, P., PAYNE, J.L., ORCHARD, M.J., WANG HONGMEI & WEI JIAYONG (2006): Timing of recovery from the end-Permian extinction: Geochronologic and biostratigraphic constraints from south China.– *Geology*, **34**: 1053–1056.
- MENNING, M. (1991): Rapid subsidence in the Central European Basin during the initial development (Permian-Triassic boundary sequences, 258–240 Ma).– *Zbl. Geol. Paläont. Teil I*, **1991**: 809–824.
- Menning, M. (1995): A numerical time scale for the Permian and Triassic Periods: An integrated time analysis.– In: Scholle, P.A., Peryt, T.M. & Ulmer-Scholle, D.S. (eds.): *The Permian of Northern Pangea*, **1**: 77–97.
- MENNING, M. (1997): Geologische Zeitskala der Mark Brandenburg. In: Stackebrandt, W., Ehmke, G. & Mahenke, V. (eds.): *Atlas zur Geologie von Brandenburg*.– Landesamt für Geologie und Rohstoffe Brandenburg: 74–75, Kleinmachnow.
- MENNING, M., GAST, R., HAGDORN, H., KÄDING, K.-C., SIMON, T., SZURLIES, M. & NITSCH, E. (2005a): Zeitskala für Perm und Trias in der Stratigraphischen Tabelle von Deutschland 2002, zyklusstratigraphische Kalibrierung der höheren Dyas und Germanischen Trias und das Alter der Stufen Radium bis Rhaetium 2005.– *Newsl. Strat.*, **41**: 173–210.
- MENNING, M., BENEK, R., BOY, J., EHLING, B.-C., FISCHER, F., GAITZSCH, B., GAST, R., KOWALCZYK, G., LÜTZNER, H., REICHEL, W. & SCHNEIDER, J.W. (2005b): Das Rotliegend in der Stratigraphischen Tabelle von Deutschland 2002 – "Paternoster-Statigraphie" auf dem Rückzug.- *Newsl. Strat.*, **41**: 91–122.
- MUNDIL, R., LUDWIG, K.R., METCALFE, I. & RENNE, P.R. (2004): Age and timing of the Permian mass extinctions: U-Pb dating of closed-system zircons.– *Science*, **305**: 1760–1763.
- OVTCHAROVA, M., BUCHER, H., SCHALTEGGER, U., GALFETTI, T.C., BRAYARD, A. & GUEX, J. (2006): New Early to Middle Triassic U-Pb ages from South China: Calibration with ammonoid biochronozones and implications for the timing of the Triassic biotic recovery.– *Earth and Planetary Sci. Letters*, **243**: 463–475.
- ROGERS, R.R., SWISHER III, C.C., SERENO, P.C., MONETTA, A.M., FORSTER, C.A. & MARTÍNEZ, R.N. (1993): The Ischigualasto tetrapod assemblage (Late Triassic, Argentina) and  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of dinosaur origins.- *Science*, **260**: 794–797.
- SCHALTEGGER, U., GUEX, J., BARTOLINI, A., SCHOENE, B. & OVTCHAROVA, M. (2008): Precise U-Pb age constraints from end-Triassic mass extinction, its correlation to volcanism and Hettangian post-extinction recovery.– *Earth and Planetary Science Letters*, **267**: 266–275.
- SZURLIES, M. (2007): Latest Permian to Middle Triassic cyclo-magnetostratigraphy from the Central European Basin, Germany: Implications for the geomagnetic polarity timescale.– *Earth and Planetary Science Letters*, **261**: 602–619.