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CALIBRATION OF EARLY AND MIDDLE TRIASSIC TIME SCALES USING ORBITAL-CLIMATE CYCLES

M. MENNING[1], J.G. OGG[2] AND R.L. ROMER[1]

[1] GeoForschungsZentrum Potsdam, Telegrafenberg C128, D-14471 Potsdam, Germany, e-mail: menne@gfz-potsdam.de, romer@gfz-potsdam.de;
[2] Department of Earth & Atmospheric Sciences, Purdue University, Civil Building, West Lafayette, IN 47907 USA, e-mail: jogg@purdue.edu

During the last decades, the time-relationship between the Early, Middle and Late Triassic epochs changed dramatically. Starting with an assumed relationship of 10:10:12.5 my (Harland et al., 1964), recently the well based relationship is about 5:10: 35 my. Duration of stages within the Early and Middle Triassic has varied significantly in publications of 1987 through 2007: Induan (Indusian) 1–6 my, Olenekian 3.1–5 my, Anisian 1.6–8 my, and Ladinian 3–9 my. The stabilization of stage definitions by GSSPs, attainment of higher analytical precision on radio-isotopic age determinations on tuffs, recognition of climatic cycles recorded in the sedimentary record that are induced by periodic orbital changes (Milankovitch cycles), and the integration of these elements using biostratigraphic and magnetostratigraphic correlations leads to a more precise numerical time scale. There is a systematic offset of ~ 1.5 my between single and multigrain U-Pb ages from the Late Permian to the Middle Triassic (Menning et al., in prep.), therefore our calibrations for all stage boundaries rely on single-grain results.

We focus on cycles as time indicators from the Germanic Triassic, particularly from the Buntsandstein (s) and Muschelkalk (m), which are completely developed in the migrating center of the Central European Basin. Extending the cycle-stratigraphy into the Late Triassic is uncertain, because recent estimates of a ~ 35-my duration for that epoch imply that the lithostratigraphic units of Central Europe are probably punctuated with gaps of uncertain duration.

The base of the Triassic at the GSSP in Meishan, South China is synchronous with the First Occurrence Datum (FOD) of the conodont *Hindeodus parvus* (Yin et al., 2001). Single-grain ID-TIMS ages for beds 25 and 28 constrain the Permian-Triassic boundary (PTB, Bed 27c) as ~ 252.5 Ma (Mundil et al., 2001, 2004; Menning et al., 2005). Following Kozur (1999), the PTB in Central Europe is within the small-scale cycle s1.2, which allocates an age of ~ 252.6 Ma to the Zechstein-Buntsandstein boundary. This anchor point has been used to age-calibrate the Regional Stratigraphic Scale (RSS) of Central Europe to durations derived from orbital-climatically induced cycles (Menning et al., 2005).

The Buntsandstein contains ~ 60 small-scale cycles obtained by Szurlies, who applied magnetostratigraphy to prepare a regional framework (Szurlies et al., 2003; Szurlies, in Menning et al., 2005). These cycles appear to be associated with climatic changes induced by the 100 ky eccentricity cycle acting on precession. Therefore, the Buntsandstein has a duration of ~ 6 my (Szurlies, in Menning et al., 2005) and spans ~ 252.6 Ma to 246.6 Ma. These Buntsandstein cycles are grouped into 7 Folgen, which are bounded by quasi-isochronous boundary planes: Calvörde-Folge (s1: s1.1–s1.10, ~ 1 my), Bernburg-Folge (s2: s2.1–s2.10, ~ 1 my), Volpriehausen-Folge (s3: s3.1–s3.12, ~ 1.2 my), Detfurth-Folge (s4: s4.1–s4.4, ~ 0.4 my), Hardegsen-Folge (s5: s5.1–s5.12, ~ 1.2 my), Solling-Folge (s6: s6.1–s6.4, ~ 0.4 my), and Röt-Folge (s7: s7.1–s7.8, ~ 0.8 my).

The Early Muschelkalk contains ~ 20 small-scale cycles (m1: m1.1–m1.9, m2: m2.1–m2.5, m3: m3.1–m3.6), the Middle Muschelkalk contains ~ 12 (m4: m4.1–m4.2, m5: m5.1–m5.8, m6: m6.1–m6.2) and the Late Muschelkalk has ~ 34 (m7: m7.1–m7.14, m8: m8.1–m8.8, m9: m9.1–m9.12) (Hagdorn et al., in Menning et al., 2005). These imply a total Muschelkalk duration of ~ 6.4 my, and a span from ~ 246.6 to 240.2 Ma.

According to magnetostratigraphic and biostratigraphic evidence, the base of the Olenekian (FOD of *Neospathodus waageni*) is at about the boundary of cycles s2.6-s2.7, the base of the Anisian (*Chiosella timorensis*) is at about the boundary of Folgen s6-s7, and the base of the Ladinian (*Eoprotrachyceras curionii*) is in the early Folge m9. Applying this cycle stratigraphy projects the durations of these Early and Middle Triassic stages as: Induan (Indusian) ~ 1.5 my, Olenekian ~ 3.6 my, Anisian ~ 6.4 my, and Ladinian ~ 4 my (Menning et al., 2005). More radio-isotopic age determinations, including using the methods Rb-Sr on clays and Re-Os on black shales, are necessary to check and confirm these estimations.

The durations of ~ 6.0 my for the Buntsandstein and ~ 6.4 my for the Muschelkalk are shorter than in previous publications. However, they are consistent with: a) radio-isotopic ages within the Changhsingian, Induan (Indusian), Olenekian, Anisian and Ladinian stages in China, Alps and Hungary (Menning et al. in prep.), b) the duration of magnetic zones (Szurlies et al., 2003; Szurlies, 2004; Menning et al., 2005), which corresponds to that of the Late Cenozoic, c) a very long Late Triassic Epoch deduced from Milankovich-cycles from the Newark Basin (Olsen & Kent, 1999), and d) radio-isotopic ages for the Triassic-Jurassic boundary of ~ 202–200 Ma (Dunning & Hodych, 1990; Pálfy et al., 2000).

REFERENCES

Dunning, G.R. & Hodych, J.P. (1990): U/Pb zircon and baddeleyite ages for the Palisades and Gettysburg sills of the north-eastern United States: Implications for the age of the Triassic/Jurassic boundary. - Geology, 18: 795-798, Boulder.

Harland, W.B., Smith, A.G. & Wilcock, B. (eds.) (1964): The Phanerozoic time-scale. (A symposium dedicated to Professor Arthur Holmes): 458 p., Quarterly J. Geol. Soc., 120s, London.

Kozur, H.W. (1999): The correlation of the Germanic Buntsandstein and Muschelkalk with the Tethyan scale. - Zbl. Geol. Paläont., Teil I, 1998, 7/8: 701-725, Stuttgart.

Menning, M., Gast, R., Hagdorn, H., Käding, K.-C., Simon, T., Szurlies, M. & Nitsch, E. (2005): Zeitskala für Perm und Trias in der Stratigraphischen Tabelle von Deutschland 2002, zyklostratigraphische Kalibrierung von höherer Dyas und Germanischer Trias und das Alter der Stufen Roadium bis Rhaetium 2005. – Newsl. Stratigr., 41, 1/3: 173–210, Berlin.

Menning, M., Ogg, J. & Romer, R. (in prep.): Numerical calibration of the Late Permian and Early and Middle Triassic using radio-isotopic age determinations and orbital-climatically induced sedimentary cycles.

Mundil, R., Metcalfe, I., Ludwig, K.R., Renne, P.R., Oberli, F. & Nicoll, R.S. (2001): Timing of the Permian-Triassic biotic crisis: implications from new zircon U/Pb age data (and their limitations). – Earth Planet. Sci. Lett., 187, 1/2: 131-145, Amsterdam.

Mundil, R., Ludwig, K.R., Metcalfe, I. & Renne, P.R. (2004): Age and timing of the Permian mass extinction: U/Pb dating of closed-system zircons. – Science, 305: 1760-1763, Washington.

Olsen, P.E. & Kent, D.V. (1999): Long-period Milankovitch cycles from the Late Triassic and Early Jurassic of eastern North America and their implications for the calibration of the Early Mesozoic time-scale and the long-term behaviour of the planets. – Phil. Trans. R. Soc. London, A 357: 1761–1786, London.

Pálfy, J., Smith, P.L. & Mortensen, J.K. (2000): U-Pb and $^{40}Ar/^{39}Ar$ time scale for the Jurassic. - Can. J. Earth Sci., 37, 6: 923-944, Ottawa.

Szurlies, M. (2004): Magnetostratigraphy: the key to a global correlation of the classic Germanic Trias – case study Volpriehausen Formation (Middle Buntsandstein), Central Germany. - Earth Planet. Sci. Lett., 227: 395-410, Amsterdam.

Szurlies, M., Bachmann, G.H., Menning, M., Nowaczyk, N.R. & Käding, K.-C. (2003): Magnetostratigraphy and high-resolution lithostratigraphy of the Permian-Triassic boundary interval in Central Germany. - Earth Planet. Sci. Lett., 212: 263-278, Amsterdam.

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, 2: 102-114, Beijing.