Abstracts

The Continental Permian-Triassic Boundary Interval, Central Germany: Evidence for long-term cosmic influx?

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The Permian-Triassic Boundary (PTB) interval in the Central European Basin (CEB) developed in continental redbed facies. Lithostratigraphically, it belongs to the uppermost Zechstein (Bröckelschiefer = Fulda Fm.) and the lowermost Buntsandstein (lower Calvörde Fm.). This study presents an integrated correlation of the continental and marine PTB. It concentrates on outcrops situated in an intermediate marginal facies in the southeastern part of the CEB.

Facies

The Fulda Fm. is approx. 30 m thick and consists of predominantly reddish, non-fissile shales, siltstones and thin layers of sandstones, so-called "Bröckelschiefer" (= crumbly shales). In the lower part there are nodular gypsum residues and mudcracks. First lacustrine shales and siltstones with conchostracans occur in the upper Fulda Fm. The approx. 150–200 m thick Calvörde Fm. consists of reddish, partly grey and greenish, mostly fissile shales, siltstones, and thin greyish sandstone beds without any evaporites basinwide in its lowermost part. At the basin margin, the depositional environment of the Fulda Fm. represents a sabkha system, which grades into a playa system in the Calvörde Fm. Both interfinger with distal fluvial systems, whereby the fluvial influx substantially increases in the Calvörde Fm.

Cyclic stratigraphy

The Fulda Fm. consists of 2 fining-upward cycles, each with sandstone beds at the base and siltstones and shales in the upper part. The Calvörde Fm. consists of ous fining-upward cycles, which are 10-20 m thick and similar to those of the Fulda Fm., but containing more sandstones. Basinwards, the basal sandstones become less abundant and gradually give way to oolite beds, so-called "Rogensteine" (roestones). The fining-upward clearly shows up in gamma-ray logs (GRL) cycles of outcrops and wells and can be correlated readily in large parts of the CEB. The cycles seem to be quasi-isochronous and provide a robust high-resolution lithostratigraphic framework. Alternatively, they can be interpreted as more or less asymmetrical baselevel cycles.

The cycles are considered to represent ~100 kyr Milankovitch eccentricity cycles. The base of the first distinct ~100 kyr cycle of the Calvörde Fm. is, by definition, the Zechstein-Buntsandstein boundary. The Milankovitch cyclicity suggests high sedimentation rates of approx. 15 m/100 kyr, i. e. 100 times more than in the Meishan section (compaction not considered) and 10 times more than in the Iranian sections (Jolfa, Zal, Shareza, Abadeh).

Biostratigraphy

The continental sections can be correlated with the marine scale by conchostracans and sporomorphs. The Upper Fulda Fm. belongs to the *Falsisca eotriassica* conchostracan Zone, which corresponds to the Late Permian (late Dorashamian) *Clarkina iranica* and *C. hauschkei* conodont Zones. The ~100 kyr cycle 1 and the first ~20 kyr cycle of ~100 kyr cycle 2 (below the so-called Oolite Alpha 2) of the Calvörde Fm. correspond to the *Falsisca postera* conchostracan Zone and the *Lundbladispora obsolete - L. noviaulensis* sporomorph Zone, which can be correlated with the *Clarkina meishanensis-Hindeodus praeparvus* conodont Zone of latest Dorashamian age. The upper part of ~100 kyr cycle 2 (so-called Oolite Alpha 2 and above) belongs to the *Lundbladispora willmotti-L. hexagona* sporomorph Zone and corresponds to the earliest Triassic (lower Gangetian Substage of the Indusian/Brahmanian Stage) and is, at least to its main part, an equivalent of the *Hindeodus parvus* Zone. The conchostracan fauna of this level consists predominantly of *Euestheria gutta,* which straddles the PTB. The lowermost Triassic index species *Falsisca verchojanica* is extremely rare in the CEB, except in SE Poland (Ptaszynsky & Kozur, in prep.). The biostratigraphically defined continental PTB is within the so-called "Graubankbereich" (= grey bed interval) of Calvörde Fm. cycle 2 (lower part), or, more precisely, at so-called Oolite Alpha 2.

Magnetostratigraphy

The cycles were used as a high-resolution lithostratigraphic framework for detailed magnetostratigraphic investigations. The uppermost

numerZechstein (upper Leine Fm. to Fulda Fm.) comprises 2 normal and 2 reversed magnetozones. The upper normal polarity zone (sn1) begins in the lower third of the Upper Fulda Fm. and extends into the Lower Buntsandstein, comprising Calvörde Fm. cycles 1 – 7 (lower part). The biostratigraphically defined PTB at Oolite Alpha 2 is in the lower third of normal polarity zone sn1. Reliable palaeomagnetic data of marine sections indicate that the PTB is in the lower third of an normal polarity zone, too. The only, not yet understood, exception is Meishan, where Bed 27, comprising the upper *meishanensis-praeparvus* Zone and the entire *parvus* Zone, seems to be within a thin reversed polarity zone (Zhu Yanming & Liu Yuyan 1999, Yin Hongfu et al. 2001). This could not be confirmed in well-dated Iranian sections or elsewhere (Kozur 2004, Szurlies & Kozur, in press).

The magnetic susceptibility curve of the PTB interval in the CEB shows, after Hansen et al. (pers. comm.), a characteristic pattern recorded also in other both marine and continental sections, which would support the PTB in Calvörde Fm. cycle 2 (Oolite alpha 2).

δ^{13}C-isotopes

The curve of $\delta^{13}C_{org}$-isotopes shows a distinct negative excursion in the lower part of Calvörde cycle 2 (Oolite Alpha 2), predated by a another, weaker negative excursion at the cycle 1/2 boundary. Both minima are characteristic for the PTB interval of other marine and continental sections (Hansen et al., pers. comm.). Plots of $\delta^{13}C_{carb}$ isotopes show a distinct drop from Calvörde Oolite Alpha 1 to Oolite Alpha 2 as well, with the minimum in the lower Oolite Alpha 2 (Korte, pers. comm.). In Meishan, the $\delta^{13}C_{carb}$ minimum is in the lower part of Bed 27, in the upper *meishanensis-praeparvus* Zone, approx. 6 cm below the PTB (Bowring et al. 1998). In Abadeh (Iran), the minimum is in the same position, with a second, somewhat stronger minimum in the *isarcica* Zone (Korte et al., in press). In Jolfa (Iran), the first minimum is also below the PTB, with a second, stronger minimum at the PTB. In Shareza and Zal the $\delta^{13}C_{carb}$ minimum is at the PTB (Korte et al., in press). Thus, the δ^{13}C isotopes indicate that the PTB is either at the base of Oolite Alpha 2 or somewhat higher up.

Microsphaerules

Microsphaerules (MS), known from several marine PTB intervals, have been found in the Fulda Fm. to the lowermost Calvörde Fm. A distinct maximum occurs in Oolite Alpha 1 and overlying grey shales of Calvörde cycle 1. A second, less distinct maximum is in Calvörde cycle 2 just above Oolite Alpha 2. The magnetic MS are 5-50 ˜m in diameter. Most of them are spherical, some are drop-shaped. They consist of matter rich in Fe, many entirely of Fe-oxide, others of Fe-rich silicates, few of spinel. There is often a typical wrinkle structure, characteristic of molten material that rapidly cooled. Some MS contain relatively much Ni and Cr. We assume that these MS are of cosmic origin. Silicatic MS with relatively high Ti content, which are especially abundant in the Fulda Fm., are considered to be of volcanic origin. Others seem to be mineralized Prasinophyte algae, typical disaster biota, which occur also in the Boundary Beds of South China and the Southern Alps. Under consideration of the supposed Milankovitch cyclicity, the time interval of increased MS occurrence at the PTB would be some 300 kyr, suggesting long-term cosmic (and volcanic) influx that may be punctuated by one or several large impacts and/or explosive volcanic eruptions.