Magnetostratigraphy at the Induan-Olenekian boundary in a global context: relationships with other correlation tools

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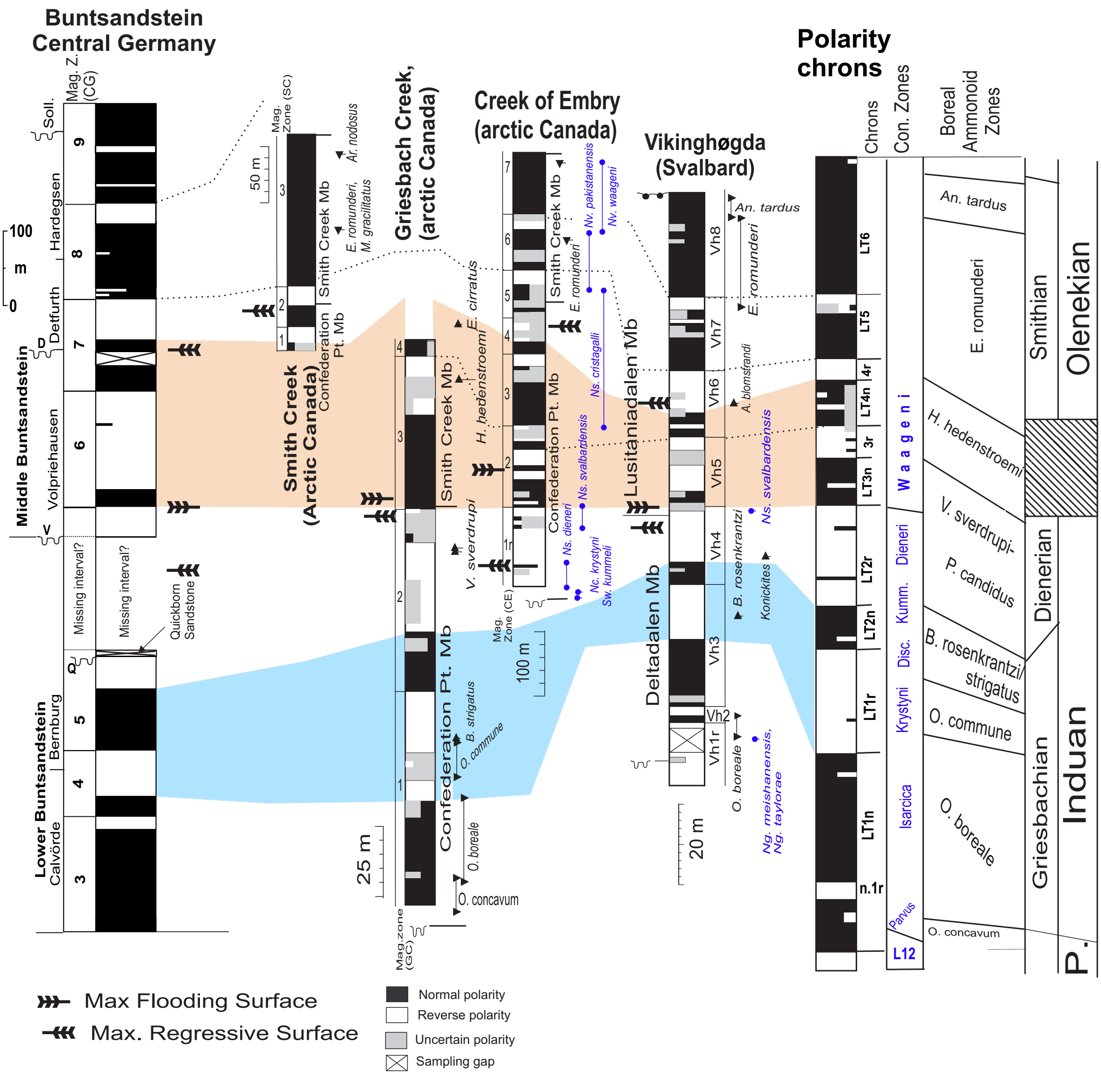

FIG. 1. Relationship between sequence stratigraphy and the magnetostratigraphy in Boreal sections and the German Buntsandstein. Data sources are indicated in Hounslow & Muttoni (2010).

The magnetic polarity stratigraphy for the Lower Triassic is fairly well established with some direct calibration against conodonts, boreal ammonoids, cyclostratigraphy and carbon isotopes (Hounslow & Muttoni, 2010; Li et al., 2016; Hounslow, 2016). Most proposals for the position of the Induan–Olenekian boundary (IOB) place it near the base of magnetochron LT3n (Sun et al., 2009; Zhao et al., 2013). This work reviews how the correlation afforded by using LT3n could provide a means for global correlation of the IOB into all sedimentary regimes, not just richly fossiliferous ones. Withstanding revision of the conodonts, various possible proposals for using a primary conodont datum place the IOB either in the upper-most part of

Tool type	Sections also with magnetostratigraphy	Nearest proxy for base of LT3n [Section]
Conodonts	Daxiakou, West Pingdingshan, Creek of Embry, Vikinghøgda	FO *Nv. w.waageni* [Dax,WP], LO *Ns. Svalbardensis* [CofE, Vik]
Ammonoids	Creek of Embry, Vikinghøgda, Greisbach Creek, Chaohu	*H. hedenstroemia* ~ 45 m above [at GC] in mid LT3r; *Euflemingites* and *Flemingites* within 1 m [Ch]
Conchostracans	Volpriehausen (Buntsandstein)	Common *Magniestheria mangaliensis* in LT2r-LT3?
Palynology	Vikinghøgda, Volpriehausen (Buntsandstein)	Acme of *Densoisporites nejburgii* [Volp.] in top LT2r; base of *Naumovaspora striata* assemblage zone in top LT2r [Vik]
Tetrapods	Volpriehausen (Buntsandstein)	Approx. base of Parotosuchus assemblage
Carbon isotopes	Daxiakou, West Pingdingshan	Initial part of $\delta^{13}C_{carb}$ peak [Dax, WP]
Geochronology	None near IOB	251.2 ±0.2 Ma from *K. densistriatus* beds [Jinya/Waili]
Cyclostratigraphy	Daxiakou, West Pingdingshan, Buntsandstein	249.92 Ma [Dax, WP], 251.14 [Dax], 250.0 [Bunts.]
Sequence stratigraphy	Creek of Embry, Vikinghøgda, Greisbach Creek, Volpriehausen (Buntsandstein)	MFS near base LT3n [Volp., GC, Vik.]

TABLE 1. Comparison of possible proxies for the Induan-Olenekian boundary based on published magnetostratigraphic studies which cover the IOB interval. The relationship of the IOB proxy to the magnetochrons is indicated using physical and biostratigraphic tools which can be directly related to those sections. Section details in Hounslow & Muttoni (2010); Daxiakou details in Hounslow et al. (this volume).

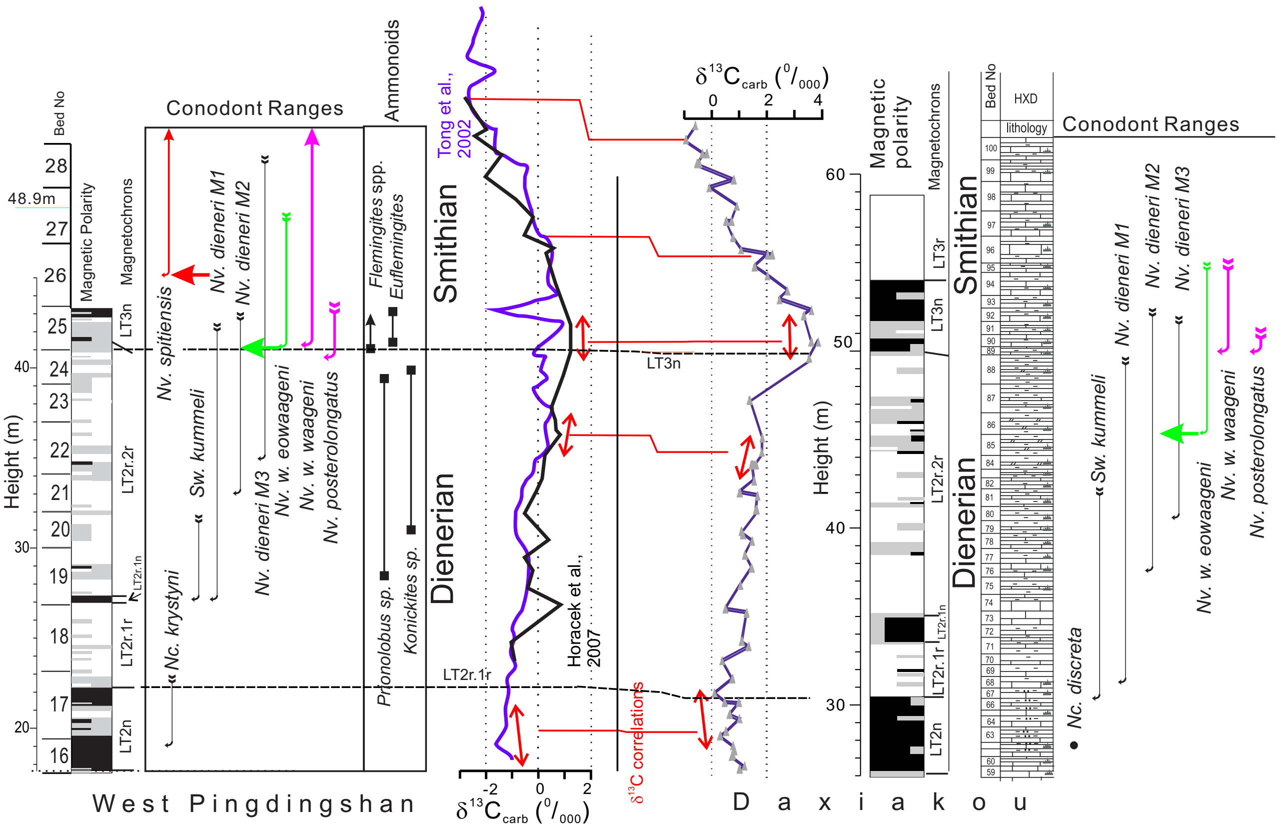

FIG. 2. Correlation relationships using the magnetostratigraphy and carbon isotope stratigraphy in the West Pingdingshan and Daxiakou sections. The large green and red arrows show possible definitions of the IOB in the two sections, using conodont datums. Data from Sun et al. (2009), Hounslow et al. (this vol.), Tong et al. (2007), Zhao et al. (2013) and Horacek et al. (2007).

LT2r or within the early part of LT3n. The data from Daxiakou and West Pingdingshan demonstrate that the FO of *Nv. waageni waageni* (Zhao et al., 2013) and the base of LT3n likely coincide in both sections, and so provide two strong combined markers for definition of the base Olenekian. In these two sections the age difference between these may be up to 10ka (based on the cyclostratigraphy). At Chaohu the first *Euflemingites* and *Flemingites* also occur with one meter of the base of LT3n. Using the base of LT3n as a means of high resolution correlation, Table 1 outlines how this boundary may be related to other kinds of correlation and dating tools, and which sections provide this information.

Magnetostratigraphy across the IOB has only been calibrated so far against good ammonoid faunas in the Sverdrup Basin and Svalbard sections, where LT3n falls in the 60 m barren interval between *V. sverdrupi* and *H. hedenstroemi*, some 15 m above *V. sverdrupi* in the Griesbach Creek section. The Buntsandstein successions and associated magnetostratigraphy (Szurlies, 2007) are important for constructing relationships with non-marine faunas. Magnetochron LT3n is probably the equivalent of magnetozone CG6n in the German Bundsandstein (Szurlies, 2007; Li et al., 2016), placing the IOB in the lower part of the Volpriehausen Fm. This relationship suggests that the common presence of the conchostracan *Magniestheria mangaliensis* (Scholze et al., 2016) and the acme of miospore *Densoisporites nejburgii* (Heunisch, 1999) both occur in the top LT2r perhaps some 100-200

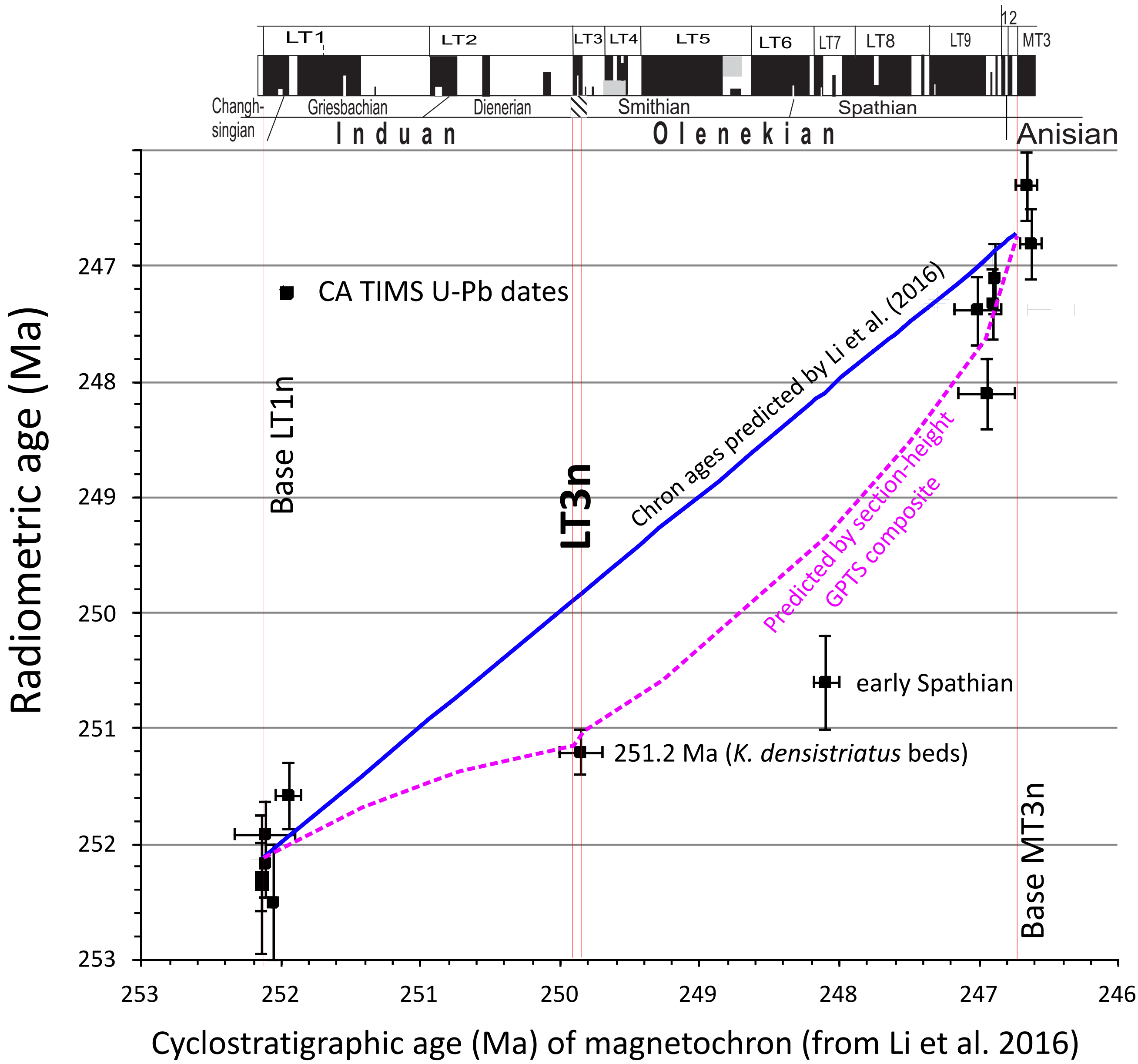

FIG. 3: Relationship between magnetostratigraphy and ages based on cyclostratigraphy and radiometric dates in the Lower Triassic. Blue line is the ages predicted by Li et al. (2016) for the magnetostratigraphy in the upper part of the panel. Radiometric dates for the Lower Triassic are plotted with respect to the magnetostratigraphy, with the error bars in the y-axis the 2σ age uncertainty, and error bars on the x-axis, the uncertainty in placing the TIMS date onto the magnetostratigraphy. Dates listed in Galfetti et al. (2007) and Hounslow (2016). Dotted line is the relationship between the magnetostratigraphy of Li et al. (2016) and the section-height composite in Hounslow & Muttoni (2010) approximately attached through the TIMS dates near the PTB and the Olenekian-Anisian boundary.

ka older than the base of LT3n. The base of the *Parotosuchus* tetrapod assemblage may relate approximately to the same point, since it occurs also in the Volpriehausen Fm (Lucas & Schoch, 2002). In the Barents Sea and Svalbard successions the *Naumovaspora striata* miospore assemblage zone also begins in the topmost part of LT2r (Vigran et al., 2014). These faunal turnovers in the late part of LT2r may relate to a maximum regressive surface seen in both the Boreal Triassic and the Buntsandstein at about the same position in the magnetostratigraphy (Fig. 1).

At Daxiakou and West Pingdingshan $\delta^{13}C_{carb}$ (Tong et al., 2007) be directly related to the magnetostratigraphy across the IOB. At both West Pingdingshan and Daxiakou the base of LT3n relates to the initial part of the main peak in $\delta^{13}C$. In both sections the isotope excursion continues throughout LT3n and into the overlying LT3r (Fig. 2). However, the magnetostratigraphy at West Pingdingshan needs re-sampling in bed 25 to more confidently locate the base of LT3n with respect to the carbon isotope variations.

The German Bundsandstein, Daxiakou and West Pingdingshan section have a cyclostratigraphy which can be related to LT3n (Li et al., 2016). Cycles from the Buntsandstein, Daxiakou and West Pingdingshan are based on gamma-counts, with the cycles for the Buntsandstein assumed to be 100 ka cycles. Their synthesis of the cyclostratigraphy has produced an age for the base of LT3n of 249.92±0.1Ma, based on an anchor to the base Induan at Meishan of 251.902 Ma. Wu et al. (2012) also generated a cyclostratigraphy at Daxiakou using two magnetic datasets which relate to the magnetite (i.e. detrital) content, in which they derived a duration of 1.16 Ma for the Induan, 0.82

Ma shorter than Li et al. (2016). Radiometric dates from the Lower Triassic suggest that the base of LT3n is around 251.2 Ma (Galfetti et al., 2007), approximately consistent with both the cyclostratigraphic duration of the Induan of Wu et al. (2012), and predicted duration, if the polarity timescale in composite section-height is stretched between base LT1n and base MT3n, and anchored through the existing radiometric dates near the base Induan and latest Spathian (Fig. 3).

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