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Preservation of successive diagenetic stages in Middle Triassic bonebeds: Evidence from in situ trace element and strontium isotope analysis of vertebrate fossils

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ABSTRACT

Bonebeds comprise reworked and time averaged constituents of different phosphatic vertebrate remains and, hence, provide an ideal substrate for the study of long and short term diagenetic processes. To test whether trace elements (U, Sr, REE) and $^{87}Sr/^{86}Sr$ ratios can be used for distinguishing between successive diagenetic signals, we performed geochemical analyses on vertebrate remains (bones, teeth, scales and coprolites) from two Triassic bonebeds located near Palzem (Germany). Trace element analysis was done on 170 vertebrate remains by LA-ICP-MS while $^{87}Sr/^{86}Sr$ ratios were determined for 39 bioclasts using LA-MC-ICP-MS. Although a low inter- and intra-bioclast REE variability indicates long-term open system behaviour, the observed REE patterns suggest the preservation of different diagenetic stages.

A distinct difference in the geochemical composition exists between dark luminescent SEM-CL domains and greyish ones. Dark domains represent dense, diagenetically more resistant material of low porosities such as enamel and ganoine. These domains display distinctly lower ΣREE contents and a higher inter-clast variability than those of various grey tones. Together with lower, hence more seawater-like $^{87}Sr/^{86}Sr$ ratios this argues for a preservation of an earlier diagenetic signal. Notably, most dark domains are characterised by negative Eu anomalies while all grey ones display positive Eu anomalies. With the exception of Eu both domains display almost identical REE patterns with different concentrations indicating that late diagenetic REE uptake is not necessarily accompanied by fractionation processes in vertebrate bioclasts. Negative Eu anomalies are most likely inherited from Eu-depleted surface waters, possibly as a result of Eu-depleted aeolian input. Conversely, positive Eu anomalies were presumably affected by Eu-enriched late diagenetic fluids with a possible high temperature origin causing a fractionation of europium. Our study therefore demonstrates the potential of high-resolution geochemical analysis in bonebed strata to disentangle different stages of diagenesis and to detect least altered areas in vertebrate fossils for recovering pristine palaeoenvironmental signals.

1. Introduction

The study of rare earth elements (REE) has become especially important in taphonomy and palaeontology since REE occur at very low abundance within living organisms and fresh fossils and are enriched by several orders of magnitude during diagenesis in fossil vertebrate remains (e.g., Trueman and Palmer, 1997; Kohn et al., 1999; Herwartz et al., 2011, 2013a, 2013b; Tütken et al., 2011). Hence, in vivo REE compositions are overprinted in fossil biogenic apatite (Herwartz et al., 2013b) and therefore REE compositions should reflect the geochemical signal of the environment in which they were fossilised (Trueman, 1999).

Traditionally, REE were believed to be incorporated into fossil vertebrate remains exclusively during early diagenesis (<100 ka) (see discussion in e.g., Kocsis et al., 2010; Herwartz et al., 2013b), which ends in bones with the total loss of organic content (mainly collagen) and its replacement by minerals (Pfretzschner, 2004). Thus, REE patterns have frequently been used to study various aspects of the fossilisation environment such as reconstruction of the palaeoenvironment, taphonomy, palaeoceanography, provenance and reworking of vertebrate remains (e.g., Wright et al., 1984, 1987; Elderfield and Pagett, 1986; Denys et al., 1996; Girard and Albarède, 1996; Samoilov et al., 2001; Picard et al., 2002; Kemp and Trueman, 2003; Trueman et al., 2003, 2005, 2006; Lécuyer et al., 2003, 2004; Metzger et al., 2004; Martin et al., 2005; Labs-Hochstein and MacFadden, 2006; Ounis et al., 2008; Anderson et al., 2007; Domingo et al., 2007, 2009a, 2009b, 2011; Cook and

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