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Rolling bones – Taphonomy of Jurassic dinosaur bones inferred from diagenetic microcracks and mineral infillings

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ABSTRACT

Dinosaur bones from the Upper Jurassic Shishugou Formation near Qitai in the Junggar Basin, NW China, show black manganese oxide and light quartz infillings in the bone pore space such as Haversian canals and diagenetic cracks. The manganese oxides are identified by X-ray diffraction as pyrolusite. Some Haversian canals are only partially filled with pyrolusite, which forms miniature geologic spirit levels. The orientations of these spirit levels have been measured and several generations of pyrolusite infillings determined, indicating that the bones were turned around once or several times during their fossilization. Characteristic desiccation cracks in the dinosaur bones indicate deposition on the soil surface and early diagenesis under dry climate conditions in the Upper Jurassic in NW China. During dry season evaporation and resulting capillary forces drove the groundwater with dissolved manganese-(II)-ions towards the soil surface and further into the capillary system of the bones. Hence the capillary system of the bones was already in contact with that of the sediment when the bones were still lying on the surface and were not yet totally embedded in the sediment. $Mn(OH)_2$ precipitated under high pH conditions in the pore space of the bones such as Haversian canals and cracks. During late diagenesis, the $Mn(OH)_2$ was oxidized to MnO_2 and transformed into pyrolusite. Mineral infillings and desiccation cracks in fossil bones thus can yield valuable insights into the taphonomic history of skeletal remains such as environmental conditions during diagenesis and fossil reworking.

1. Introduction

Fossil bones are valuable histological and geochemical archives that record information about the life history and palaeobiology of extinct vertebrates. The microstructure of dinosaur bones is commonly well-preserved down to the micrometer scale and growth marks such as growth rings or lines of arrested growth (LAGs) are widely used to reconstruct the growth rates and life history of dinosaurs (e.g., Reid, 1997; Tütken et al., 2004; Erickson, 2005). However, the original chemical and isotope composition of fossil bones is in most cases altered during diagenesis (e.g. Nelson et al., 1986; Kolodny et al., 1996; Safont et al., 1998; Trueman and Tuross, 2002; Trueman et al., 2003a; Goodwin et al., 2007). Dinosaur bones are recrystallized and usually transformed to carbonate fluorapatite, commonly with secondary diagenetic infillings of various mineral phases, e.g., calcite, pyrite, quartz, pyrolusite and others (Hubert et al., 1996; Kolodny et al., 1996; Elorza et al., 1999; Pfretzschner, 2001a,b; Wings, 2004). Due to these chemical and mineralogical changes during diagenesis, fossil dinosaur bones can usually not be used for reliable dietary and palaeoenvironmental reconstruction whereas enamel of dinosaur teeth may still preserve original isotope compositions (Fricke and Rogers, 2000; Stanton-Thomas and Carlson, 2004; Straight et al., 2004; Amiot et al., 2006; Fricke and Pearson, 2008; Fricke et al., 2008, 2009; Tütken, 2011). However, the altered chemical composition of fossil bones, especially rare earth elements (REE) (e.g. Trueman and Benton, 1997; Trueman, 1999; Trueman et al., 2004, 2006; Kohn 2008; Hinz and Kohn, 2010; Kocsis et al., 2010; Suarez et al., 2010; Herwartz et al., 2011) and the secondary minerals precipitated in the bone pore space during fossilization (Martill, 1991; Barker et al., 1996; Pfretzschner, 2001a,b; Trueman et al., 2003b; Wings, 2004) can yield important information about the taphonomic history of the bones such as the physico-chemical milieu and timing of diagenetic processes. Furthermore, the *postmortem* changes in bone microstructure such as microbial alteration or crack formation (e.g., Hackett, 1981; Piepenbrink, 1986; Bell et al., 1996; Pfretzschner, 2000; Trueman and Martill, 2002; Pfretzschner, 2006; Turner-Walker and Jans, 2008) can help to characterize diagenetic processes and the depositional setting of the bones. In this study we analyzed the mineral infillings and bone microstructure of Upper Jurassic dinosaur bones from terrestrial deposits of the Junggar Basin in NW China to characterize the taphonomic and palaeoclimatic conditions under which the bones were fossilized.

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