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Bone diagenesis in arid environments: An intra-skeletal approach

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Bone trace element content and isotopic composition are closely related to human nutrition. The investigation of archaeological bone geochemistry can help us to better understand the relationship between past populations and their environment alongside cultural practices as inferred from dietary reconstruction. However, dietary information may be altered post-mortem by diagenetic processes in soil. In this study, bone mineralogy (Ca/P, secondary minerals, organic matter content and bone apatite crystallinity), histology, element content (Mg, Na, F, Sr, Ba, Mn, Fe, La, Ce and U) and stable isotope composition ($\delta^{13}C$ and $\delta^{18}O$ carbonate) were investigated at the intra-individual scale in order to understand the effects of diagenesis on skeletons buried in different saharo-sahelian environments. Between 10 to 18 bone samples were taken from 4 Neolithic skeletons excavated in the Mauritanian *Dhar* Oualata and Néma and in the Daounas, Mali. Additionally, the enamel of two third molar teeth was also analysed from each skeleton for comparison with bone.

The results show that the four skeletons, buried in the same desert climate area, all exhibited different degrees of diagenetic modification, related to local taphonomic conditions. Highly drained and periodically flooded environments generated substantial bone bacterial damage, low to moderate apatite crystallinity and secondary minerals in bone pores. Bone trace element content and isotopic composition were more diagenetically affected than in bones from skeletons buried in a drier environment, which display little bioerosion, high apatite crystallinity and the absence or late precipitation of secondary minerals in their bone pores.

Intra-skeletal variability of the geochemical composition, and the comparison of geochemical data from bones and teeth, enables the approximation of ante-mortem bone trace element and stable isotope compositions using the best preserved bones from each skeleton.

1. Introduction

As stated by the saying “we are what we eat” the geochemical composition of skeletal remains constitutes a direct witness of the diet of prehistoric populations and therefore provides a powerful tool for deciphering cultural practices (White, 2005). Teeth and bones both yield dietary information related to different ontogenetic periods in humans: teeth record the diet ingested during childhood as they mineralise from birth (first molar) to around 16 years of age (third molar) after which they do not remodel further (Hillson, 1986) whilst bones constantly renew over a lifetime (Toppets et al., 2004) therefore recording the diet over the last couple of years to decades before death (Marshall et al., 1973; Tanaka et al., 1981; Hedges et al., 2007). During burial, however, the geochemical signatures related to diet recorded *in vivo* may be transformed, hampering reconstruction of past human diets. This alteration is referred to as diagenesis, which encompasses multi-phase (Trueman and Martill, 2002; Pfretzschner, 2004) complex processes (reviewed in Hedges, 2002; Trueman and Tuross, 2002) altering the mineral (bioapatite, $Ca_{10}[(PO_4)_{6-x}(CO3)_x](OH)_2$; Chang et al., 1996) and organic (collagen) matrices of bones and teeth. Bioapatite may undergo dissolution, recrystallisation, crystal growth and ionic substitution (Pate et al., 1989), while collagen is bacterially or abiotically hydrolysed (Collins et al., 2002; Hedges, 2002). Meanwhile, detrital and authigenic minerals may infill bone pores (Hubert et al., 1996; Trueman et al., 2004).

Tooth enamel is generally thought to be relatively stable during burial (Koch et al., 1997; Budd et al., 2000; Hoppe et al., 2003; Trickett et al., 2003; Zazzo et al., 2004a,b; Bentley, 2006; Horstwood et al., 2008; Copeland et al., 2010; Domingo et al., 2012; Madgwick et al., 2012), although it is not completely immune from diagenesis (Kohn et al., 1999; Sponheimer and Lee-Thorp, 1999; Schoeninger et al., 2003; Ségalen et al., 2008; Roche et al., 2010; Hollund et al., 2013). In contrast, bones are well known to suffer profound chemical and mineralogical post-mortem modifications (Hedges, 2002; Trueman and Martill,

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