INTRODUCTION

Vertebrates, by definition, develop a mineralized internal skeleton composed of bioapatite that provides the animal with structural and mechanical support (e.g., Akkus et al. 2004), a reservoir of ions to maintain acid-base homeostasis (Green and Kleeman 1991) and permits terrestrial locomotion. Bioapatite consists of an organic and inorganic fraction forming a composite material that provides the skeleton and bones with a degree of flexibility as well as strength (e.g., Alexander et al. 2012). The composition of the inorganic, or mineralized, fraction of bioapatite is a non-stoichiometric apatite phase most similar in structure and composition to hydroxylapatite, with additional minor elements incorporated in the lattice {\(\text{Na}_x\text{(Ca},\text{Mg})_{10-x-y}\{\text{PO}_4\}_{6-x-y}\text{(CO}_3\}_{x+y}\) (OH)\(_{2-x}\)} (Li and Pasteris 2014b). In a living organism, bioapatite of bone is in a dynamic state of equilibrium with the body, undergoing precipitation and dissolution over the lifetime of the animal (Green and Kleeman 1991). For example, bone provides the body with a reservoir of Na, Ca, P, Mg (e.g., Green and Kleeman 1991), as well as other important sorbed species, such as citrate (e.g., Dickens 1941; Hu et al. 2010). The composition of bioapatite in bone reflects vital processes occurring over the animal’s lifetime. For paleobiologists, the use of isotopes to reconstruct past diet, climate, and ecology of extinct animals is enabled by the preservation of endogenous indicators of vital processes in the form of isotopes (e.g., Nd and Sr: Tütken et al. 2011; \(\delta^{13}C\) from tooth enamel: Cerling et al. 1993; \(\delta^{18}O\): Kohn 1996; Suarez et al. 2014). At the macro- and micro-scale, the bioapatite found in vertebrate teeth (enamel) and bones is distinct. Tooth enamel has larger, well-ordered bioapatite crystallites that contain less carbonate and more fluorine compared to bones (Wopenka and Pasteris 2005). Additionally, enamel has a low organic content (<1% by volume), which contrasts with bone (32–44% by volume; Olasz et al. 2007). The presence of organics plays a critical role in diagenesis (discussed below).

FROM LIVING TISSUE TO FOSSIL

Once removed from an organism, bioapatite undergoes necrolysis, biostratinomy, and diagenesis, potentially transforming the original living tissue into fossil bioapatite phase(s) (Figs. 1 and 2). The process of diagenesis—the chemical, physical, and biological interactions that result in the transformation of an original compound—is divided into two broad intervals for describing fossilization: early and late. For bones, early diagenesis generally refers to the initial alteration of bone once introduced into a geochemical system, although there is some ambiguity regarding the timing of this period (Trueman et al. 2008a, 2008b). Early diagenetic processes specific to bone include the removal of soft tissues (i.e., muscle and skin), degradation of collagen (abiotic and biotic), and initial chemical and structural changes to the mineralized component of bone, bioapatite, ultimately resulting in decomposition or potentially in preservation (e.g., Greenlee 1996; Sponheimer and Lee-Thorp 1999). The removal of organic