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The Potential of Direct Dating Late Cenozoic Fossils by Combined ESR/U-series Method

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Fossil assemblages were traditionally used to designate the relative ages of strata. Since a large change in fauna was required to create a new time period, most of the periods we recognize today are terminated by a major extinction or faunal turnover. However, these events occurred in different places often passed a period of time, and they could not constrain the stratigraphic age precisely. The direct dating of the fossils contained in the sediment layers would be helpful to provide more clearly and detailed chronological information of stratigraphy. Combined electron spin resonance (ESR) and U-series dating (ESR-US dating) of fossil teeth have been applied in archaeological study in recent years, and exhibit a good potential of dating Pliocene-Pleistocene sites (Bahain *et al.*, 2012; Duval *et al.*, 2012; Han *et al.*, 2012a). The tooth enamel is mainly constituted by mineral hydroxyapatite, displaying radiation-sensitive ESR signal. The lifetime of this ESR signal is in the order of 10^7 years at room temperature (Schwarcz, 1985), which allows the dating of fossil tooth sample up to several million years. The age in ESR-US dating is derived from two components, paleodose and dose rate. The paleodose corresponds to the radioactive dose the sample has received since it was formed and is determined from ESR analysis. The dose rate is the dose the sample has received each year and is derived from the radioactive element contents (U, Th and K) in the sample and its surroundings. For fossil tooth, the dose rate determination is rather complex because of the opening of uranium radiometric system for each dental tissue. Several models have been suggested to describe such uranium accumulation: Early uranium uptake (EU) model (U-accumulation shortly after tooth burial) and linear uranium uptake (LU) model (continuous U-accumulation) are the two U-uptake models commonly used in the early ESR dating studies of tooth. More recently, US-ESR model was proposed to describe uranium accumulation in tooth with an U-uptake parameter p ($p \geqslant -1$) (Grün *et al.*, 1988). By combination of the ESR method with U-series analysis, the U-uptake history of tooth tissues is represented by specific p-values varying from one tissue to the others, so the US-ESR model gives more reliable fossil age than EU and LU models. In the case of uranium leaching in fossil teeth, which could not be dated by US-ESR model, an updated Accelerating Uptake (AU) model (Shao *et al.*, 2012) may give a solution by introducing two parameters, initial uptake rate and acceleration of this uptake rate, to describe the U-uptake into dental tissue as an accelerating process, and is able to reconstruct a process combining incorporation followed by leaching. The AU model has the potential for extending the applicability of the combined ESR/U-series dating of fossil tooth, and it works for some middle Pleistocene fossil tooth samples. Although several problems regarding the combined ESR/U-series method are still under study, such as the paleodose determination and the external dose rate reconstruction (Han *et al.*, 2012b), this combined dating method has turned out to be a valuable tool for establishing geological chronologies, and it has the potential of direct dating the Pliocene-Pleistocene fossils preserved in the sediment layers and could give a more precise stratigraphic age concerning with biostratigraphy.

Key words: ESR/U-series dating, fossil tooth, late Cenozoic

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