

Petrogenesis of Paleogene basaltic rocks drilled from Western Taiwan: insight to rifting at the SE Asian continental margin

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Since the Cenozoic time, the SE Asian continental margin was subjected to extension, which is generally believed as a consequence of the India-Asia collision during late Cretaceous [1]. This extension led to submergence of the margin and formation of rift basins with widespread intraplate basaltic volcanism. The Paleogene volcanics occur sporadically in the rift basins, whereas only Neogene basalts are exposed on land in Penghu Islands and NW Taiwan [2, 3]. In this study, volcanic rocks recovered from the CPC deep boreholes in the SW Taiwan, in the Taiwan Strait and in Penghu Islands, and from the outcrop on Huahsu islet are studied for their ages and geochemical characteristics. ⁴⁰Ar/³⁹Ar dating results of these volcanic rocks show two episodes of volcanic activities: ~57-38 Ma (Eocene) and ~11-10 Ma (Miocene). The volcanic rocks are composed dominantly of basalts and basaltic andesites, with few dacites and rhyolites, but no andesite was found. The two episodes of basaltic rocks have distinct chemical characteristics. Some Eocene basalts belong to alkaline series, while all Miocene basalts are sub-alkaline. In comparison to the Miocene basalts, the Eocene basalts are more depleted in basaltic components such as Ca, Fe and Ti but have higher Al content. They are also more enriched in large ion lithophile elements (LILE) and light rare earth elements (LREE) and depleted in high field strength elements (HFSE). The Sr-Nd-Pb isotope compositions show the Miocene basalts are relatively homogeneous and unradiogenic ($\epsilon_{\text{Nd}} = 3.8 \sim 6$) similar to the depleted onland Miocene basalts [3] and the MORB-type South China Sea basalts [4], whereas the Eocene basalts have the wider range ($\epsilon_{\text{Nd}} = 5.6 \sim -3.2$) with more radiogenic feature towards an enriched mantle source. The overall geochemical characteristics suggest these two episodes of basalts originated from distinct mantle sources: a refractory mantle source metasomatized by subduction-related processes to generate the Eocene basalts and a fertile but isotopically depleted mantle source similar to that of MORB for the Miocene basalts. These two mantle sources most likely reside in the lithospheric mantle and asthenospheric mantle, respectively. The change of magma mantle sources with time reflects evolution of the tectonic regime from the initial rifting along the continental margin to upwelling of the asthenosphere due to thinning of lithosphere. Considering the extension regime is dominant in the Paleogene, together with lack of the intermediate andesite indicative of subduction, the subduction origin proposed for the Eocene basalts due to their HFSE depletion appears unfavorable.

[1] Tapponnier et al. (1982) *Geol.* 10, 611-616. [2] Chung et al. (1994) *Chem. Geol.* 112, 1-20. [3] Chung et al. (1995) *GCA* 59, 549-555. [4] Tu et al. (1992) *Chem. Geol.* 97, 47-63.

Kinetics of calcium phosphate nucleation and growth on calcite

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Introduction

Calcium orthophosphate (Ca-P) is the most ubiquitous form of P among the geological phosphate-bearing minerals [1]. Unraveling the kinetics of Ca-P precipitation and dissolution is important for our understanding of the transformation and mobility of dissolved phosphate species in soils [2]. Here we use *in situ* atomic force microscopy (AFM) coupled with a fluid reaction cell to study the interaction of phosphate-bearing solutions with calcite surfaces.

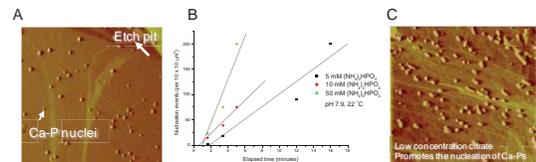


Figure 1: Kinetic analysis of surface nucleation of Ca-P phases on calcite substrates. (A) AFM image of Ca-P particles on a calcite surface during *in situ* nucleation events. Image $10 \times 10 \mu\text{m}$. (B) Plot against time of different concentrations of $(\text{NH}_4)_2\text{HPO}_4$. (C) AFM image of Ca-P phases on calcite in the presence of $1 \mu\text{M}$ citrate with $50 \text{ mM } (\text{NH}_4)_2\text{HPO}_4$ at pH 7.9. Image $10 \times 10 \mu\text{m}$.

Results and conclusion

We observe that the mineral surface-induced formation of Ca-P phases is initiated with the aggregation of clusters leading to the nucleation and subsequent growth of Ca-P phases on calcite, at various pH values and ionic strengths relevant to soil solution conditions. A significant decrease in the dissolved phosphate concentration occurs due to the promoted nucleation of Ca-P phases on calcite surfaces at elevated phosphate concentrations and more significantly at high salt concentrations. Also, kinetic data analyses show that low concentrations of citrate caused an increase in the nucleation rate of Ca-P phases. However, at higher concentrations of citrate, nucleation acceleration was reversed with much longer induction times to form Ca-P nuclei. These results demonstrate that the nucleation-modifying properties of small organic molecules may be scaled up to analyze Ca-P dissolution - precipitation processes that are mediated by a more complex soil environment. This *in situ* observation, albeit preliminary, may contribute to an improved understanding of the fate of dissolved phosphate species in diverse soil systems.

[1] Filippelli (2008) *Elements* 4, 89-95. [2] Wang & Nancollas (2008) *Chem. Rev.* 108, 4628-4669.