Thallium-mineralization during late magmatic activity in the peralkaline complex Ilimaussaq, Greenland

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The layered peralkaline igenous Ilimaussaq complex (Gardar failed-rift province in southwest Greenland) has attracted exploration activities in past and present. The intrusion was emplaced in three magmatic phases, evolving in an essentially closed-system. The composition of the rocks covers a broad range of alkaline rocks, ranging from alkaline to peralkaline granites and syenites to highly evolved nepheline syenites. The latest magmatic rocks are among the most differentiated, known on earth [1]. During late-stage magmatic activity hydrothermal fluids released by the magma formed veins cutting earlier rocks of the complex. The rare mineralization of the Tl-Cu-Fe-minerals thalcusite, chalcothallite and djerfisherite-thalfenisite solid-solutions occurs associated with veins containing aegirine-feldspar-sodalite-ussingite assemblages [2]. These assemblages were formed by CH_4- and H_2O-rich fluids at temperatures ranging from 200 to 400°C and anomalous high pH (7 to 9) [3, 4]. The unusual enrichment of Tl in these late magmatic fluids was most likely triggered by fluid-wall rock interaction. During magma crystallization, Tl shows an incompatible lithophile behavior and is incorporated into silicate minerals exchanging for K [5]. During vein formation, K-bearing minerals were partly replaced by K-poor minerals. The resulting K-excess causes astrophyllite to crystallize at the expense of primary mafic minerals (aegirine+aenigmatite±Na-amphibole). The Tl released by these reactions is enriched in the Cu-bearing fluids and lead to the formation of Tl-Cu-Fe-sulfides, which are thermodynamically stable at high pH-conditions. This process is an example for the decoupling of elements with coherent magmatic behavior under hydrothermal conditions.

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Calcium isotope systematics of dinosaur teeth

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We present new data on the Ca isotopic compositions of Late Cretaceous to Early Triassic dinosaur teeth (enamel and dentin) from different sympatric herbivorous and carnivorous dinosaurs. To investigate potential diagenetic alteration we analyzed teeth of various extant reptiles for comparison.

Diagenetic alteration of the dinosaur teeth seems negligible as they have a similar $\delta^{44/40}$Ca difference of ~0.4‰ between enamel and dentin compared to extant reptiles. Furthermore, no systematic relationship between $\delta^{44/40}$Ca of fossil teeth and the embedding sediment is observed. Preservation of original $\delta^{44/40}$Ca in Mesozoic fossil bones and teeth thus seems likely.

Extant mammalian bones display a trophic level effect with $\delta^{44/40}$Ca values from carnivores being ~1‰ lighter compared to herbivores [1]. However, $\delta^{44/40}$Ca values of skeletal apatite of sympatric herbivorous and carnivorous dinosaurs do not show any systematic difference. Since no Ca isotope fractionation between diet and soft tissue occurs [2] the lack of a trophic level offset between herbivores and carnivores can be explained if the investigated carnivorous dinosaurs only fed on soft tissue from herbivores. This would result in very similar $\delta^{44/40}$Ca of the diet of herbivores and non-bone-ingesting carnivores and thus in very similar $\delta^{44/40}$Ca ratios of the mineralized tissues.

In contrast, a *Tyrannosaurus rex* tooth yields an enamel $\delta^{44/40}$Ca value ~1‰ lower than those of all other herbivorous and carnivorous dinosaurs analyzed. T-Rex was capable to crush and ingest bone [3]. Thus we hypothesize that T-Rex ingested significant amounts of bone tissue with low $\delta^{44/40}$Ca. This would explain the lower $\delta^{44/40}$Ca values than for presumably non-bone-ingesting carnivorous dinosaurs. This hypothesis will be further tested by analyzing teeth of sympatric smaller theropods as well as extant hyenas and lions.

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