Early thermal events of the HED parent body (4 Vesta) from eucrite zircon U-Th-Pb-Ti depth profiles

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Meteoritic zircons provide a means to probe the thermal evolution of asteroids, but this technique has been limited due to generally low yields of small (~10μm ∅) grains in thin sections cut at random orientations and analyzed in 2-D "spot mode". Conversely, the 3-D zircon depth-profile method chemically and isotopically maps minute (sub-µm) domains within individual grains that conventional 2-D spot analyses cannot capture. We report data from coupled Ti-thermometry and U-Th-Pb profiles used to evaluate apparent crystallization temperature and composition as a function of age in zircons from the Millbillille brecciated eucrite. Crushed and sieved ~3g aliquots were separated using reagent grade methylene iodide to extract the largest zircons. Two large grains (mb1_gr1 ~40μm; mb7_gr1 ~20μm) were imaged by back-scattered electrons, and the internal distributions of U-Th-Pb-^{49}Ti (and -^{57}Fe-^{177}Hf^{++}-^{89}Y) in each zircon measured on the UCLA Cameca ims1270 ion microprobe in depth-profile mode. Results show that mb1_gr1 preserves a concordant core age of 4561±13 Ma (2σ; mswd=0.72; n=7) and a 4.5μm overgrowth at 4524±9 Ma (2σ; mswd=2.52; n=19). Sample mb7_gr1 shows one domain age of 4537±10 Ma (2σ; mswd=3.0; n=19) statistically indistinguishable from the younger mantle in zircon mb1_gr1. Core ages from mb1_gr1 correlate well with other reported crystallization ages for eucrites [1] and ^{40}Ar-^{39}Ar ages of unbrecciated eucrites [2]. Because the decay of ^{26}Al was effectively complete 5 Myr after t_0, we propose that later ~4530 Ma events that overprint ca. 4560 Ma ages were caused by shock-heating from a large impact, or burial of hot material excavated by impact. The manifestation of such a large and early impact event on a small (900km) body such as 4 Vesta should be as a subdued impact basin from the mechanical relaxation of the asteroid's crust. NASA's DAWN mission will encounter Vesta (July, 2011) and should be capable of resolving whether such an old basin is present.

[1] Bukovanska *et al*. (1997) *Journal of GEOsciences*, **42**, 20.
[2] Bogard & Garrison (2003) *Meteor Planet Sci,* **38**, 669-710.

Rejuvenation of an old magmatic system at Parinacota Volcano, Chile

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The history of Parinacota Volcano in the Andean CVZ represents a transition between two fundamentally different modes in which magmatic reservoirs can operate: long-term crystal accumulation and storage vs. rapid throughput with minimal crustal transit times. Changes in volcanic output rate and compositional range parallel reorganization of the magma system preceding a sector collapse, after which the volcano was rapidly rebuilt [1]. ^{238}U-^{230}Th disequilibria indicate crystal ages of >120 k.y. in the pre-collapse time interval. In contrast, some post-collapse magmas have $(^{230}Th/^{238}U)_0$ eruption-age-corrected activity ratios as high as 1.33, implying that transit times from a region of garnet-residual partial melting in the lower crust to the surface were < 20 ky.

Minerals from pre-collapse highly porphyritic rhyodacite domes (eruption age 47-40 ka) do not form a linear array on an U-Th equiline diagram, but rather define a pair of wedges delineated by reference isochrons that have ages of 47.7 and 168 ka [2]. Because these are bulk crystal ages, two possible explanations are: (1) a protracted crystallization interval, during which crystals were nucleating continuously, or (2) crystal cores from a nascent pluton or crystal-rich mush zone that are older than 168 ka were subsequently overgrown with younger rims of variable thickness, resulting in average ages that in some cases approach that of eruption.

The phase assemblage present in these domes allows several geothermometers to be applied, recording different points along a pre-eruption Temperature-time path. Fe-Ti oxide equilibria yield temperatures of 792±30°C, whereas Zr-in-titanite gives temperatures that are ~85°C cooler. Because Zr diffusion in titanite is slow [3] compared to Fe-Ti oxide reequilibration, it is likely that the lower temperatures in titanite record an earlier point in T-t history. This would contradict the hypothesis of protracted monotonic cooling prior to eruption. Instead, it may indicate a re-heating event associated with recharge that remobilizes older (colder) crystals and facilitates their eruption after a long period of storage.

[1] Hora *et al* (2009) *EPSL* **285**:75-86, [2] Hora *et al*. (2010) *Geology* **38**:923-926, [3] Cherniak (2006) *CMP* **152**:639-647