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Nanoscale evidence of metamorphism – insights from natural and experimentally-treated zircon

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Nanoscale analyses of zircon have demonstrated that trace elements, including Pb, can be mobilized to discrete sites in radiation damaged zircon. Although several mechanisms for trace element mobility and segregation in zircon have been proposed, most of this work has been conducted on zircon grains with complex geologic histories, making it difficult to directly determine the mechanisms driving trace element mobility and segregation in zircon. To test among the existing hypotheses for mechanisms driving trace element mobility and segregation, we analyzed both untreated and experimentally heated (1450°C for 24h) Archean zircon using atom probe tomography and transmission electron microscopy (TEM). The sample has a simple, well-characterized thermal history, with no significant thermal events since original crystallization. Despite a high calculated radiation dose (>4 x 10^{18} a/g), the untreated zircon does not contain anomalous nanoscale features. In contrast, the experimentally heated zircon contains abundant clusters of Y, Mg, Al, Pb + Yb that range from 5 nm to 25 nm in diameter with toroidal polyhedral morphologies. The $^{207}Pb/^{206}Pb$ measured from Pb atoms located within these features is consistent with present-day segregation, thus confirming that these nanoscale features were produced by experimental heating in the laboratory. TEM analysis determined that the clusters are dislocation loops, and that cluster morphology is therefore crystallographically controlled. The largest loops are located in {100} and contain high concentrations of Mg and Al.

These experimentally induced, trace-element-enriched clusters are similar in size, morphology, composition, and crystallographic orientation to clusters observed in zircon affected by natural geologic processes (cf. Valley et al., 2015; Peterman et al., 2016). Although the calculated radiation doses for all analyzed grains are high, comparison of the nanoscale features indicates no apparent correlation between the radiation dose and the density or distribution of clusters. We also observe that trace-element-enriched clusters are conspicuously absent from zircon grains that lack younger igneous or metamorphic rims. These findings suggest that the pressure-temperature-time (P-T-t) history and the dT/dt significantly impact both the nanoscale redistribution of trace elements and the density of these features within zircon. Systematic evaluation of the composition and distribution of these features provides a framework for understanding the nanoscale record of metamorphism.

References:

Peterman, E.M., Reddy, S.M, Saxey, D.W., Snoeyenbos, D.R., Rickard, W.D.A., Fougerouse, D., and Kylander-Clark, A.R.C. (2016) Nanogeochronology of discordant zircon measured by atom probe microscopy of Pb-enriched dislocation loops. Science Advances, 2, e:1601218.

Valley, J.W., Reinhard, D.A., Cavosie, A.J., Ushikubo, T., Lawrence, D.F., Larson, D.J., Kelly, T.F., Snoeyenbos, DR., and Strickland, A. (2015) Nano-and micro-geochronology in Hadean and Archean zircons by atom-probe tomography and SIMS: New tools for old minerals. American Mineralogist, 100, 1355-1377.