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Geochronological implications of metallic Pb nanospheres in zircon exposed to high-grade metamorphism.

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Zircons from Neoarchean granulite and ultra-high temperature gneisses in the Napier Complex of East Antarctica preserve magmatic U-Pb ages greater than 3.8 Ga [1,2]. Early Secondary Ion Mass Spectrometry (SIMS) studies [3] identified isotopic disturbance of >3.4 Ga zircons, through reversely discordant age estimates (where $^{206}Pb/^{238}U$ ages are older than $^{207}Pb/^{206}Pb$ ages) and excessive within-run instability of Pb isotope counts during analysis. These results were confirmed by ion imaging studies that indicated within-grain separation and redistribution of radiogenic Pb from radiation-damaged zircon [4,5]. Isotopic mapping of ^{48}Ti, ^{89}Y, ^{180}Hf, ^{232}Th, ^{238}U, ^{204}Pb, ^{206}Pb and ^{207}Pb in sub-grain areas of zircon was done by SIMS using a CAMECA IMS 1280 at the Swedish Museum of Natural History in Stockholm, using both mono- and multi-collection modes. Maps of Pb and Ti isotopes revealed sub-2 µm patches of anomalously high concentration, with variably high $^{207}Pb/^{206}Pb$ values corresponding to apparent ages up to 4.1 Ga; there is no evidence of common Pb contamination as would be indicated by detectable ^{204}Pb. Inhomogeneous distribution of Pb in zircon affected by high-temperature metamorphism has also been detected in gneisses from India in a study combining ion imaging with ion tomography that revealed the likely tens of nanometer scale movement of the unsupported Pb [6], as well as in detrital zircon grains from the Jack Hills [7].

Using high-resolution scanning transmission electron microscopy (TEM) at the GeoForschungsZentrum in Potsdam, Germany, it was discovered, that these domains of anomalous Pb contain metallic lead nanospheres 5-35 nm in size [8] in a matrix of zircon (Fig. 1). The nanospheres occur in isolation (Fig. 1) and as multi-phase inclusions 20-80 nm across that also contain Ti and Al-rich phases and silica glass. These were interpreted as having formed as melt inclusions generated during annealing of radiation-damaged zircon by high-temperature metamorphism [8]. The presence of Pb nanospheres in zircon from high-temperature gneisses goes some way in explaining anomalous isotopic age estimates that are sometimes obtained during SIMS analysis. Reverse discordance, including spuriously old $^{207}Pb/^{206}Pb$ age estimates, may result from the migration of radiogenic Pb within heat-annealed zircon, as well as from analytical effects induced by the non-simultaneous measurement of isotopes in zircon that contains Pb in nanospheres.

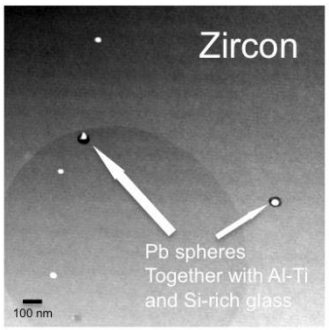

Figure 1: TEM image of zircon showing Pb nanospheres (white) in Si-rich glass together with Ti–Al-rich phases (dark areas around Pb nanospheres).

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