Geochronological Evaluation of the Cooling Rate of the Diabasic Angrite Northwest Africa 12320.

C. Datta[1], Y. Amelin[1], E. Krestianinov[1]. Research School of Earth Sciences, The Australian National University, Canberra ACT 2601, Australia (u6665653@anu.edu.au)

Introduction: The Angrite meteorite group refers to a collection of differentiated achondrites of roughly basaltic composition with U-Pb crystallisation ages dating back to only 3-10 million years after CAIs [1,2]. Data on the cooling rates of angrites may allow interpretations of the size/depth of magmatic intrusions they were produced from, and the size/thermal properties of the yet unidentified Angrite parent body. Some cooling rates of angrites have been reported already [e.g., 3,4] but there is a need for more data for any rigorous thermal modelling studies. Pb-Pb dating of the diabasic textured angrite NWA 12320 by [5] yielded two precise and well resolved Pb -isotopic ages for acid soluble and acid insoluble minerals, providing an opportunity to calculate a cooling rate if this apparent age difference is not due to differences in $^{235}U/^{238}U$ between the acid soluble and insoluble mineral hosts of radiogenic Pb.

Methods: Pb-Pb isotopic ages found by [5] were recalculated using $^{235}U/^{238}U$ ratios measured directly in NWA 12320 washes, residues and whole rock fractions through procedures described in [6]. A petrologic study of the angrite was carried out using QEMSCAN to identify all mineral phases in a polished mount of the angrite. The composition of phosphates identified in the NWA 12320 was also constrained by EPMA. Finally, the U, Th, and Pb concentrations as well as Pb isotopes in all identified mineral phases were measured on SHRIMP II at ANU. XRD to constrain phosphate structures is currently in progress.

Results: The U isotopic composition of NWA 12320 residue and whole rock fractions are indistinguishable ($^{238}U/^{235}U$ of whole rock=137.8089 ± 0.0067 (n=2) and residue=137.7987± 0.0102 (n=4). Wash fractions could not be analysed due to an instrument glitch, but it can be assumed that they are indistinguishable from the bulk $^{235}U/^{238}U$ ratio. QEMSCAN mapping confirmed that the mineralogy of NWA 12320 matches with prior petrologic characterisation by [7] but with one novel discovery of two varieties of phosphates evenly distributed throughout the NWA 12320 groundmass: a high-silica variety and a low silica variety with chemical compositions corresponding to the minerals tsangpoite and matyhite respectively, both of which have been found in D'Orbigny [8]. SHRIMP measurements revealed that the major hosts of U, Th and radiogenic Pb in NWA 12320 are Al-Ti rich augite which makes up approx. 20 mode % of the rock and the two phosphate varieties which make up only <1 mode % of the rock but have up to two orders of magnitude higher U, Th and Pb concentrations compared to augite.

Cooling rate calculation and discussion: Our SHRIMP data and knowledge that phosphates are readily soluble in nitric acids used in early acid leaching steps lead to the interpretation that 'acid soluble' and 'acid insoluble' hosts of radiogenic Pb referred to in [5] are phosphates and Al-Ti rich augite respectively. Recalculation of Pb-Pb ages using U isotopic data specific to NWA 12320 yields ages (with uncertainties reported as ± 2SD) of 4563.23 ± 0.46 Ma for the bulk wash+ residue isochron, 4562.84 ± 0.36 Ma for the washes, and 4564.17 ± 0.50 Ma for the residues. This yields an age difference of 1.33± 0.62 Ma between washes and residues. The formalism of [9] and diffusion parameters of augite [10] and apatite [11] was used to compute closure temperatures of 820 ± 90 °C for augite and 450± 80°C for apatite (chosen as a proxy for the phosphates present since structure of NWA 12320 phosphates has not been constrained and diffusion data on other Ca phosphate minerals does not yet exist), using measured grain sizes and assuming cylindrical geometries of augite and phosphates.Using these closure temperatures and the age gap between acid soluble and acid insoluble mineral isochrons yields a model cooling rate of 280± 160 °C/Ma. This is orders of magnitude slower than petrologic cooling rates of [4], suggesting a non-linear cooling history for this angrite: fast cooling at high temperatures and slow cooling at lower temperatures, perhaps due to initial subaerial eruption onto the surface of the angrite parent body/rapid heat loss by radiation, followed by burial and insulation of NWA12320 magma by subsequent lava flows.

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