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Late-Stage Metasomatism of Brachinite-Like Achondrites Revealed by U-Pb Dating of Apatite

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The primitive achondrites offer an important "snapshot" of differentiation processes on the earliest parent bodies in the Solar System, with formation of many primitive achondrites predating major accretion of major chondrite groups [1-2]. The brachinites and related brachinite-like achondrites (BLA) are the primitive achondrites with the lowest silicate Mg#, owing largely to a higher oxygen fugacity during melting than other groups [3]. They are mineralogically similar to terrestrial peridotites containing chiefly olivine, along with pyroxene, plagioclase and accessory metal, oxides, sulfides and phosphates, and also exhibiting equilibrated textures [2]. Ages of differentiation of brachinites are not well constrained, with a Mn-Cr model age of 4563.7 ± 0.3 Ma of type specimen Brachina being the best estimate for crystallization age currently available [4].

Two meteorites, the brachinite El Medano (EM) 395 and the BLA Northwest Africa (NWA) 12532 were analyzed for their mineral chemistry, bulk rock major and trace element systematics and their Sr isotope systematics. The BLA NWA 12532 shows a notable enrichment in Cl-rich apatite relative to all other known brachinites/BLA (~1.26% modal), while EM 395 has mineralogy and geochemistry typical of most brachinites. The large size of NWA 12532 apatite (~400 mm) allowed for precise U-Pb dating of the phase at 4491.3 ± 14.1 Ma, ~70 Ma younger than the Mn-Cr model age for Brachina. The REE pattern of the apatite in NWA 12532 shows a negligible Eu anomaly, despite the presence of a strongly positive Eu anomaly in co-existing plagioclase. These two observations suggest that the apatite was added to NWA 12532 by a late metasomatic event and never fully equilibrated with the silicate phases. This metasomatic event is likely connected with impact heating that melted halogen-rich surficial ices, as short-lived radiogenic isotopes were gone by ~4491 Ma. Rubidium-Sr isotope systematics show significant scatter due to terrestrial weathering but are more consistent with the ^{87}Rb-^{87}Sr system closing within each meteorite at 4491 rather than 4564 Ma.

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