EPSC Abstracts
Vol. 15, EPSC2021-846, 2021
https://doi.org/10.5194/epsc2021-846
Europlanet Science Congress 2021

Early and sequential formation of planetesimals in an outer region of the protoplanetary disc

Audrey Bouvier[1], Ning Ma[1], Wladimir Neumann[2], Adrien Neri[1], Winfried H. Schwarz[2], Thomas Ludwig[2], Mario Trieloff[2], and Hubert Klahr[3]
[1]Bayerisches Geoinstitut, Universität Bayreuth, Bayreuth, Germany
[2]Institut für Geowissenschaften, Universität Heidelberg, Heidelberg, Germany
[3]Max-Planck-Institut für Astronomie, Heidelberg, Germany

Isotopic anomalies in meteorites have revealed two reservoirs of planetesimal formation corresponding to non-carbonaceous (NC) and carbonaceous (C) compositions sampling the inner and more outer regions of the disc respectively (Kruijer et al. 2020), or possibly formed at different periods (Lichtenberg et al. 2021). Chronological studies provide constraints on the timing of such separation lasting between 1 and 4 Myr after CAIs. Generally, differentiated planetesimals are found to be prevalent in the NC region and accreted within <0.5-2 Myr after solar system formation, forming before undifferentiated NC and C parent bodies (2 to 4 Myr). NC irons started accreting slightly before C irons but all within 1 Myr (Kruijer et al. 2020; Lichtenberg et al. 2021).

We present here a first group of 12 partially differentiated primitive C achondrites which are isotopically related to the CR2 chondrites. We propose the name of Tafassites after the Tafassasset meteorite. These meteorites are currently classed as CR6, CR7, ungrouped chondrites and achondrites, or primitive achondrites. Among these, we investigated Taffassasset, NWA 7317, NWA 11561 and NWA 12455 for their mineralogy and textures, and modelled their two-pyroxene equilibration temperatures (1334 to 1413 K), and fO_2 (-1.4 ± 0.1 in log unit below the iron-wüstite buffer). We also obtained in-situ SIMS U-Pb ages in merrillite phosphates (closure temperature T_c ~720 K) ranging from the oldest at 4561.0 ± 2.9 Ma (n=21, uncertainties reported as ±1σ) for NWA 11561, 4560.1 ± 2.9 Ma (n=10) for NWA 7317, 4558.4 ± 3.5 Ma (n=16) for NWA 12455 and slightly younger 4549 ± 8 Ma (n=7) for Tafassasset (Schwarz et al. 2021). On average, the duration of cooling recorded by phosphates lasts for 8 ± 4 Myr after formation of calcium aluminium-rich inclusions (CAIs).

We use these observations and parameters along with geochemical and geochronological literature data to constrain the formation and thermal evolution of the Tafassite parent body (TPB). We performed numerical modelling of the accretion and thermal evolution of the TPB (Neumann et al. 2018). The best fit for accretion occurs at 0.9 ± 0.1 Myr after CAIs, with a corresponding radius of >50 km. This age is before the formation of two other CR-related differentiated achondrite and the CR2 chondrite PBs at ~1.5, ~1.7, and ~4 Myr, respectively (Sanborn et al. 2019). Our results indicate that TPB formed concurrently with NC primitive achondrite PB (Neumann et al. 2018).

Based on geochemistry and reported ^{17}O-^{54}Cr-^{50}Ti isotopic anomalies (Sanborn et al. 2019), Tafassites can be further distinguished from CR2 chondrite and NWA 011 and NWA 6704

differentiated achondrite parent bodies (PB). While a high pebble flux is a preferred mechanism for regulating early planetesimal formation (Lenz et al. 2019; 2020), the close relationship of isotopic anomalies for ^{54}Cr among these CR-related planetesimals suggest instead that limited radial mixing of pebbles as building material occurred after 1 Myr of disc evolution. The late formation and compositional observations of CR chondrites require both a change to less efficient planetesimal formation and a pebble storage mechanism, e.g., in disc ring structures (Hartlep and Cuzzi 2020). Our results therefore demonstrate that rocky parent bodies accreted early and sequentially, from 1 to 4 Myr after CAIs, and depict different accretion mechanisms within a limited region of the outer solar system.

References:

Hartlep and Cuzzi. 2020. Cascade Model for Planetesimal Formation by Turbulent Clustering, *The Astrophysical Journal*, 892: 120.

Kruijer, Kleine and Borg. 2020. The great isotopic dichotomy of the early Solar System, *Nature Astronomy*, 4: 32–40.

Lenz, Klahr and Birnstiel. 2019. Planetesimal population synthesis: Pebble flux-regulated planetesimal formation, *The Astrophysical Journal*, 874: 36.

Lenz, Klahr, Birnstiel, Kretke and Stammler. 2020. Constraining the parameter space for the solar nebula-The effect of disk properties on planetesimal formation, *Astronomy & Astrophysics*, 640: A61.

Lichtenberg, Dra□żkowska, Schönbächler, Golabek and Hands, 2021. Bifurcation of planetary building blocks during Solar System formation, *Science*, 371: 365-70.

Neumann et al. 2018. Modeling the evolution of the parent body of acapulcoites and lodranites: A case study for partially differentiated asteroids, *Icarus*, 311: 146-69.

Sanborn et al. 2019. Carbonaceous achondrites Northwest Africa 6704/6693: Milestones for early Solar System chronology and genealogy, *Geochimica et Cosmochimica Acta*, 245: 577-96.

Schwarz et al. 2021. Pb-Pb Ages of Chondritic Phosphates. *Lunar and Planetary Science Conference*, Abstract # 1981.