Incipient melting and differentiation of the CR chondrite parent body

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Introduction: Primitive achondrites preserve records of transitional stages from chondrites to differentiated achondrites. They provide a great opportunity to deduce the thermal histories (e.g., thermal metamorphism, partial melting and differentiation) of planetesimals in the early solar system. North West Africa (NWA) 12869 is a newly identified primitive achondrite. Petrographically and geochemically, it resembles some other primitive achondrites (e.g., Tafassasset, NWA 5131, NWA 12455, NWA 3250, NWA 11112, NWA 3100, NWA 2994, NWA 6921 and NWA 7317), ungrouped basaltic achondrites (e.g., NWA 011/2976) as well as orthopyroxenites (e.g., NWA 6704/6693) [1].

Results and discussion: This work reports a comprehensive study of petrography, mineralogy and O-Cr isotope systematics of four ungrouped primitive achondrites (NWA 12869, 3250, 11112 and Tafassasset). These meteorites have essentially the same mineralogy. Major phases are olivine, pyroxene and feldspar, with similar chemical compositions ($Fa_{28.6\sim38.2}$, $Fs_{23.6\sim30.4}$). They might have formed in a similar oxygen fugacity (fO_2=-19). Based on two-pyroxene geothermometer and 3D spatial distributions of feldspar and metal-sulfide, the estimated thermal metamorphic temperature of NWA 12869, 3250 and 11112 is less than 1000 ℃, and therefore can be classified as Type 6 (silicates unmelted). In contrast, plagioclase in Tafassasset are extensively interconnected to form as a network, indicating Tafassasset experienced higher thermal metamorphism temperature (~ 1100 ℃). Tafassasset can thus be classified as Type 7 (producing silicate melt and removal). Based on mineralogical, petrological and geochemical observations in our work, a close affinity among NWA 12869, 3250, 11112 and Tafassasset can be established. By combining ^{54}Cr nucleosynthetic anomalies and mass-independent oxygen anomalies, it is possible to infer that these four primitive achondrites are closely related to CR carbonaceous chondrites. It points towards the possibility of a common CR parent body (Fig. 1), which may experience substantial thermal metamorphism and even internal igneous differentiation. To hold various types of meteorites in one parent body, CR parent body must have been sufficiently large to have undergone substantial, non-isochemical internal thermal metamorphism and partially differentiation (probably fluid mediated), while also possessing a chondritic regolith (CR1, CR2 and CR3). This layered, differentiated parent body structure containing metamorphic and igneous lithologies overlain by a chondrite veneer has previously been proposed for CV chondrite parent body by Elkins-Tanton [2] as well as acapulcoite-lodranite parent body by Eugster and Lorenzetti [3], Neumann et al. [4] and Li et al. [5].

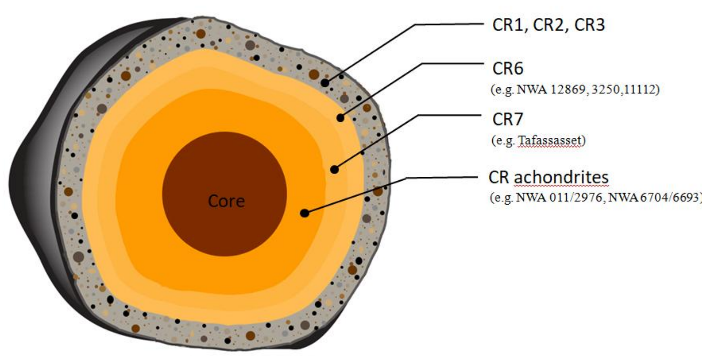

Fig. 1 A schematic diagram showing a possible inner structure of a partially differentiated CR carbonaceous chondrite parent planetesimal with unmelted chondritic crust, achondritic silicate mantle and metallic core.

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