RAGING ROCKS AND SHIVERING SHOCKS: EVIDENCE FOR IMPACT-HEATING IN CR CHONDRITE CLASTS.

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Introduction: The Renazzo-like carbonaceous (CR) chondrites are amongst the most primitive early Solar System materials available for study ([1] and references therein). Some CR chondrites contain optically dark regions of CR chondrite material that have experienced intense aqueous alteration, known as dark inclusions [2]. Since the CR chondrites were one of the last carbonaceous chondrite groups to accrete [3,4], in addition to containing brecciated CR chondrite material, they may have incorporated material from other sources during or after accretion (i.e., they may contain xenoliths). Indeed, in the last decade, a variety of clast types distinct from dark inclusions have been recognized in CR chondrites, providing valuable information about early Solar System processes [5–8]. We summarize the clastic material identified in CR chondrites to date and discuss their significance.

Results: The array of clasts identified in CR chondrites include: (**1**) A xenolithic clast of ultracarbonaceous cometary building block material in the CR2 LaPaz Icefield (LAP) 02342 that supports the idea of inward radial transport of material from the outer protoplanetary disk to the CR chondrite forming region [5]. (**2**) An omphacite, amphibole, and graphite-bearing clast in the CR2 Queen Alexandra Range (QUE) 99177 that may be a metamorphosed xenolith from a large ~760 km wide asteroid [6]. (**3**) Three eclogitic xenolithic clasts were identified in the CR2 Northwest Africa (NWA) 801 and may have formed in a large moon-sized body [7,8]. (**4**) We recently identified a clast in the CR2 Pecora Escarpment (PCA) 91082 that represents heated CR2 chondrite material that was not aqueously altered [9] and likely formed by slower cooling than seen in carbonaceous chondrite impact melts [10,11]. (**5**) We also recently reported the identification of a clast in the CR2 Miller Range (MIL) 11231, which underwent extensive aqueous alteration followed by heating, furthering our understanding of the CR chondrite parent body's alteration history [12].

Discussion: The variety of different clasts identified in CR chondrites have the potential to inform us about different processes in small planetary bodies, particularly the the post-accretionary history of the CR parent body. Since the CR chondrite parent body accreted too late for ^{26}Al to be a significant heat source [3,4], the only evidence for substantial heating is attributable to impacts. For example, foliation in the CR2.7 MIL 090657 likely resulted from multiple low-energy shock events [1], similar to what has been seen in CM chondrites [13]. Furthermore, the carbonates in CR1 GRO 95577 are ~8 Myr younger than those in CR2 chondrites, potentially due to later formation as a result of localized heating of water induced by impact activity [14]. The clasts in PCA 91082 (heated, not aqueously altered) and MIL 11231 (aqueously altered, subsequently heated) are products of impact-heating of CR chondrite material with different initial degrees of aqueous alteration. Thus, clasts in CR chondrites provide invaluable insights into the physical and chemical processes occurring in both the protoplanetary disk (e.g., [5]) and in the CR chondrite parent body, including incorporation of xenolithic material from other bodies (e.g., [6–8]) and impact processing of preexisting CR material [9, 12].

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