Anomalous and ungrouped carbonaceous chondrites in the US Antarctic meteorite collection and their potential relevance to Ryugu and Bennu

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With two different carbonaceous asteroid sample return missions in full swing, attention has focused on what connections can be made between the asteroid samples and the wide range of carbonaceous chondrite meteorites in worldwide collections. The US Antarctic meteorite collection contains nearly 1000 carbonaceous chondrites of various types including many in well-established groups as well as ungrouped, unusual or anomalous groups [1]. Some of the latter have been included in, or are possibly related to, recently proposed new carbonaceous chondrite classifications – CA and CY chondrites [2,3]. In addition to these, there are numerous ungrouped samples that have properties intermediate between established groups (like CM and CO; [4]), distinct from any other groups [5], or have anomalous properties that might be attributable to parent body processes such as heating, fluid interaction, or impacts [6].

Some CM anomalous or ungrouped chondrites share spectral features with Ryugu, which has a small hydration peak arguably due to hydrated minerals left after either impact heating or shock in carbonaceous chondrites [7]. PCA 91008, PCA 02012, GRO 95566, and LEW 85311 are all CMs that have experienced heating or metamorphism that may be due to impacts, solar radiation, or radiogenic decay [6]. These samples all have low H contents, C/H (bulk), and low $\Delta^{17}O$ [6,8] and may hold clues to understanding the mineralogy of Ryugu, or interpretations of its spectral properties.

WIS 91600, on the other hand, appears to be related to several other highly altered CM [6], and shares properties with the newly proposed CY chondrites [6]. An understanding of this grouplet will also aid in the interpretation of Bennu samples which have strong hydration features. In addition, ungrouped carbonaceous chondrites may provide valuable insights into the aqueous alteration potentially recorded in Bennu and Ryugu samples; such as the relatively moderate aqueous alteration recognized and dated at 4-5 myr after CAIs in MAC 88107 (C2-ungrouped) by [9] to the extensive aqueous alteration apparent in MIL 090292 (C1-ungrouped) [10].

Finally, LON 94101/94102 is a brecciated CM chondrite with numerous lithologies. Its appearance is similar to some of the brecciated lithologies visible at the surface of Bennu and Ryugu [11]. Although CM chondrites with multiple lithologies are common (e.g., [12]), the lithologies are often difficult to resolve at the hand specimen scale and only after some detailed e-beam characterization are the subtle lithologic differences evident (e.g., [13]). LON 94102 contains visibly distinct clasts at the hand specimen scale, relatively rare for CM breccias.

The largest CM chondrites by mass from the U.S. Antarctic meteorite collection may provide insights into the extent of brecciation and heterogeneity within more typical CM chondrite-like source asteroids. For example, recent curation CT scans [14] show possible clasts within in a subsplit of ALH 83100 (CM1/2) which is the largest CM chondrite or CM chondrite pairing group in the U.S. Antarctic collection with an original mass of 3.019 kg. Similar work on additional subsplits or meteorites may aid our understanding of heterogeneity within CM chondrites from Antarctica.

Initial classification of CM chondrites in the U.S. Antarctic meteorite collection includes preliminary pairing when petrographically similar CM chondrites that have been previously found in the same field area. The two largest CM chondrite preliminary pairing groups by mass are the ALH 83102 (CM2) pairing group with an original mass of 2.554 kg and the EET 96005 (CM2) pairing group with an original mass of 1.125 kg. However, preliminary pairing groups assigned at classification—intrinsically—do not include stones that are petrographically distinct. Rigorous pairing group studies of CM chondrites from specific field sites are needed to investigate if there is unrecognized heterogeneity in CM chondrites from Antarctica that may represent common asteroid impactors (pre-atmospheric entry asteroids/meteoroids). Detailed pairing studies have the potential to recognize initial stones with multiple lithologies and investigate if there are stones that only sample one of those respective lithologies in the collection.

These groups of heated CMs, extensively hydrated CMs, intermediate between CM and CO chondrites, and brecciated samples are all potentially relevant to Bennu and Ryugu samples, where heating, hydration, and brecciation have all come into play. These bodies might also be comprised of material intermediate to CM and CO chondrites, or at least distinct from the well-established CC groups. These small and unusual groups of carbonaceous chondrites may help to unlock new information about early solar system processes and aid in the understanding of the evolution of these carbonaceous asteroids.

References

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