REVISITING THE CY (YAMATO) CARBONACEOUS CHONDRITE GROUP. A. J. King[1] and S. S. Russell[1], [1]Department of Earth Science, The Natural History Museum, Cromwell Road, London, SW7 5BD, U.K. (a.king@nhm.ac.uk).

Introduction: Carbonaceous chondrites are among the most primitive extraterrestrial materials available for study. Making up <5% of all known meteorites, they are classified into at least eight petrologic groups based on their mineralogical, chemical, and isotopic properties. Variations in these properties reflect differences in the spatial and/or temporal formation and geological evolution of their asteroid parent bodies.

The phyllosilicate-rich (>60 vol%) CI, CM and CR carbonaceous chondrites indicate that low temperature (<150°C) aqueous alteration was a significant process on primitive asteroids [1]. Studying the hydrated chondrites can tell us about the nature of water and other volatile species in the early solar system. There are also a number of carbonaceous chondrites that underwent extensive aqueous alteration, but do not fit into the traditional CI, CM and CR groups. These ungrouped hydrated chondrites potentially offer new insights into the conditions on asteroids and the diversity of materials that delivered water to the terrestrial planets [2].

The CY Group. In 1987 three unusual meteorites, Y-82162, Y-86720, and B-7904, were recovered from Antarctica. An international consortium was set up to study these meteorites, with the final results summarized by Ikeda [3]. All three experienced aqueous alteration, with mineralogy, textures and elemental compositions intermediate between the CI and CM chondrites. Aqueous alteration was followed by a late stage thermal metamorphic event(s) at peak temperatures >500°C that dehydrated and recrystallized the phyllosilicates into olivine. The bulk oxygen isotopic compositions of Y-82162 ($C1/2_{ung}$), Y-86720 ($C2_{ung}$), and B-7904 ($C2_{ung}$) were found to be heavier than any other carbonaceous chondrite, leading Ikeda [3] to propose that they formed a new group, the CYs ("Yamato-type"). However, the CY nomenclature was never widely adopted and in the *Meteoritical Bulletin* they remain ungrouped carbonaceous chondrites.

In the last ~30 years other potential members of the CY group have been identified; Y-86789 ($C2_{ung}$) is likely paired with Y-86720 [4], and Y-86029 and Y-980115, although classified as CI chondrites, have very similar mineralogical and chemical characteristics to Y-82162 [5, 6]. The petrologic classification of carbonaceous chondrites is a crucial step towards understanding the complex processes that formed and modified the first planetesimals. Here, we revisit the major characteristics of the CY meteorites and outline the evidence for them forming a distinct chondrite group. This effort is timely as meteorites such as Y-82162 appear to be the closest spectral match to the surface of asteroid Ryugu, from which the Hayabusa2 mission will return samples in 2020 [e.g. 7].

The Case For CY Chondrites: *Oxygen Isotopes.* The bulk oxygen isotopic composition of the CY chondrites is δ^{17}O ~12‰, δ^{18}O ~22 ‰, above the CI chondrite field and close to the intersection of the terrestrial and CM fractionation lines (Fig. 1). The high values have been linked to thermal metamorphism, i.e. preferential loss of isotopically light water and associated heavy isotope enrichment in the solids [8]. This suggests that prior to heating the oxygen isotopic composition of the CYs might have been similar to the CI chondrites. However, oxygen isotope analyses of artificially heated CI and CM chondrites contradict this model, showing either minimal changes in composition, or even shifts to lower δ^{17}O and δ^{18}O values [5, 8]. We therefore agree with Ikeda's [3] proposal that bulk oxygen isotopic compositions define the CYs as a chondrite group.

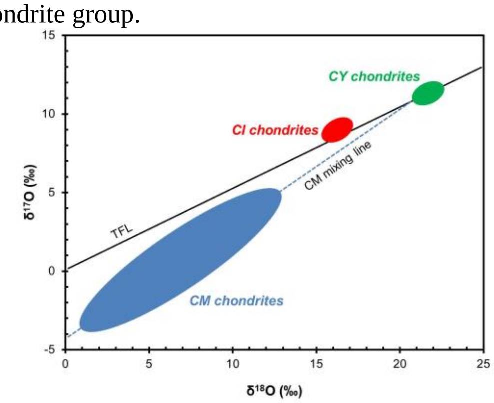

Figure 1. *Three-oxygen isotope plot showing the CI, CM and CY carbonaceous chondrite fields. Data are from [8].*

Bulk Mineralogy. Fig. 2 compares the bulk mineralogy of Y-82162 and Y-980115 to the CI and CM chondrites. The CYs contain a highly disordered phase (~70 vol%) formed via dehydration of the phyllosilicates, and fine-grained and/or poorly crystalline olivine (~10 vol%) that recrystallized from the phyllosilicates during heating [6]. Preliminary analysis of Y-86720, Y-86789, and Y-86029 are consistent with this mineralogy, but B-7904 contains fewer sulphides and metal is present. The mineralogy of the CYs is different from both the CI and CM chondrites, with a particular discrepancy in the abundance of sulphides (~20 vol% vs. <5 vol%) that was also reported by Ikeda [3]. We argue that this cannot be attributed to the effects of thermal metamorphism alone, and instead attests to the CY chondrites having a different starting mineralogy and/or alteration history.

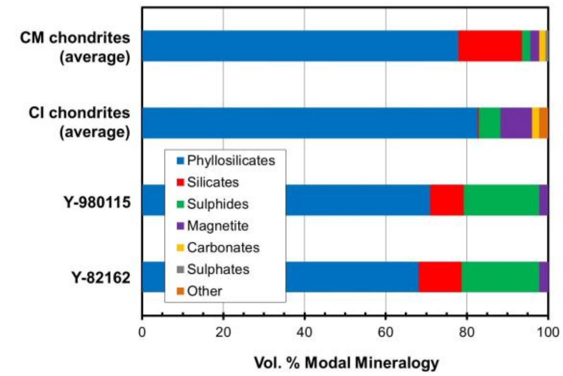

Figure 2. *Bulk mineralogy of CM and CI chondrites, and the CY chondrites Y-82162 and Y-980115. "Phyllosilicates" in the CYs are highly disordered due to thermal metamorphism and subsequent dehydration. Data are from [1, 6].*

Petrography & Matrix Composition. Y-82162 and Y-980115 contain numerous large (10's to 100's μm) clasts of phyllosilicates, periclase, and Mg-Ca-Fe-bearing phases set within a sulphide-rich matrix (Fig. 3). The composition of the matrix is a mixture of serpentines and smectites. Some of the clasts could be relict chondrules and are mantled by what look like accretionary rims. In contrast, CI chondrites contain abundant matrix and lack obvious chondrules and Ca-Al-rich inclusions (CAIs), whereas the CMs consist of partially altered chondrules and CAIs, and patches of intergrown tochilinite-cronstedtite within a matrix.

The unusual clasts in Y-82162 and Y-980115 are not seen in CI or CM chondrites (or any other chondrite groups) but comparable features have been observed in Y-86720 and Y-86029 [3, 5], providing further evidence for a genetic relationship between these meteorites. B-7904 differs slightly from the other members of the CY group in containing chondrules (~20 vol%) and rare CAIs (<1 vol%) [3].

Reflectance Spectra. The visible and near-IR (0.5 – 1.1 μm) spectra of Y-82162 and Y-980115 are relatively flat and featureless, with an overall reflectance of ~2%. Both meteorites show a weak 3 μm feature – attributed to -OH/H_2O bonds – due to dehydration of the phyllosilicates. Although terrestrial and space weathering effects need to be taken into account, qualitatively these characteristics are in good agreement with initial observations of the C-type asteroid Ryugu [7].

Discussion: Interpreting the CY chondrites is challenging; they all experienced aqueous alteration, the effects of which were later overprinted by thermal metamorphism. The presence of rounded and sub-rounded clasts in the CYs indicates that prior to alteration they probably contained chondrules. A lack of primary olivine is consistent with a classification of CY1, except for B-7904 which we speculate is a CY2.

The majority of the CY chondrites were recovered from the Yamato Mountain range in Antarctica. This may be a sampling bias or could be related to the young surface age of this collection site and variations in the meteoroid flux over time [9]. We note that there are other CY candidates including two small (<15 g) meteorites, Y-86737 and Y-980134, that are currently classified as CIs, and the hot desert finds Dho 1988 ($C2_{ung}$) and Dho 2066 ($C2_{ung}$), which have oxygen isotopic compositions that fall within the CY field.

The reflectance spectra of the CY chondrites are very similar to low albedo, C-type asteroids, suggesting that CY-like materials could be widespread throughout the solar system.

References: [1] Howard K. T. et al. (2015) *GCA 149*, 206–222. [2] Alexander C. M. O'D. et al. (2012) *Science 337*, 721–723. [3] Ikeda Y. (1992) *Proc. NIPR Symp. Antarct. Meteorites 5*, 49–73. [4] Matsuoka K. et al. (1996) *Proc. NIPR Symp. Antarct. Meteorites 9*, 20–36. [5] Tonui E. et al. (2014) *GCA 126*, 284–306. [6] King A. J. et al. (2015) *GCA 165*, 148–160. [7] Matsuoka M. et al. (2018) *Hayabusa Symposium*, Abstract #1050. [8] Clayton R. N. & Mayeda T. K. (1999) *GCA 63*, 2089–2104. [9] Zolensky M. E. et al. (2005) *LPSC XXXVI*, #2084.

Acknowledgements: This work was funded by the UK's STFC. Reflectance spectra were collected as part of a EuroPlanet visit to the Planetary Spectroscopy Laboratory at the DLR, Berlin.

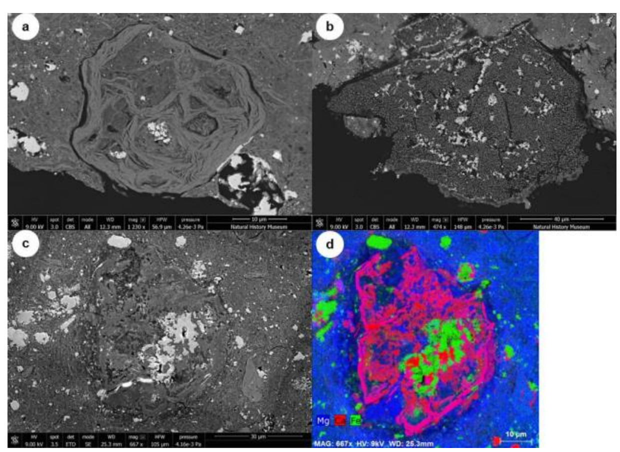

Figure 3. *(a) BSE image of a phyllosilicate clast; (b) BSE image of a periclase clast; (c) SE image of a clast containing Mg-Ca-Fe-bearing phases; (d) EDX map of the clast shown in (c). All images are from the CY chondrite Y-82162.*