K ISOTOPE SYSTEMATICS OF THE CB CHONDRITE GUJBA: TESTING THE IMPACT PLUME MODEL OF FORMATION P. Koefoed[1,2], O. Pravdivtseva[1,3], R. Ogliore[1,3], Y. Jiang[4], K. Lodders[1,2], and K. Wang (王昆)[1,2] [1]McDonnell Center for the Space Sciences, [2]Dept. of Earth & Planetary Sciences, [3]Dept. of Physics, Washington University in St. Louis, One Brookings Drive, St. Louis, MO 63130 USA (piers.koefoed@wustl.edu), [4]CAS Key Laboratory of Planetary Sciences, Purple Mountain Observatory, Chinese Academy of Sciences.

Introduction: Among the various chondrite groups, CB chondrites show many characteristics which significantly distinguish them. Most distinctively, CB chondrites are very rich in Fe-Ni metal (60-70%) and have a near complete absence of fine grained matrix [1,2]. While the formation mechanisms of CB chondrites remain hotly debated, several key features strongly indicate that they likely formed in a single high temperature, high partial pressure event. Firstly, chondrules in CB chondrites show a distinct lack of both relic grains and rims and have exclusively non-porphyritic chondrule textures suggesting only one high temperature rapid cooling formation event [2,3,4]. Secondly, CB chondrites show both a significant depletion in volatile elements and lack metal grains in chondrules suggesting high formation temperatures [3]. Thirdly, the siderophile element ratios in the CB metal grains indicate formation under partial pressures much higher than is possible in the solar nebula [5,6]. Lastly, the indistinguishable, very precise, and very young age of ~4562.5 Myr common to all CB chondrites using multiple isotopic chronometers with distinct closure temperatures strongly indicates they all formed simultaneously, were rapidly cooled, and formed at a time when large planetesimals were likely abundant [4,7]. This mounting body of evidence resulted in the impact plume formation model becoming the currently dominant hypothesis for CB chondrite formation.

The isotopic analysis of the moderately volatile element K could provide further constraints on CB chondrite formation. As an impact plume formation mechanism would be expected to result in significant re-condensation and evaporation processes, it can be anticipated that understanding the K isotopic behavior of CB chondrites will shed further light on the mechanism and conditions of their formation. The lack of much secondary alteration and the apparent singular formation event CB chondrites experienced make them ideal for study using the K isotope system. Here, in order to investigate the impact plume model of CB chondrite formation, we undertook K isotope analysis on the CB_a chondrite Gujba. This sample was chosen as 1) Gujba is a meteorite fall, which reduces the possibility of terrestrial contamination, and 2) Gujba possess large chondrules, counteracting the issues posed by the low K concentrations in CB chondrites.

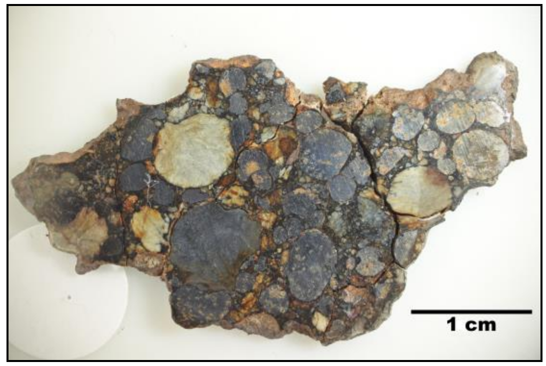

Figure 1. *Image of the Gujba sample used in this study.*

Methods: A total of fourteen fractions were selected for analysis, consisting of thirteen chondrule fractions and two bulk fractions. The chondrule fractions masses ranged from 33 to 104 mg, while the bulk fractions weighed 221 mg and 256 mg. Chondrules were extracted by gently crushing the meteorite piece to break-out the chondrules and then cleaned up under a binocular microscope. Each fraction was dissolved in concentrated HF and HNO_3 at a 3:1 ratio. After complete sample dissolution, 5% of each fraction was taken for elemental analysis using a Thermo Fisher iCAP Q ICP-MS at Washington University in St. Louis. Between 50 and 70% of each fraction then underwent K separation by means of a triple pass column chemistry procedure using Bio-Rad AG50W-X8 100-200 mesh cation exchange resin where 0.5 M HNO_3 was used as the elution liquid. Potassium isotopic analyses were conducted using the Neptune *Plus* MC-ICP-MS at Washington University in St. Louis. The standard used in this study was SRM 3141a and the total procedure K blank was 20 ng, which is negligible compared to the sample K concentrations.

Results: The $\delta^{41}K$ for all Gujba chondrules measured in this study range from –2.24‰ to –0.41‰, while the bulk samples measured –0.81‰ and −0.72‰. The K concentrations of the chondrules range from 710 ppm to 127 ppm while the bulk samples have 503 ppm and 303 ppm K, which fall in the range seen in other studies [2,8]. Figure 2 indicates a possible inverse correlation of $\delta^{41}K$ and K concertation in chondrules. Similarly, Na concentrations show a comparable but more robust correlation with $\delta^{41}K$ (Fig. 3), (Na has similar volatility and geochemical properties to K). Interestingly, the bulk samples follow the general chondrule trend for $\delta^{41}K$ vs Na_2O but not for $\delta^{41}K$

vs K_2O. This could indicate the presence of a significant K-rich but Na-poor reservoir in the non-chondrule components of Gujba.

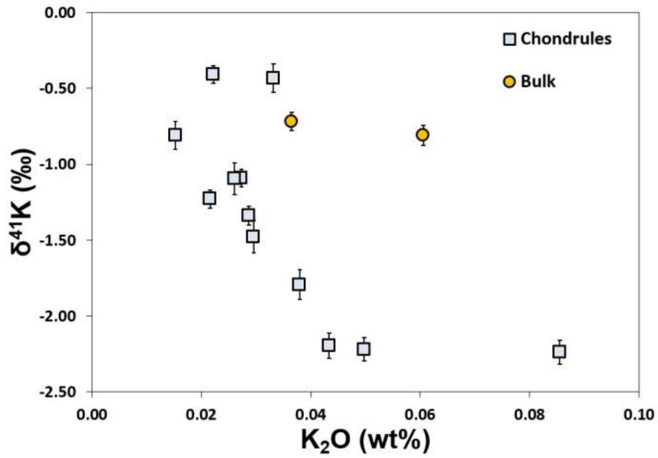

Figure 2. *$\delta^{41}K$ vs K_2O for all Gujba chondrule and bulk fractions. Errors shown are 95% C.I.*

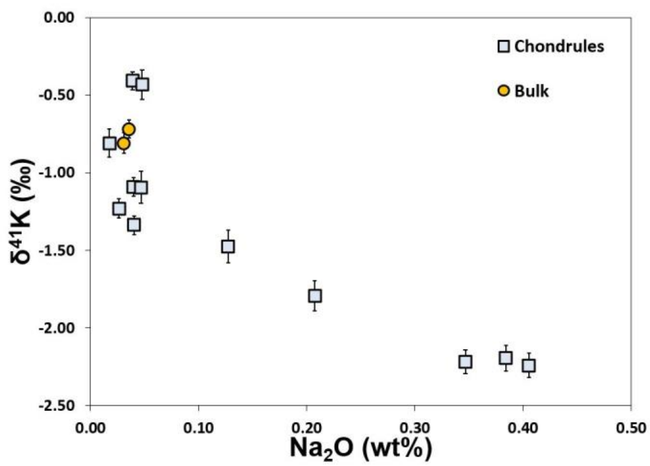

Figure 3. *$\delta^{41}K$ vs Na_2O for all Gujba chondrule and bulk fractions. Errors shown are 95% C.I.*

Discussion: As seen in Figure 4, Gujba's chondrules cover a wide range of $\delta^{41}K$ values compared to the other major chondrite groups. In fact, the lowest $\delta^{41}K$ values of –2.2‰ to –2.3‰ seen in Gujba's chondrules extend beyond the total range seen in any chondrite components measured by bulk MC-ICP-MS so far (–1.6‰ was reported in a LL3.2/3.4 GRO 95658 chondrule) [9]. Previous SIMS *in situ* chondrule analysis have recorded values down to –15‰ [10]. Nevertheless, it is not feasible to compare these bulk and *in situ* analysis here due to intra- vs inter-chondrule variation, significant uncertainty differences, and possible SIMS analytical artefacts. As such, the extreme light values seen here in some of Gujba's chondrules suggest they likely experienced some difference in formation process compared to chondrules from the other types of chondrites.

Further insight into the formation of chondrules in Gujba can be found in the correlation between both K_2O and Na_2O concentrations and $\delta^{41}K$. This trend of heavier $\delta^{41}K$ values correlating with lower elemental concentration is consistent with evaporation experiments [11]. This indicates that the dominant processes affecting the K isotopic variation observed in Gujba's chondrules was K loss during evaporation. However, the K isotopic composition of the most Na and K-rich samples indicate a pre-evaporation K isotopic composition of below –2.3‰. This extremely light K isotopic composition is most likely caused by kinetic isotopic fractionation during condensation. Thus, the K isotopic composition of Gujba's chondrules lend support to the impact plume model of formation for CB chondrites.

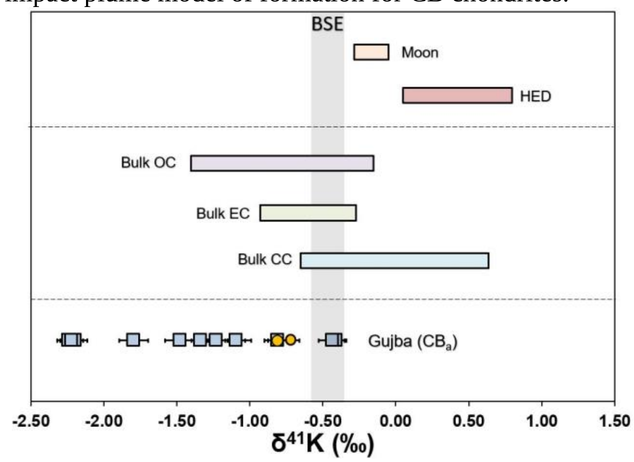

Figure 4. *K isotopic compositions of the Gujba fractions compared to bulk analysis of relevant materials. Blue squares represent chondrules while orange circles represent bulks. BSE = the bulk silicate Earth $\delta^{41}K$ value. Comparison data taken from [12,13,14,15]*

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References: [1] Weisberg M. K. et al. (2001) MAPS, 36, 401-418. [2] Rubin A. E. et al. (2003) GCA, 67, 3283-3298. [3] Krot A. N. et al. (2001) Science, 291, 1776-1779. [4] Krot A.N. et al. (2005) Nature, 436, 989-992. [5] Campbell A.J. et al. (2002) GCA, 66, 647-660. [6] Fedkin A. V. et al. (2015) GCA, 164, 236-261. [7] Bollard J. et al. (2015) MAPS, 50, 1197-1216. [8] Oulton J. et al. (2016) GCA, 177, 254-274. [9] Koefoed P. and Wang K. (2020) LPSC, #2522. [10] Alexander C. M. et al. (2000) MAPS, 35, 859-868. [11] Yu Y. et al. (2013) GCA, 67, 773–786. [12] Wang K. and Jacobsen S. B. (2016) Nature, 538, 487-490. [13] Tian Z. et al. (2019) GCA, 266, 611-632. [14] Bloom H. et al. (2020) GCA, 277, 111-131. [15] Ku Y. and Jacobsen S. B. (2020) Sci. Adv., 6.