

CHROMIUM ISOTOPE SYSTEMATICS OF THE CARBONACEOUS IRON METEORITE JEMINAY. A. M. Miller¹, S. Dey¹, S.J. Li², H.-L. Tang³, E. D. Young³, and Q.-Z. Yin¹, ¹Department of Earth and Planetary Sciences, University of California at Davis, Davis, CA 95616 USA (Email: aumiller@ucdavis.edu, qyin@ucdavis.edu); ²Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, China. ³Dept. of Earth and Space Sci. UCLA, Los Angeles, CA 90095.

Introduction: The iron meteorite Jeminay was found in 2017 in the Gobi Desert in Xinjiang, China [1]. Jeminay is composed of Fe-Ni metal with minor silicate inclusions, and has been classified as an ungrouped iron meteorite due to its unique geochemistry. The high Ni (16.7 wt%) and Ir (13.4 ug/g) values point towards a genetic linkage with the IVB group, which has the highest Ni and Ir concentrations of all the iron groups [1,2]. However, the remaining elemental concentrations do not match up as nicely with the IVB group [1]. In particular, the volatile and moderately-volatile siderophile elements Ga, As, Au, and Cu in Jeminay are higher than concentrations found in the IVB group, which is characterized by depletions in volatile elements and enrichments in refractory elements compared to other iron meteorites [1–5]. Petrographically, the Widmanstätten pattern of Jeminay is within the size range of finest octahedrite, a structure which is not associated with any specific iron group [6]. IVB irons typically fall within the “ataxite” structural class, with kamacite lamellae too small to be observed without a microscope [6]. To date, no silicate inclusions have been observed in IVB irons [6].

While Jeminay does not appear to fit in with any known iron groupings, here we use nucleosynthetic isotope anomalies (*e.g.*, ^{54}Cr) to gain further insights about the formation reservoir of its parent body. When combined, isotope systematics such as $\Delta^{17}\text{O}-\epsilon^{54}\text{Cr}$ provide a robust method to identify common isotopic reservoirs within the protoplanetary disk [7,8]. $\Delta^{17}\text{O}-\epsilon^{54}\text{Cr}$ isotope systematics have revealed a dichotomy between ‘carbonaceous’ (CC) and ‘non-carbonaceous’ (NC) meteorites, which has been linked back to a large-scale isotopic separation within the protoplanetary disk [7–14]. The formation of Jupiter is often invoked as a separation mechanism between NC and CC reservoirs, suggesting the CC meteorites formed in the outer Solar System and the NC meteorites formed in the inner Solar System [8,10,13,14]. Within both reservoirs, small-scale differences in Cr-O isotopes can further distinguish isotopic pockets that represent individual parent bodies or formation reservoirs for groups of planetesimals [8,13–15].

Many chondrite and achondrite groupings have been well-established in $\Delta^{17}\text{O}-\epsilon^{54}\text{Cr}$ space, and linkages between these groups and iron meteorites are possible if the iron meteorite contains suitable phases in which

both Cr and O isotopes can be measured. In this study, $\Delta^{17}\text{O}-\epsilon^{54}\text{Cr}$ data have been collected to elucidate the provenance of the ungrouped iron meteorite Jeminay.

Methods: A slab of the Jeminay meteorite (Fig. 1a, below red line) was donated for this study by a school teacher, Ye Erbo Lati, who discovered the meteorite. Four aliquots of sample were prepared from a portion of this slab: (1) inclusion-derived silicates, (2) inclusion-derived chromites, (3) metal-derived silicates, and (4) metal-derived chromites.

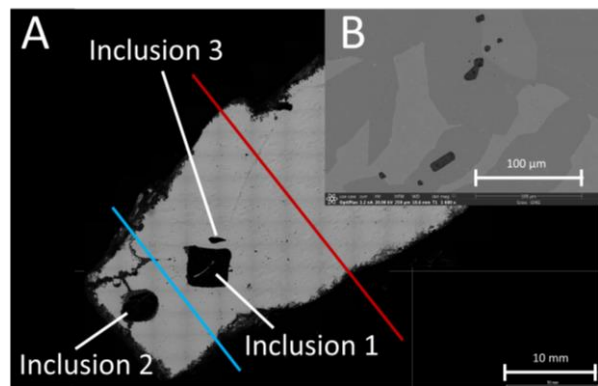


Fig. 1. (A) BSE image of Jeminay thick section. The red line indicates where the slab was cut in half, with the lower portion received at UC Davis for Cr isotope analysis. The blue line indicates where slab was cut at UC Davis for dissolution, with the segment between the blue and red lines used to extract exsolution chromites and silicates. **(B)** Exsolution chromites distributed in the metal as small (<10 µm) inclusions.

First, both silicates and chromites were separated from inclusions 1 and 3 (Fig. 1a). These inclusions were drilled out and placed in 1N HCl at 70°C to leach away any attached metal. Once all the metal had been leached away, the residual solid sample was rinsed with MQ water multiple times and ultrasonicated. The remaining material from the inclusions underwent partial dissolution in a 3:1 mixture of concentrated HF:HNO₃ on a hot plate at 160°C for 96 hours to dissolve the silicates. The dissolved silicates and solid chromites were separated further, and the clean residual chromites were placed into a PTFE capsule with concentrated HNO₃ that was sealed in a stainless-steel Parr bomb

jacket. The Parr bomb was heated at 190°C for another 96 hours to ensure chromite dissolution.

Second, chromites and silicates were extracted from tiny exsolution veins and inclusions (e.g., Fig. 1b) found in the metal itself. Rather than drilling these tiny veins, the remaining Jeminay slab was cut in half with a diamond saw (Fig. 1a, blue line), and the region between the red and blue lines was placed in 1N HCl at 70°C to leach away all the metal. The silicates and chromites recovered from the undissolved solids were separated and dissolved in the same fashion as the silicates and chromites from Jeminay inclusions 1 and 3, as outlined above.

Once the chromites and silicates from both the metal veins as well as inclusions 1 and 3 were completely dissolved, the samples were processed through a 3-column Cr extraction procedure to separate Cr from all other matrix elements [16]. Purity and yield of the samples were verified with elemental analysis on a Thermo Scientific XR HR-ICP-MS, and the Cr isotopic composition for all four aliquots was measured using a Thermo Triton Plus thermal ionization mass spectrometer (TIMS) at UC Davis [8,16]. All reported $^{54}\text{Cr}/^{52}\text{Cr}$ ratios are expressed in ϵ -notation (parts per 10,000 deviations from the measured standard). Oxygen isotope ratios were determined by laser-assisted fluorination at UCLA.

Results and Discussion: The newly collected $\epsilon^{54}\text{Cr}$ isotopic data for the ungrouped iron meteorite Jeminay reveal isotopic similarities between the inclusion-derived and metal-derived chromites and silicates (Figs. 2 and 3). These similarities indicate that the silicate inclusions and the metal itself likely come from the same isotopic reservoir. The addition of $\Delta^{17}\text{O}$ data for the bulk inclusion (silicates + chromites) points to a carbonaceous (CC) origin with a potential genetic linkage to either CO or CK chondrites.

Based on the $\epsilon^{54}\text{Cr}$ results presented here, the case for Jeminay as a magmatic iron is plausible. Magmatic iron meteorites formed via fractional crystallization, and likely represent the cores of differentiated planetesimals [2,17]. Since the $\epsilon^{54}\text{Cr}$ values for both inclusion-derived and metal-derived minerals are similar, these materials were likely sourced from the same parent body. The silicate inclusions present within Jeminay are almost entirely composed of olivine, indicating these inclusions could be mantle remnants of a differentiated asteroid, potentially from incomplete separation of metal and silicate during differentiation [17]. Thus, Jeminay represents yet another differentiated body in the outer Solar System (CC reservoir).

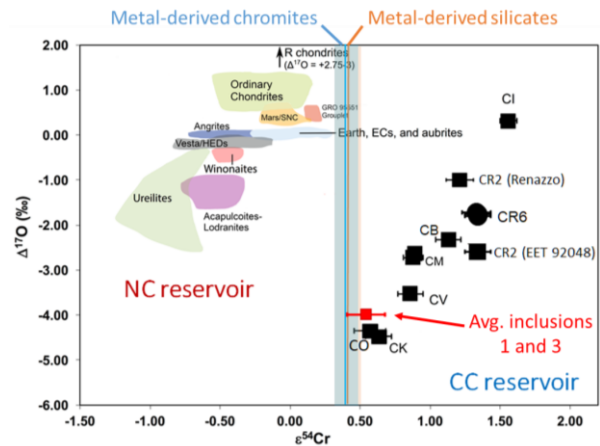


Fig. 2. Jeminay $\Delta^{17}\text{O}$ - $\epsilon^{54}\text{Cr}$ isotope systematics. Inclusion-derived silicates and chromites (averaged, in red) plot in the CC reservoir, near the CO and CK groups. Metal-derived chromites (blue) and silicates (orange) do not yet have corresponding $\Delta^{17}\text{O}$ data.

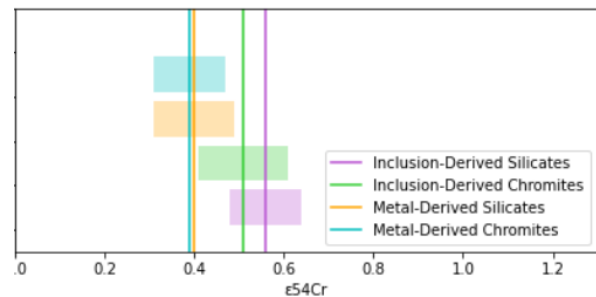


Fig. 3. Detailed $\epsilon^{54}\text{Cr}$ isotopes with associated error for Jeminay. Inclusion-derived refers to inclusions 1 and 3.

References: [1] Meteoritical Bulletin, no. 107 (2020) *MAPS* 55, 460–462. [2] Scott E. R. D. and Wasson J. T. (1975) *Rev. Geophys.* 13, 527–546. [3] Kelly W. R. and Larimer J. W. (1977) *GCA* 41, 93–111. [4] Scott E. R. D. (1972) *GCA* 36, 1205–1236. [5] Wasson J. T. and Wai C. M. (1976) *Nature* 261, 114–116. [6] Scott E. R. D. (2020) *Oxford Research Encyclopedias, Planetary Science* 1. [7] Yin Q.-Z. et al. (2009) *LPSC* 40, #2006. [8] Sanborn M. E. et al. (2019) *GCA* 245, 577–596. [9] Trinquier A. et al. (2007) *ApJ* 655, 1179–1185. [10] Warren P. H. (2011) *EPSL* 311, 93–100. [11] Schmitz B. et al. (2016) *Nat. Comm.* 7. [12] Kruijer T. S. et al. (2017) *PNAS* 114, 6712–6716. [13] Williams C. D. et al. (2020) *PNAS* 117, 23426–23435. [14] Dey, S. et al. (2019) *LPSC* 50, #2977. [15] Goodrich C. A. et al. (2021) *Planet. Sci. J.* 2, 13. [16] Yamakawa A. et al. (2009) *Anal. Chem.* 81, 9787–9794. [17] Krot A. N. et al. (2014) in: *Treatise on Geochemistry (Second Edition)* (Holland, H.D., Turekian, K.K., eds.), pp. 1–63.