

^{53}Mn – ^{53}Cr Radiometric Dating of Secondary Carbonates in a Hydrated Antarctic Micrometeorite

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Introduction

- Hydrated fine-grained Antarctic micrometeorites (H-FgMMs) → *mineralogy similar* to type 1-2 carbonaceous chondrites
- H-FgMMs → *O isotopes* in magnetite **not similar** to type 1-2 CCs (Dobrică et al., *MAPS*, 2019)

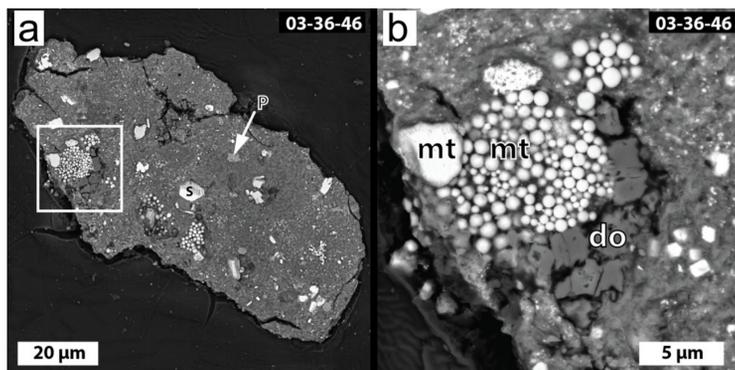


Figure 1: a) Backscattered electron image of 03-36-46 (P=Ca-phosphate, S=sulfide). b) Closer view showing magnetites (mt) and dolomite (do).

- H-FgMM 03-36-46** (Concordia): magnetite-dolomite assemblage that precipitated 160°–280°C
- Mineralogy + O isotopes + precipitation temperature of 03-36-46 do not all match a known meteorite type
- What was the formation time of carbonates in 03-36-46 compared to carbonates in CCs?**
- ^{53}Mn – ^{53}Cr radiometric dating of carbonates in Renazzo (CR2) and 03-36-46 by *in-situ* NanoSIMS measurements

Technique Development

Challenges...

- Duoplasmatron** → insufficient stability and spot size for measurements of carbonates smaller than $\sim 5 \mu\text{m}$
- Isochrons** → Traditional isochrons have sub-optimal precision (combining variable parent/daughter ratios into spots) and accuracy (ratio bias and spurious correlation from correlated ratios)

Solutions...

- Oregon Physics Hyperion RF plasma source** → better stability, spot size, brightness
- A ratio-free isochron alternative** → analyze scanning ion images directly, without binning or ratio bias:

$$^{53}\text{Cr} = (A)^{52}\text{Cr} + (B)^{55}\text{Mn} + \dots$$

- Uncertainties calculated from a Monte Carlo bootstrap
- Simulated ^{53}Cr counts and real ^{52}Cr and ^{55}Mn data used to estimate precision and accuracy of algorithm

Methods

Wash U NanoSIMS Analytical Conditions

- Focused 10 pA primary beam of $^{16}\text{O}^-$: $\sim 150 \text{ nm}$ spot size (60 pA for presputtering).
- Measured $^{50}\text{Cr}^+$, $^{52}\text{Cr}^+$, $^{43}\text{Ca}^+$, $^{54}\text{Fe}^+$ then $^{53}\text{Cr}^+$, $^{44}\text{Ca}^+$, $^{55}\text{Mn}^+$ by peak jumping
- Mass-resolving power ≈ 5000 , sufficient to resolve interferences
- Collected scanning ion images with raster sizes $1.5 \times 1.5 - 10 \times 10 \mu\text{m}$, and $32 \times 32 - 128 \times 128$ pixels
- Synthesized calcite standard with high Mn and Cr concentrations to constrain the Mn/Cr relative sensitivity factor (RSF) to be ~ 0.69
- First we measured a dolomite grain in Renazzo to verify precision and accuracy of our NanoSIMS analytical protocol and ratio-free isochron alternative**

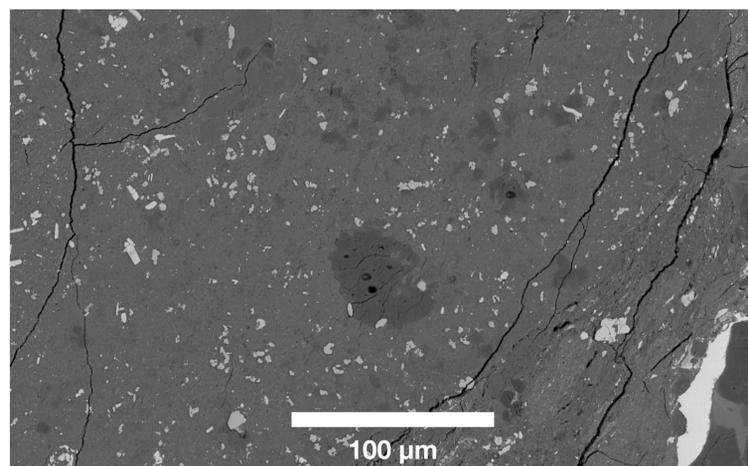
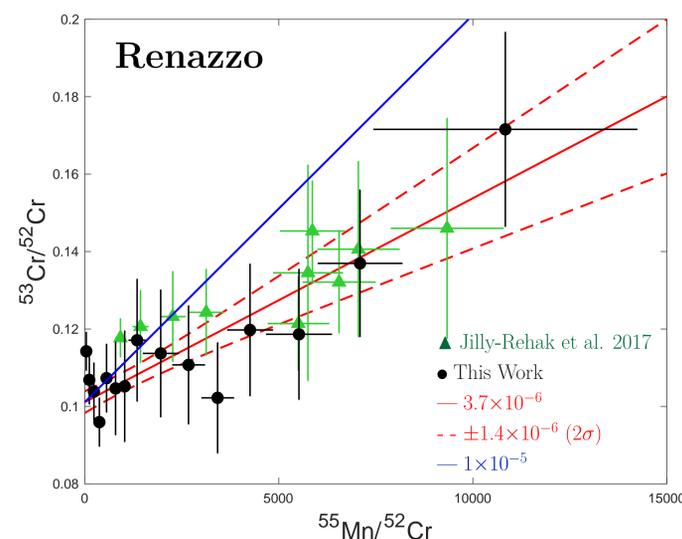
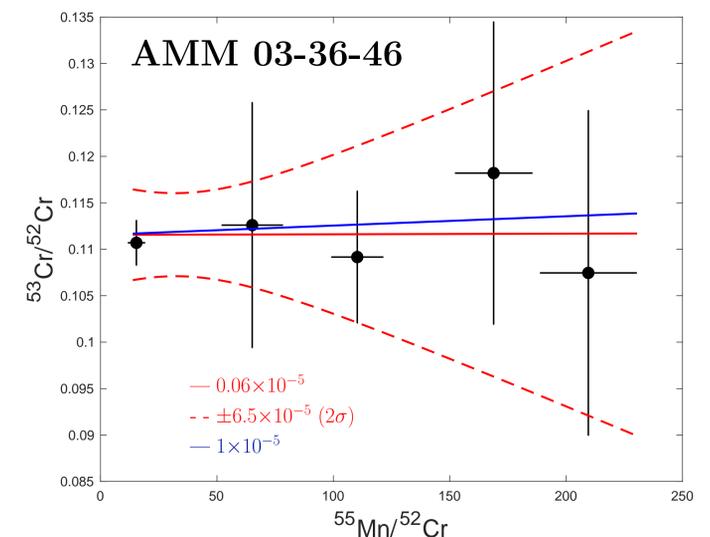


Figure 2: BSE image of Renazzo dolomite (after 1280 measurements but before NanoSIMS measurements)

Results



Results (continued)



- Initial $^{53}\text{Mn}/^{55}\text{Mn}$ for *one* Renazzo dolomite:
 $(3.7 \pm 1.4) \times 10^{-6}$ (2σ)
- This is consistent with $(3.1 \pm 1.4) \times 10^{-6}$ (2σ) measured by Jilly-Rehak et al. (2017) in seven dolomite grains
- Our imaging measurements are more *precise* because we measure a larger variance in Mn/Cr ratios compared to spot analyses resulting a more precise estimate of the slope
- Initial $^{53}\text{Mn}/^{55}\text{Mn}$ for AMM 03-36-46 carbonate:
 $(0.06 \pm 6.5) \times 10^{-5}$ (2σ)
- Mn/Cr ratios were not sufficiently high to obtain a precise measurement

Conclusions

- We have developed a NanoSIMS analytical protocol to measure the initial $^{53}\text{Mn}/^{55}\text{Mn}$ in carbonates using a spot size of $\sim 150 \text{ nm}$
- Scanning ion imaging yields a more precise measurement of the isochron slope
- Direct maximum likelihood calculation of isochron slope yields a more precise and more accurate estimate of the initial ratio, though visualization of the data using a traditional isochron is still useful
- Mn/Cr ratios of ~ 200 in AMM 03-36-46 carbonate did not allow for a precise estimate of initial $^{53}\text{Mn}/^{55}\text{Mn}$*

Future measurements...

We will prepare FIB sections of carbonates in Antarctic micrometeorites and interplanetary dust particles to screen for phases with high Mn/Cr ratios, then analyze FIB sections of these phases in the Wash U NanoSIMS using this analytical protocol.